Comment on "Extreme environments in the forests of Ushuaia, Argentina" by Hector D'Antoni et al.

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Received 13 February 2008; revised 7 May 2008; accepted 12 May 2008; published 15 July 2008.

Citation: Flint, S. D., C. L. Ballaré, M. M. Caldwell, and R. L. McKenzie (2008), Comment on ''Extreme environments in the forests of Ushuaia, Argentina'' by Hector D'Antoni et al., *Geophys. Res. Lett.*, *35*, L13710, doi:10.1029/2008GL033570.

1. Introduction

[1] An investigation of influences on treeline near Ushuaia, Tierra del Fuego, Argentina, by *D'Antoni et al.* [2007] reported high ultraviolet-C radiation (UV-C, $\lambda <$ 280 nm) in terrestrial sunlight. Because of well-known atmospheric absorption of UV, any portion of the ground-level UV-C fluxes they reported would be impossible. We suspect these UV-C fluxes to be spurious results of instrument limitations. Their report also speculates on vegetation response to UV while neglecting extensive research in Tierra del Fuego which would have shown vastly different effects had UV-C been present.

2. UV Radiation

[2] Data of *D'Antoni et al.* [2007] show typical ground-level solar UV spectra except for dramatic increases in UV-C radiation, especially as λ approaches 200 nm. These UV-C fluxes far exceeded those they reported in the UV-A and UV-B and were high even in the forest where UV-A and UV-B fluxes were low. These short wavelength values and potential effects receive considerable attention (see [15, 16] in original article). While outside the instrument's maximum sensitivity, as specified by the authors, the measured shortwave values were clearly not considered noise in the original article. There is a fundamental problem with these measurements: the irradiance reported near 200 nm exceeds the extraterrestrial irradiance there by a large factor. For this reason, the short-wavelength UV-C data should never have been presented.

[3] Even within the instrument's range of maximum sensitivity, significant irradiance near 250 nm was reported. We present calculated irradiance (''tuv'' model of *Madronich and Flocke* [1995]) in Figure 1, along with the 250 nm values of *D'Antoni et al.* [2007] Even using a much lower ozone level in the model than would have occurred on the date of their UV measurements (100 DU instead of 300 DU), the 250 nm values they report exceed the calculated values by more than 15 orders of magnitude. They even considerably exceed the irradiance calculated for zero ozone, and in two cases (CG1 and CG3 at 8 and 12 μW cm^{-2} nm^{-1}, respectively) they surpass the extraterrestrial flux. These measured values are not credible and most likely a result of limitations of the instrument used (see Section 3).

[4] Factors attenuating UV in the atmosphere are well known. At short UV-B wavelengths and in much of the UV-C, ozone absorption is very high [*Molina and Molina*, 1986, and references therein]. Although ozone absorption decreases dramatically at $\lambda <$ 240 nm, the extraterrestrial solar flux also drops over an order of magnitude in this region, and oxygen also absorbs strongly at λ 120–210 nm. Losses through Rayleigh scattering also increase markedly at shorter wavelengths. These wavelength dependences are clearly illustrated by *Zeng et al.* [1994, Figures 1 and 2] and *Houghton* [1977]. Because of these combined factors, it is widely considered that virtually no UV-C radiation reaches the ground [*Rottman et al.*, 2004]. A previous claim to detecting UV-C radiation at the Earth's surface [*Córdoba et al.*, 1997] estimated 250 nm values approximately six orders of magnitude less than the UV-B. This is much closer to our model-calculated value, though still rather large in our opinion.

3. Instrumentation

[5] Ocean Optics spectrographs are not suitable for measuring solar spectra in the UV-B region without modifications because their stray light rejection is insufficient. Even in measuring sun-bed irradiance, a much less demanding application, great care is needed in processing UV-B data [*Ylianttila et al.*, 2005]. The multichannel (CCD type) detector in *D'Antoni et al.*'s [2007] spectroradiometer may be particularly susceptible to spectral scattering [*Kostkowski*, 1997], especially with the high flux from the background of sunlight. This high visible flux is not removed by the 200–850 longpass filter. Usually when UV-B spectra are measured, data are plotted on a logarithmic scale and compared with model calculations to ensure that there is not a problem with stray light. This has not been done in this case, and the stray light rejection figures quoted are far below what is required to properly measure even UV-B radiation to high precision [e.g., see *McKenzie et al.*, 1997; *Seckmeyer et al.*, 2001]. Further, field tests to check for stray light (e.g., with sharp cutoff filters such as a Schott WG 320 [*McKenzie et al.*, 1997]) were not conducted. Variations in dark current may also be an issue.

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0094-8276/08/2008GL033570

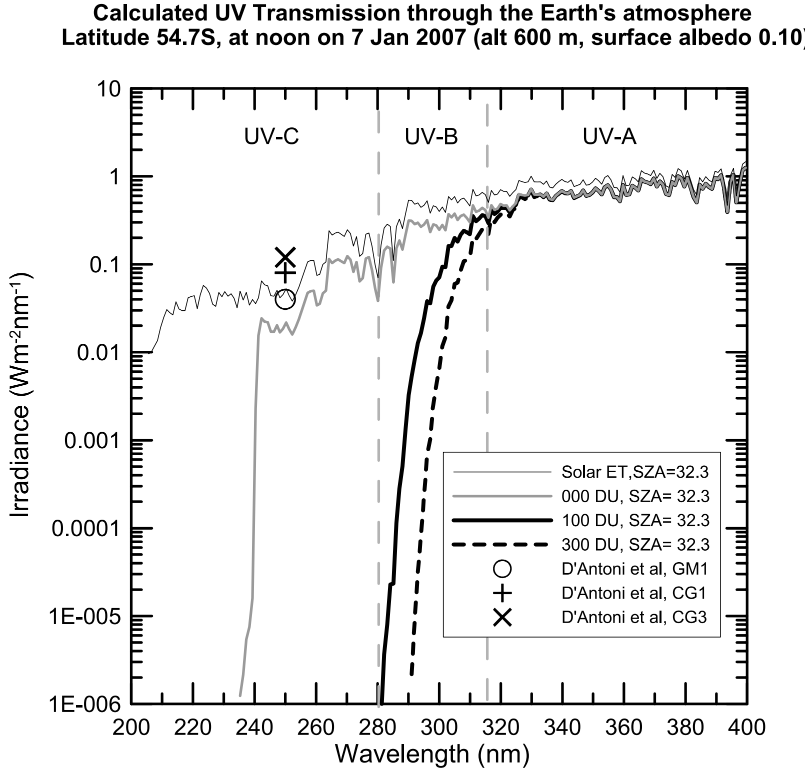

Figure 1. Clear-sky spectral irradiance (8-stream version of the tuv radiative transfer model [*Madronich and Flocke*, 1995]) and 250 nm values from *D'Antoni et al.* [2007]. Model values calculated for 100 DU ozone (close to the lowest value ever recorded), and for 300 DU (a reasonable value for the date of D'Antoni's measurements). Also shown are extraterrestrial irradiance and ground-level irradiance with no ozone present. Predicted irradiance at 250 nm with 100 DU ozone is 10^{-18} W m^{-2} nm^{-1}. Our Y-axis starts at 10^{-6} W m^{-2} nm^{-1} as this is the detection level of state-of-the-art spectroradiometers monitoring solar UV [*McKenzie et al.*, 1997]. Below 280 nm, the calculated irradiance is essentially zero in any practical scenario.

[6] Little detail is given regarding instrument calibration, but the manufacturer (http://www.oceanoptics.com/products/dh2000cal.asp) indicates the lower bound of their calibration is 220 nm. Thus the highest UV-C values reported lie outside the calibrated wavelengths.

4. Plant responses to UV in Ushuaia

[7] Long-term research in Tierra del Fuego (manipulating sunlight with selective filters) has shown subtle effects of near-ambient UV-B on native plant growth and ecosystem function [*Ballaré et al.*, 2001; *Robson et al.*, 2003, 2005]. One filter was UV-transparent and the other removed radiation below 315 nm. If UV-C was present, these studies would have excluded UV-B and UV-C in one treatment and not the other. Even if one only considers the radiation reported by *D'Antoni et al.* [2007] near 254 nm, sufficient UV-C would be present to cause severe plant stunting, based on effects seen in other studies using UV-C [e.g., *Tiburcio et al.*, 1985]. If UV-C radiation was present as D'Antoni et al. suggest, plant stunting in the near-ambient UV treatment would have been visibly obvious in comparison to the UV-reduction treatment. Effects in these experiments [*Ballaré et al.*, 2001; *Robson et al.*, 2003, 2005], however, were subtle and only detectable by careful measurement.

[8] *D'Antoni et al.* [2007] speculate on UV-absorbing compounds and leaf optical properties protecting *Nothofagus* from UV damage. *Nothofagus* increases UV-B reflectance [*Hunt and McNeil*, 1999] and specific UV-absorbing compounds [*Rousseaux et al.*, 2004] in response to ambient UV-B, and epidermal attenuation of UV-B transmittance into *Nothofagus* leaves is substantial [*Barnes et al.*, 2000]. Many of the UV-B absorbing compounds absorb equally well, or sometimes even more strongly, in the UV-C [*Mabry et al.*, 1970]. Thus the neglected UV-B research is actually very pertinent.

5. Conclusion

[9] We maintain this study is flawed in its physical component (the UV-C measurements are not credible because they were obtained with an inappropriate instrument and they do not agree with theoretical predictions), and superficial in its approach to addressing biological impacts of enhanced solar UV radiation.

[10] **Acknowledgments.** SDF was funded by the USDA UV-B Radiation Monitoring and Research Program (contract G1507-2); CLB was funded by ANPCyT, CONICET and UBACyT.

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