Reply to comment by Stephan D. Flint et al. on "Extreme environments in the forests of Ushuaia, Argentina"

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1. Introduction

[1] We are pleased at the attention our paper has received from *Flint et al.* [2008], and others. We agree that the results presented are startling, and are grateful for the opportunity to address the points brought up by *Flint et al.* [2008]. Their comments fall into two categories: first, the veracity of our measurements, and second, the significance of UV-C for the plant response. Here we address these points in detail.

[2] The second word of paragraph [1] of *D'Antoni et al.* [2007] is "survey" (i.e., "sampling, or partial collection of facts, figures or opinions taken and used to approximate or indicate what a complete collection or analysis might reveal." [*Stein*, 1982]). By no means do we attempt to present a final discussion on a phenomenon that surprised all of us.

[3] The second sentence of *Flint et al.* [2008] states that "the ground level UV-C fluxes presented by *D'Antoni et al.* [2007] would be impossible anywhere in the world." We present data on the 250–280 nm range, and at 250 nm the fluxes are no larger than 12 to 15 μW cm^2 nm^{-1}. *Rottman et al.* [2004, Figure 1] show that in space the band of solar UV of 120–400 nm rises from 10^{-5} W m^{-2} nm^{-1} to 10^0 W m^{-2} nm^{-1}. In λ 250 nm this is larger than 10 μW cm^2 nm^{-1}, i.e., in the same order of magnitude of our records at ground level. Also, Rottman et al. state, "The ultraviolet ($120 < \lambda < 300$ nm) important to our middle atmosphere, is less than 1% of Total Solar Irradiance (TSI), and even the near UV ($300 < \lambda < 400$ nm) is less than 10%. Although their contributions to TSI are relatively small, these portions of the solar irradiance are quite variable and extremely important to the Earth's atmosphere." Our data are within the same order of magnitude of those presented by *Rottman et al.* [2004] and because of that, and not the noise shown in our figures, we speak of high levels of UV-C.

[4] The fourth sentence states that our report "speculates on vegetation response to UV while neglecting extensive research on the subject. . .." In fact, we speculate in order to generate one or more testable hypotheses that might explain why UV-C may not damage the leaves of *Nothofagus* sp. trees and other plants. Otherwise, to the best of our knowledge, there is no extensive literature whatsoever. However, in section 5 of *D'Antoni et al.* [2007], we pose the question "How can the forest survive current UV fluxes?" that generalizes to the UV band instead of focusing exclusively on our finding of UV-C and that misleads readers. Then the sentence goes "and ignores detailed UV measurements collected since 1988 in Ushuaia. . .." No, we do not ignore that. In fact, the NSF Polar Programs UV Monitoring Network has deployed SUV-100 spectroradiometers (and newer versions) at McMurdo, Palmer, South Pole, Ushuaia, San Diego, Barrow, and more recently in Summit (Greenland) that measure the solar spectral irradiance over the range of 280 through 600 nm, not UV-C (www.biospherical.com/nsf/instruments.asp). Thus, both statements by *Flint et al.* [2008] are irrelevant in the discussion of the possible presence of UV-C at ground level.

2. UV Radiation

[5] *Flint et al.* [2008] view our data for midday summer as "typical UV spectrum except that dramatic increases in UV-C radiation between 200 and 250 nm are reported." This is in part our fault for, in fact, the figures show irradiance from 200 through 400 nm. However, in both figures we show "instrument maximum sensitivity" as a horizontal line running from 250 through 400 nm, while we consider as noise the portion of the signal between 250 and 200 nm. In the text, we analyze the UV-C record from 250 through 280 nm. We described the noise portion (200–250 nm) without attempting any interpretation of the errors, which magnitudes are inversely proportional to the wavelength below 250 nm, because we do not have information of the signal-to-noise ratio for that region (200–250 nm) and the manufacturer does not provide numerical data for that region in the calibration file.

[6] We are in agreement with the statements in paragraph [3] of *Flint et al.* [2008]. In paragraph [4] of *Flint et al.* [2008], we receive a critique for a matter we do not discuss in the paper. However, the reader may notice that the y-axis scale of our graphs is in μW cm^2 nm^{-1}.

3. Radiation Measurements in Ushuaia

[7] We are well aware of the history of the NSF station in Ushuaia, the effort invested to bring this network to reality by C. R. Booth, T. Lucas, and others, and the precision work that S. Díaz and collaborators have done in Ushuaia, and we hold them in the highest consideration. Although their work provides context to a subset of our measurements and their geography, it is not germane to the problem we present, namely, the presence of UV-C at ground level and its possible consequences.

[8] *Flint et al.* [2008] state that our UV-A and UV-B measurements are not remarkable and that satellite-derived

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ozone amounts are not available for our measurement dates. We did not expect great variations in the longer wavelengths of UV but emphasize the finding of UV-C in the range of 250–280 nm. The second part of this comment is wrong: those data are available as maps as well as numerical files at ftp://toms.gsfc.nasa.gov/pub/omi/data.ozone/Y2007/. The values are 275–300 for 7 January 2007 and 250–275 the next day, so their guessed value of 300 DU is not far off. And, yes, one can expect higher UV values in the Altiplano, but we do not address that problem.

4. Instrumentation

[9] All these general statements are legitimate, and we have no problems with them, but the strong paragraph changes into speculation that the 200–850 longpass filter used may not have removed sufficient long-wave radiation to eliminate the spectral scattering problem. The manufacturer uses coatings to prevent the problem pointed out by *Flint et al.* [2008], and that seems to be the right choice in view of the article by *Graham and Vincent* [2008], very specifically for the range of 220–400 nm.

[10] "Ocean Optics spectrographs are not suitable for measuring solar spectra in the UV-B region without modifications because their stray light rejection is insufficient." [*Flint et al.*, 2008, paragraph [5]]. All the spectrometers we used were specially configured to record solar irradiance including the UV range and have been corrected for stray-light with what is the state of the art in technology [*Graham and Vincent*, 2008]. Moreover, at our request, Ocean Optics recalibrated our instruments and concluded that nothing was wrong with the hardware (in contrast with our critics' opinion). Given our uneasiness with the repeated findings of UV-C at ground level, we insisted on understanding how the absolute irradiance was calculated from the intensities recorded by the spectroradiometer. The company was kind enough to trust us with their proprietary calculation spreadsheets, thus allowing us to calculate irradiance values. Their calibration files contain what our critics are claiming we did not do, but in fact is done by the factory and the way they do it is proprietary. The software package they use, SpectraSuite, is not open code software that we were kindly allowed to see and use. These files evidence proper and rigorous conversion of the intensity data into irradiance in the range of 250–400 nm, with logarithmic scale and comparison to a reference file. At the end of paragraph [8], *Flint et al.* [2008] consider that our measurements are wrong also in the UV-B, although they suggest that the UV-A and UV-B irradiance we measured near Ushuaia (55°S, 68°W, at altitudes up to 655 m) are not remarkable. Further, in paragraph [2] they state, "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, "thus invalidating their own criticism.

[11] The October 2006 calibration of our instrument (Certificate # 1481) shows a bandwidth of 200–800 nm. With either that or the new one (October 2007), the values reported from 220 nm up are similar. In any case, we only discuss the 250–280 nm band based on the maximum sensitivity idea. Thus, the highest values of UV-C shown in our figures are outside the new calibration limit. This change was introduced after we took our measurements; otherwise, our figures would have started at 220 nm but our discussion would have continued to start at 250 nm.

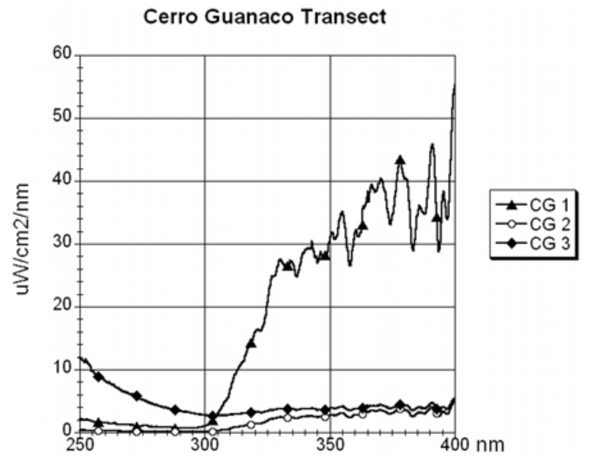

Figure 1. Solar irradiance at Cerro Guanaco. Notice that sample CG 3 shows low values in the UV-A, and the highest in the UV-C.

5. Plant Responses to UV in Ushuaia

[12] *Flint et al.* [2008, section 4] speaks of works using filters to manipulate the spectrum that reaches the plants, and we have no comments since this is a good approach, except that the authors did not mention UV-C nor try to identify its effects separate from those attributed to UV-B.

[13] *Flint et al.* [2008] state that we neglected appropriate research work related to UV radiation although none of these works refers to UV-C measured at ground level. We must acknowledge that some of the references brought up by Flint et al. provide context to our generalizations about the UV environment in Ushuaia. Reflecting on the results of the list of references they present, the critics state that, "If UV-C was present, these studies would have excluded UV-B and UV-C in one treatment and not the other, "implying that if UV-C was present at ground level in Tierra del Fuego, these studies would have reported much larger biological effects. We can speculate that the studies may have reported no larger biological effects in the presence of UV-C because those effects have been assigned to the UV-A and UV-B, neglecting the presence and role of UV-C.

6. Conclusion

[14] *Flint et al.* [2008] agree that the upper elevation treeline in Ushuaia represents a remarkably abrupt transition. That is the focus of our original article. The methods we used to arrive at that conclusion are criticized. Due to the survey nature of our work, we did not intend to make an exhaustive citation of all works about plants and solar radiation done in Tierra del Fuego and elsewhere but rather show a surprising measurement of UV-C at ground level. Our untactful inclusion of the entire spectrum 200–400 nm delivered by the spectroradiometer in both figures and the description of such curves at the end of our *D'Antoni et al.*'s [2007] paragraph [15] may have caused confusion. However, in both figures we show that the range of maximum sensitivity of the instrument ends at 250 nm (technically, the

instrument's shut-off limit). The figures should have been as the one shown in Figure 1.

[15] In closing, we submit that measurable amounts of UV-C in the range of 250–280 nm reach the surface, and this may not be a new phenomenon so plants may have selected structures and mechanisms to avoid its effects that have been overlooked by scientists so far. The advantage of using diode array based instruments versus the double monochromators fitted with sets of exclusion filters is that the diode array instruments are fast, sturdy and truly portable since they have no moving parts. The drawbacks have been progressively solved by a rather intensive dialog between scientists and technologist, users and manufacturers, and we foresee better and more precise results in the future.

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