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Atmospheric Measurement Techniques Discussions

Interactive comment on "Note on rotational-Raman scattering in the O_2 A- and B-bands: implications for retrieval of trace-gas concentrations and terrestrial chlorophyll fluorescence" *by* A. Vasilkov et al.

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Dear Dr. Sanders:

Thank you very much for your comments that have helped us to improve our paper. Below are our responses to your comments shown for convenience in bold face.

p.8790, l.21-22: "To the best of our knowledge, RRS effects in the O2 A- and B-bands have not been quantified in the literature." But see Sioris and Evans

(2000) in GRL.

Thank you for providing this reference. We have added this paper in the list of references in a revised version and compare our results with those reported by Sioris and Evans in a new Appendix (see Figs. 1 and 2). Corresponding corrections and additions are made in Introduction; we replaced "To the best of our knowledge, RRS effects in the O_2 A- and B-bands have not been quantified in the literature. However, RRS effects are worthy of consideration owing to the high accuracy and precision requirements..." with "RRS effects in the O_2 A- and B-bands have been quantified in the literature (Sioris and Evans, 2000). However, RRS effects are worthy of further consideration owing to the high accuracy and precision requirements..."

In the conclusions, we added "Note that our definition of RRS filling-in differs from that of Sioris and Evans (2000) who define it as a percentage of the continuum radiance. Use of different definitions of filling-in may lead to somewhat different conclusions regarding the importance of RRS, particularly within the O_2 A-band. Fluorescence contributes a signal with a similar spectral response to RRS, and low levels of fluorescence have a similar magnitude to RRS. It has also been shown that the fluorescence signal may bias xCO_2 retrievals Frankenberg et al. (2012). Therefore, our definition is more relevant to applications related to retrievals of fluorescence and xCO_2 and leads to the conclusion that the RRS effect is small, but non-negligible even at moderate solar zenith angles."

p.8792, l.13-15: "The far-red fluorescence radiance feature at the surface is approximated by a Gaussian function, [...]. " Could you please provide a reference for this parameterization?

The Gaussian parameterization of fluorescence emission spectra at the leaf level can be found in the following papers that we have referenced a revised version:

Subhash, N. and Mohanan, C.N.: Curve-fit analysis of chlorophyll fluorescence spec-

tra: Application to nutrient stress detection in sunflower, Remote Sens. Environ., 60, 347-356, 1997.

Zarko-Tejada, P.J., Miller, J.R., Mohammed, G.H., and Noland, T.L.: Chlorophyll fluorescence effects on vegetation apparent reflectance: I. Leaf-level measurements and model simulations, Remote Sens. Environ., 74, 582-595, 2000.

p.8792, l.23-24: "Quasi-monochromatic computations are carried out at a spectral sampling of 0.01 nm, that of the solar irradiance reference spectrum from Chance and Kurucz (2010)." I guess I would be interested to know the spectral resolution of the solar irradiance reference spectrum here. This seems a relevant quantity to compare with the minimum FWHM for the instrument response function of 0.03 nm.

The reference spectrum from Chance and Kurucz (2010) was constructed from high resolution spectra by convolving them to a Gaussian FWHM of 0.04 nm and this is now specified explicitly in a revised version. This spectrum is commonly referred to as SAO2010. However, our simulations with a higher resolution solar spectrum (see Fig. 5 that is now in an Appendix A2) show that differences between results computed with two solar spectra are generally small except for a few narrow and deep Fraunhofer lines beyond the oxygen A-band. We clarify this point in a revised version of the paper: "However, note that convolution of these instrument response functions with the solar spectrum of Chance and Kurucz (2010) (that has spectral resolution similar to our highest spectral resolution simulation) will somewhat underestimate solar line filling as shown in Appendix A2.

p.8798, l.5-7: "Neglect of RRS filling in the O2 A-band may therefore lead to biases in satellite-retrieved CO2 mixing ratios similar to effect of chlorophyll fluorescence shown in (Frankenberg et al., 2012)." No support for this statement is provided. It would be very interesting to know, of course, whether this statement

is indeed true, but I think that the manuscript does not address this question. I am afraid that I therefore find the title presumptuous.

Firstly, we agree that the title of the paper may not be appropriate; we have therefore changed the title of the paper by removing "Implications for retrieval of trace-gas concentrations and terrestrial chlorophyll fluorescence".

Secondly, we have removed the above statement and replaced it with "The calculations of Frankenberg et al. (2012) showed that an additive signal from fluorescence of 1% of the continuum could lead to $\sim$1 ppm errors in retrieved xCO_2. Assuming linearity, the neglect of RRS filling-in within the O_2 A-band may then lead to biases in satellite-retrieved xCO_2 of approximately 0.3 ppm." We also rearranged the conclusions a bit and changed "Our calculations show that RRS filling-in of telluric lines is comparable with small to moderate amounts of filling-in due to terrestrial chlorophyll fluorescence" to "Our calculations show that RRS filling-in of telluric lines is spectrally comparable with small to moderate amounts of filling-in due to terrestrial chlorophyll fluorescence (of the order of 0.5 $\mathrm{mW\,m^2\,sr^{-1}\,nm^{-1}}$)."

Thirdly, to illustrate how RRS might affect a retrieval related to photon path length in the O2A band, we changed the old Fig. 10 comparing the RRS spectral response with that of fluorescence. We removed one the upper fluorescence curve and replaced it with one showing the spectral response due to a 3 hPa change in surface pressure. This surface pressure change produces a similar magnitude and spectral response as RRS, although there are subtle differences (see Fig. 3).

p.8794, l.15-16: "A comparison the RRS filling-ins computed" missing words, typo?

We corrected the typo. Thank you.

On behalf of the authors, Alexander Vasilkov and Joanna Joiner

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Interactive comment on Atmos. Meas. Tech. Discuss., 5, 8789, 2012.

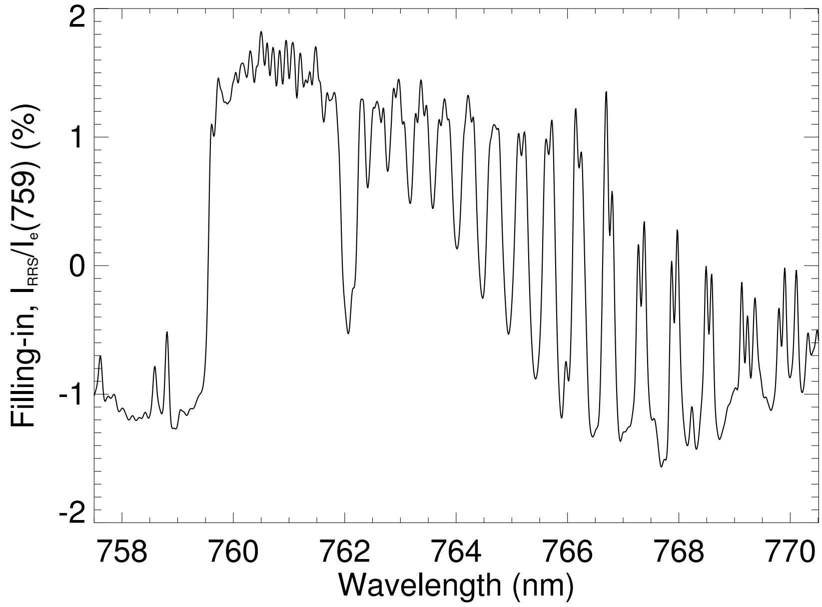

Fig. 1. RRS filling-in computed for conditions similar to Sioris and Evans (2000) with their definition of filling-in.

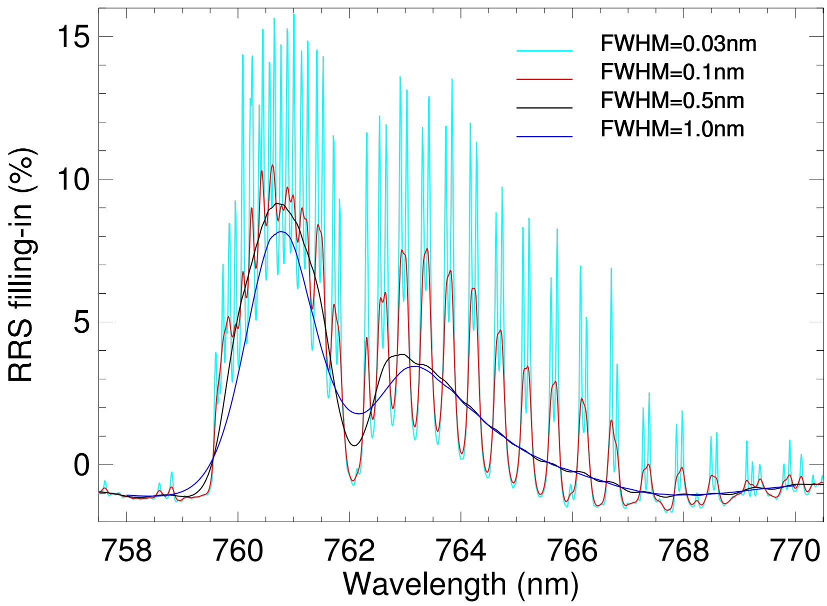

Fig. 2. Filling-in computed for the same conditions as in Fig. 1 with our definition of filling-in and different spectral resolutions.

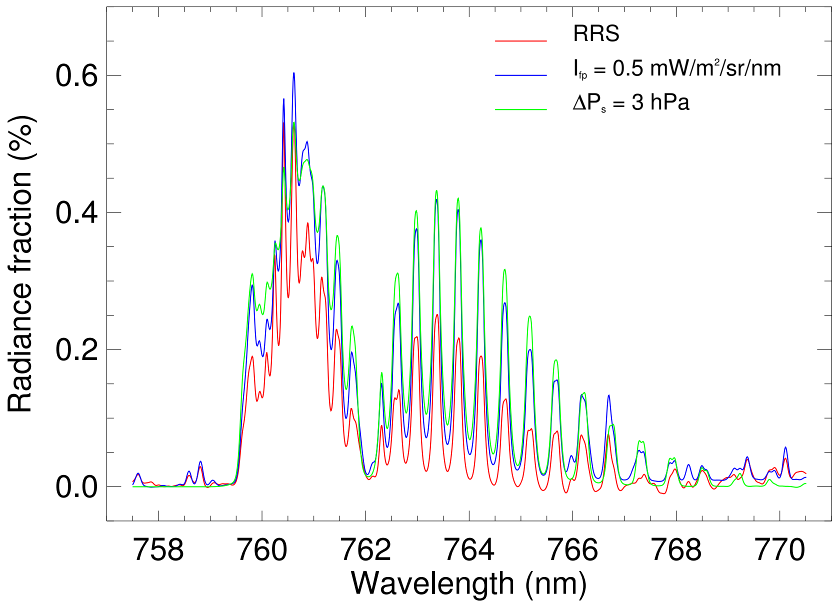

Fig. 3. Comparison of fractional radiance effect of RRS (red), fluorescence (blue), and surface pressure change of 3hPa (green) for FWHM=0.1nm, SZA=45 degrees at nadir, surface albedo=0.3.