

Interactive comment on “Chlorophyll fluorescence remote sensing from space in scattering atmospheres: implications for its retrieval and interferences with atmospheric CO₂ retrievals” by C. Frankenberg et al.

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We wish to thank Elizabeth Middleton for her thorough and thoughtful review. Our responses are given below.

Suggested Full Title: Remote sensing of NIR chlorophyll fluorescence from space in scattering atmospheres: implications for its retrieval and interferences with atmospheric CO₂ retrievals.

C1213

→ ### Response #####

Changed title to “Remote sensing of near-infrared chlorophyll fluorescence from space in scattering atmospheres: implications for its retrieval and interferences with atmospheric \chem{CO_2} retrievals” Changed short title to “Remote sensing of NIR chlorophyll fluorescence from space”

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... This will likely limit usefulness in predicting vegetation processes. This point should be clarified in the Goals of the paper (Page 2489, lines 18-25): the Fs retrievals addressed here are those in the 750-775 nm range, only a subset of the full chlorophyll emission range (650-800 nm). Therefore, the full and short titles for the article should indicate that the fluorescence topic discussed is limited to this region, not the entire emission region. Suggested titles are given at the top.

→ ### Response #####

We changed the titles to reflect this concern

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The authors should cite the recently published paper by Joiner et al. (2012) in this same on-line journal, AMT, throughout the paper as appropriate. This should be cited on Page 2489 (line 24), Page 2491 (line 3), Page 2498 (line 16), and Page 2504 (lines 1 & 8). The citation is: Joiner, J., Yoshida, Y., Vasilkov, A. P., Middleton, E. M., Campbell, P. K. E., Yoshida, Y., Kuze, A., and Corp, L. A.: Filling-in of near-infrared solar lines by terrestrial fluorescence and other geophysical effects: simulations and space-based observations from SCIAMACHY and GOSAT, Atmos. Meas. Tech., 5, 809-829, doi:10.5194/amt-5-809-2012, 2012.

→ ### Response #####

Done

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My comments address the more tangential issues raised and discussed by others: 1] the characterization of the “true” (aka, ideal) condition against which the results are compared; 2] the presumed usefulness of the retrieved NIR fluorescence signal in this region (675-775 nm) for describing photosynthetic function in vegetation regionally and globally; and 3] the statements made about the FLEX mission. My first suggestion, in support of an earlier posted comment, is to replace the term “full-physics retrievals” with “realistic-physics retrievals” or “optimized physics retrievals” or similar term throughout. This is because the simulations, although accounting for many effects, are still lacking “full-physical descriptions” in some important ways.

-> ### Response #####

Added the following in the introduction: The term “full-physics” algorithm is commonly used in the atmospheric remote sensing community for retrievals based on the full modeling of the radiative transfer instead of parameterizations or a decoupling of the retrieval of trace gas slant column densities and radiative transfer modeling.

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The term F_s is defined on p 2489 (line 14), and could thereafter be used in place of the words “chlorophyll fluorescence”.

-> ### Response #####

Kept it as is as it shouldn't be too long to mention it in full words here and there

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Another issue involves terminology and overstatement of capability. One example is found in the second sentence of Section 2 (Chlorophyll fluorescence, page 2490, lines 13-15). [“During photosynthesis, visible solar energy absorbed by chlorophyll can either be used for carbon fixation, be dissipated into heat, or be re-emitted via

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fluorescence at longer wavelengths in the 660–800nm window. This so-called solar-induced chlorophyll fluorescence (Krause and Weis, 1991; Baker, 2008, and references therein) thus offers a very direct measure of photosynthetic activity.”] To be correct, this should be re-written. I suggest this: Shortwave energy obtained from a laser or a visible light pulse with laboratory or field instruments, or by the sun, is collected within vegetation by chlorophyll. Under optimal conditions, most of this energy is routed through photosynthesis, but typically some energy is dissipated as heat or re-emitted via fluorescence at longer wavelengths in the 660-800 nm window. When determined under natural conditions outdoors, the fluorescence obtained is referred to as solar-induced chlorophyll fluorescence. Fluorescence intensity is an indicator of photosynthetic activity.”

-> ### Response #####

We use your suggestion now.

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On Page 2492, please clarify the spectral locations of the two Gaussian A1 and A2.

-> ### Response #####

As for position of peaks, these are provided in the table (cumbersome to read in the AMTD format but will be easy in the final format)

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References to the FLEX mission should be stated correctly. For example, a rewrite is provided here for Page 2498 (lines 18-19). “These are typically used in ground-based studies and suggested for inclusion in the FLEX mission retrieval scheme along with fluorescence and reflectance information to be acquired in additional spectral regions. That broader approach is necessary because TOA retrievals that rely solely on the O₂ bands are problematic, as will be corroborated in the following section.”

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-> ### Response #####

We removed the FLEX reference here.

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C959 Furthermore, it should be noted (e.g., Page 2499, lines 27-29) that the FLEX mission will measure Fs at more optimal regions of the emission spectrum than can be obtained with the GOSAT or similar NIR instruments, and will make vastly improved spatially explicit measurements at 300m that can be validated against ground-based measurements. So, please also correct the reference to FLEX (incorrect statement about only using O2 bands for Fs retrievals) on page 2505 (lines 6-9). I suggest that you do not delete references to the FLEX mission, as stated in one of the posted online comments in reply to those of W. Verhoef, but rather that correct information be substituted.

-> ### Response #####

We removed the FLEX reference here as well. The only place where FLEX is still mentioned is in the following sentence: A combination of A and B-bands, such as envisioned in the FLEX mission concept, would be preferred if spectral resolution is not high enough to exploit Fraunhofer line features (Guanter:2010p3726,amtd-4-6779-2011). We think this is a fair statement and neither over nor understated FLEX capabilities.

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Edits Page 2489, lines 14-16: Frankenberg et al. (2011a) found that NIR chlorophyll fluorescence (Fs) between 750-775 nm cannot be unambiguously distinguished from the effect of scattering on the depth and shape of atmospheric O2 absorption features in the 0.76 μm range.

-> done

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Page 2490 (lines 17-18): . . . in the two emission peaks around 680 and 740 nm, the latter which encompasses the strongly saturated O2 A-band around 760 nm. (line 27) . . . retrievals cannot be readily applied if only the O2 A-band is measured and a ground reference value is unavailable.

-> done

Page 2491 (line 9): . . . resembles vegetation patterns associated with optimal GPP. [Note: The GPP patterns provided in Beers et al. and GOSAT publications (Frankenberg et al., 2011; Joiner et al., 2011, 2012) describe very low spatial resolution (e.g., 0.5 x 0.5 deg).

-> ### Response #####

Don't see a need to mention coarse spatial resolution here as you suggested. However, we changed to "will thus resemble these regional-scale spatial structures, which, in turn, are related to GPP."

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Page 2492 (line 1): retrieved is mis-spelled. Page 2495 (line 14): . . . where when Page 2497 (line 13): . . . as well as. . . (line 27): Please clarify what parameter (for which energy units are given) are related to the error in XCO2 of 0.55ppm.

-> All clarified (some typos must have entered in the typesetting stage, thanks for spotting those!).

Page 2499 (line 11): The inclusion of fluorescence as fitting parameters caused some outliers in retrieved XCO2 at low simulated Fs values though. Why do you call these "true" Fs values? (line 19)

-> because we know the truth (i.e. simulated=truth)

. . . because for interferences are introduced.

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-> done

C960Page 2500 (lines 4-12): This is vague. Please rewrite this. (line 19): Are you referring to operational retrievals of O2 or CO2?

-> Not changed, looked clear to us.

Page 2503 (lines 2-4): Please give a better justification for re-using Aeronet data for the same months (but different year) that these data were not collected or available. Fig. 13. shows that inter-annual variation is apparent. (lines 6 & 15): change "to" to "with"

-> Sentence indeed didn't make sense. we changed to: Since only an estimate of what the impact of realistic AOD levels can have on F_{s} , one year of AOD values have been replicated to cover the entire 22 months of the F_{s} series.

-> Since we were only interested in an estimate of the impact of realistic AOD levels on the retrieval of F_{s} , one year of AOD values have been replicated to cover the entire 22 months of the F_{s} series.

Page 2504 (line 6): Refers to Fs?

-> Done

Page 2505 (lines 21-23): Please limit this claim to the NIR Fs (two places in one sentence).

-> Done

Figure Captions: RMSEs for linear fits would be useful. Figs. 3, 4, 5, & 6. Captions should include NIR Fs at 755 nm. Fig. 5. "known" Figs. 6, 7, 8, & 10: what are the units for Y axis of bottom panel?

-> Y-axis units are same as X-axis (too little space to repeat it here)

Fig. 7 & 8: Clarify second sentence.

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-> Don't fully understand that remark

Fig. 9: zero level offset in XCO2?

-> Don't understand this remark. Yes, the 0-level offset is impacting XCO2 AND the fluorescence fit.

Fig. 11: True Fs values? Or, expected values with model conditions X?

-> in simulations, we know the "truth", hence it should be ok to use this term.

Fig. 12: Red lines (plural)

-> done

Fig. 13. These are simulated surface and TOA NIR Fs at 755 for 0.5 x 0.5 deg areas. Instead of 'Goddard', put Greenbelt, MD (middle).

-> Done

Fig. 14: The plot only shows X axis to 759 nm, but caption says 760 nm

-> changed to 759nm

Interactive comment on Atmos. Meas. Tech. Discuss., 5, 2487, 2012.

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