

***Interactive comment on “Chlorophyll fluorescence remote sensing from space in scattering atmospheres: implications for its retrieval and interferences with atmospheric CO<sub>2</sub> retrievals” by C. Frankenberg et al.***

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Received and published: 11 June 2012

Dear Albert Porcar-Castell,

We highly appreciate this well-balanced comment on potential limitations regarding the interpretation of the fluorescence signal. This manuscript is mainly focussed on the impact of fluorescence on XCO<sub>2</sub> retrievals and on some technical aspects of the fluorescence retrieval itself. However, we see the need for correct (not over-stated) statements

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regarding the applicability of the signal and we are always open (and thankful) for objective and constructive criticism such as yours. Even though passive remote sensing of fluorescence certainly advanced rapidly, there are still some caveats regarding the data, mostly related to incomplete global coverage, large ground-pixel sizes and high single measurement noise.

Some general comments (hopefully in the positive direction):

In Frankenberg et al, (GRL, “New observations..”), we have investigated the relationship with GPP models and vegetation indices (more related to greenness). Especially evergreen needle-leaf forest didn’t show a good relationship between EVI and GPP but with F<sub>s</sub> and GPP, showing that the remotely sensed F<sub>s</sub> signal (in that case) was indeed indicative of photosynthetic activity rather than pure greenness. Also, Daumard et al (IEEE, 2010) observed a strong decrease in both O<sub>2</sub>-A and O<sub>2</sub>-B spectral band region F<sub>s</sub> after a prolonged dry period. No changes in vegetation indices could be observed though. In this case, F<sub>s</sub> at 760nm clearly reacted to drought without yet showing any clear decrease in chlorophyll content.

On the other hand, assuming the worst scenario that NIR fluorescence is only linked to absorbed photosynthetically active radiation (APAR) and showed no sensitivity to instantaneous photosynthetic efficiency, it could be argued that this is not a severe limitation to application of GOSAT observations: the low signal-to-noise ratio of the retrievals doesn’t allow analysis to temporal scales of few days for which the direct link to LUE could be best exploited. In this worst case scenario, fluorescence would provide a direct, self-contained measurement of chlorophyll content and green APAR BUT which would be free from all the known limitations of reflectance-based vegetation indices (sensitivity to atmospheric effects and canopy structure, saturation under high biomass conditions, sensitivity to non-photosynthetic elements of the canopy...) and of PAR estimations from external sources (also prone to modeling errors and deficient spatial sampling). We consider that the improved APAR provided by fluorescence should already be a great step forward in the estimation of vegetation productivity from space.

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Mild stress conditions affecting slightly the canopy chlorophyll content without leading to visible changes in the leaves would already be detected by the fluorescence signal in 760 nm. In a more positive scenario, there will be information on both, chlorophyll content (and APAR) as well as down-regulation of photosynthetic efficiency through NPQ.

However, we fully agree though that more research is needed to be able to provide a more robust and quantitative interpretation of the observed signal. It indeed seems to be the case that fluorescence field measurements with focus on steady state sun-induced Fs and its modeling from the leaf to the canopy scale (including aspects of the PSI contribution) still require more research. Hopefully, missions like FLEX and the recent GOSAT results help trigger this.

As for the manuscript: To address your and other comments, we added the following:

However, there are still uncertainties regarding the contribution of Photosystem I (PSI, \cite{pfuendel\_1998}) to the chlorophyll fluorescence signal in the 755–770~nm window under natural and stressed conditions. The primary driver of fluorescence is certainly absorbed photosynthetically active radiation but the inter-play between photosynthesis and fluorescence yield in steady-state conditions may require further research before fluorescence modeling \cite{ToI} offers a consolidated physiology-based link between NIR fluorescence and photosynthetic efficiency. A good correlation of space-based fluorescence retrievals with gross primary production on the coarser regional scale, however, was demonstrated in \cite{Frankenberg:2011p6380, Guanter\_SVD\_2012}.

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