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Atmospheric Measurement Techniques Discussions

Interactive comment on "Potential of the TROPOspheric Monitoring Instrument (TROPOMI) onboard the Sentinel-5 Precursor for the monitoring of terrestrial chlorophyll fluorescence" *by* L. Guanter et al.

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We would like to thank the referee for his/her comments and the positive review. Please, see our responses in bold below.

Manuscript "Potential of the TROPOsphericMonitoring Instrument (TROPOMI) onboard the Sentinel-5 Precursor for the monitoring of terrestrial chlorophyll fluorescence" from Guanter et al. covers an interesting scientific topic relevant for Atmos. Meas. Tech., presents new material and is well written. I therefore recommend publication

after the items listed below have been carefully addressed by the authors.

Abstract: Concerning: “Our results illustrate the enormous improvement in SIF monitoring achievable with TROPOMI with respect to comparable spectrometers currently in-flight, such as the Global Ozone Monitoring Experiment-2 (GOME-2) instrument. We find that TROPOMI can reduce global uncertainties in SIF mapping by more than a factor 2 with respect to GOME-2 ...”: This statement is based on the assessment of simulated re- trievals essentially assuming that the retrieval precision improves with the square root of the number of observations added (i.e., using Eq. (6)). Although reasonable, it is strictly speaking unclear to what extent this is valid. As the authors have published SIF retrievals based on real GOME-2 data I recommend to provide evidence based on real data that Eq. (6) is appropriate to model the precision improvement expected from averaging individual SIF retrievals. If this seems not possible, e.g., due to lack of validation data, this should at least be clearly mentioned (e.g., already in the abstract by adding “Assuming that the precision improves with the square root of the number of measurements added, our results...”).

Thanks for the comment. From our understanding, the standard error of the mean (SEM) expressed by Eq. 6 is a widely-used statistical figure intended to quantify the error with which the mean value of a distribution is known, taking into account both the uncertainty of single elements and the total number of elements in the sample. In our study we selected the SEM to characterize the precision of spatio-temporal composites and serve as a basis for the comparison of TROPOMI and GOME-2 results. We feel that discussing the validity of the SEM to characterize precision is somewhat out of the scope of our work. In any case, the claim that TROPOMI will provide a much better precision for fluorescence retrieval than GOME-2 based on the calculated SEM’s holds, since we are applying the same equation to both TROPOMI and GOME-2 results.

On the other hand, in line with the reviewer’s concern on the validation of our simulation set-up, we have modified Fig. 7b so that it now includes a comparison

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between our simulated single-retrieval precision estimates for GOME-2 and the ones derived from real GOME-2 retrievals over Sahara. We believe that the good match between the two strongly supports the reliability of our simulations.

Concerning: "Finally, we discuss the potential of TROPOMI to accurately map other important vegetation parameters, such as leaf photosynthetic pigments and proxies for canopy structure, which will complement SIF retrievals for a self-contained description of vegetation condition and functioning.": To my knowledge it has not yet been shown using real satellite data (e.g., GOME-2, SCIAMACHY) that this is possible. I therefore recommend to modify this sentence as follows: " ... which, if feasible, will complement ... ".

Thanks. We have rephrased this as "Finally, we discuss the potential of TROPOMI to map other important vegetation parameters at a global scale with moderate spatial resolution and short revisit time. Those include leaf photosynthetic pigments and proxies for canopy structure, which will complement SIF retrievals for a self-contained description of vegetation condition and functioning" in order to put the emphasis in the moderate spatial resolution achievable from TROPOMI with respect to GOME-2 and SCIAMACHY.

Introduction:

Page 12550, line 3 and following: Concerning "This wide spectral sampling will potentially allow to exploit the information carried by the full SIF spectrum and not only by the longer wavelength peak at the NIR". Existing satellite instruments (GOME-2, SCIAMACHY) also have wide spectral coverage. TROPOMI is not unique here. It is therefore unclear why this should be possible with TROPOMI but not with existing instruments.

We didn't mean that TROPOMI was unique. The clarification ", also covered by GOME-2 and SCIAMACHY but a much coarser spatial resolution" has been added.

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2.3 Retrieval random error

Page 12554, line 15: Please check formula for J(alpha) (I guess v2-nv needs to be replaced by vi). Please also use subscript s in Fs. Section 3: Please add (here or later, e.g., when discussing Fig. 8) more information on the differ- ence of the training data set and the data used for the sensitivity studies especially with respect to systematic differences so that the reader can better judge the relevance of the results with respect to systematic SIF errors ("accuracy").

Modifications added, thanks.

4.1 Estimates of retrieval precision and accuracy

Page 12560, line 26 and following: Concerning "However, despite those biases we consider these results to be of high interest, as they show the potential for red SIF retrievals with TROPOMI.": Again: TROPOMI is not unique here. Are the conclusions supported using real data from existing missions (GOME-2, SCIAMACHY). If not this should at least be clearly mentioned.

We have added "(and potentially from GOME-2 and SCIAMACHY as well)"

4.3 Global estimates of retrieval precision

Page 12562, line 8 and following: Concerning "The results discussed in Sect. 4.1 demonstrate that instrumental noise is the main contribution to the error budget in SIF retrieval for clear-sky observations.": This statement is too strong as no attempts have been made to establish a full error budget. What about various instrument related errors not discussed (e.g., zero-level-offsets, effects of inhomogeneous scenes resulting in slit function variations and other issues) ? Please use a less strong statement here.

Thanks. We have added "in absence of instrumental issues significantly affecting the radiometric performance."

5.1 Validation ... First paragraph: Are any results available based on real data showing

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that the indicated airborne measurements can be used for validation? If yes please add the relevant references. If not please state that so far this has not been demonstrated.

A reference to Damm et al., (2014) has been added to Rascher et al., (2009) and Guanter et al., (2007) at the end of the paragraph.

5.2 Towards a global representation ... See also my comment on the last part of the abstract: As far as I know it has not yet been demonstrated that this is possible using real data although existing instruments (GOME-2, SCIAMACHY) should also be able to deliver the discussed parameters. 6. Conclusions Page 12568, line 20 and following: Concerning: "However, this is only a worst case scenario because of the conservative, mission requirement-based SNR curve used for TROPOMI in this study.": I am not convinced that this is "worst case" because of the assumption used with respect to precision improvement with square root of n and because several instrument related errors have not been addressed (see above).

Thanks, comment taken. The following paragraph is now in the Conclusions "We would like to state that we expect a better retrieval precision for real TROPOMI data because of the conservative SNR-radiance curve used for TROPOMI in this study. On the other hand, the instrument model used in our simulations does not include potential systematic measurement errors, such as from calibration offsets or stray light, which might severely affect SIF retrievals. A more accurate analysis of absolute error figures will be performed when more details on the TROPOMI radiometric and spectral performance become available.".

Page 12569, line 24 and following: Concerning: "This includes TEMPO ... and ... FLEX ... ". This also includes CarbonSat, which needs to be added, see the assess- ments reported in Buchwitz et al., Atmos. Meas. Tech., 6, 3477-3500, 2013.

Thanks for the comment. We agree that CarbonSat would have a high potential for SIF monitoring if selected for implementation, but disagree that it should be mentioned here. As stated by "TROPOMI will be the precursor for upcom-

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ing spaceborne instruments with similar spectral coverage and resolution", this paragraph refers to SCIA-like spectrometers, with a wider spectral widow and coarser spectral resolution than GOSAT, OCO-2 or CarbonSat.

Figures:

Figures 1 and 2: The (very thin) lines are hardly visible in a printout, especially the yellow (and green) lines. Please improve. I recommend to use thicker lines.

Figure 3: Annotation and numbers (radiances? If yes please add units) given on top unclear.

Figure 5: What are "Accesses"? Are these the number of overpasses for a given latitude?

Modifications made, thank you.

Interactive comment on Atmos. Meas. Tech. Discuss., 7, 12545, 2014.