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Interactive comment on "Sun-induced Fluorescence and Near Infrared Reflectance of vegetation track the seasonal dynamics of gross primary production over Africa" *by* Anteneh Getachew Mengistu et al.

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GPP seasonal dynamics of Africa

Mengistu et al

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Discussion paper

Authors Response to an interactive comment on “Sun-induced Fluorescence and Near Infrared Reflectance of vegetation track the seasonal dynamics of gross primary production over Africa"

Anteneh Getachew Mengistu et al.

November 4, 2020

Authors response to anonymous Referee #2 Comments:

We thank the anonymous referee for the time spent to read our manuscript and provide important comments and suggestions. They are enormously constructive and are used to improve the quality of the manuscript. Our reply included two extra analyses and two extra figures that are included and discussed in this document. We will respond to the comments in detail and indicate the changes made in the revised manuscript as follows.

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1 Overview:

Overview: Review of “Sun-induced Fluorescence and Near Infrared Reflectance of vegetation track the seasonal dynamics of gross primary production over Africa” by Mengistu et al. My sincere apologies for the delay in my review.

Response: Thank you for the comment, we fully understand the difficulty in thee times to perform tasks like this.

Overview: Mengistu et al. present an analysis of SIF, NIRv, EVI, and NDVI over the African continent. They compare these remote-sensing products to flux towers across multiple ecosystems. They find soil moisture to be the dominant driver for much of their data. They also find both SIF and NIRv do a better job of reproducing GPP than EVI or NDVI. Overall, the study is both interesting and useful.

Response: We thank the reviewer for kind understanding and acknowledgment that this study is interesting and useful.

Overview: My main comments relate to quantitatively assessing the claim that SIF and NIRv are performing better.

Response: We demonstrated that SIF and NIRv do a better job than EVI and NDVI in capturing the seasonal dynamics of GPP. However, a performance comparison of SIF and NIRv against VI’s (EVI or NDVI) is needed to conclude which one is better than the other. We did not do that in this study, as our focus is mostly on these products given their promise as demonstrated in recent work (**???**).

Overview: The figures are reasonably easy to follow and the text is quite well written. I would recommend minor revisions.

Response: We thank the reviewer for his kind appreciation. We provide response to his minor revisions.

2 Major comments:

Both of my main comments relate to the claim that SIF and NIRv are performing better than NDVI and EVI.

2.1 Are SIF and NIRv actually performing demonstrably better?

Comment: In the conclusions, the authors state: “The mean climatology of SIF and NIRv agrees widely with the MPI-BGC GPP products in large parts of Africa, confirming their values as a more robust GPP proxy than the commonly used MODIS vegetation indices. However, it’s not clear to me that 1) agreement with the MPI-BGC GPP estimate is the metric by which to justify that statement and 2) that the differences between some of the products is not within the noise. The latter statement implies to me that SIF and NIRv are both performing comparably well while NDVI and EVI are performing measurably worse.

Response: In this particular study, we did not aim to provide a performance comparison of SIF/NIRv against the NDVI or EVI. Our target is to assess how good are SIF and NIRv to track the seasonal dynamics of GPP over Africa. We agree with the reviewer that MPI-BGC GPP products are not the metric. Moreover, we demonstrated that SIF and NIRv have better correlation to tower GPP than MPI-BGC (See Fig. 2 of the main text, for towers CG-Thc and SN-Dem). Therefore, it is clear that our conclusion need to be rephrased and we now edit the statement and read as “The mean climatology of SIF and NIRv correlates well with GPP from EC-towers, confirming their value as a robust GPP proxy."

Comment: From examination of Figure 2, it’s not clear that is the case. I would certainly agree that NIRv are and SIF are performing better than EVI at CG-Tch, but NIRv and EVI seem nearly identical at GH-Ank while SIF seems to show no real correspon-

dence with the EC data.

Response: Our analysis shows that SIF and NIRv have a better correlation than EVI over SN-Dhr, CG-Tch, and ZA-Kru flux towers. We agree that EVI shows better performance for ZM-Mon flux tower. However, for this particular site, both SIF and NIRv also showed a strong correlation >0.96. This strong correlation for all proxies is expected as the region is dominated by a deciduous broadleaf vegetation which has a clear seasonality of leaves up and down.

Comment: I'm wondering if it would be possible to set up some hypothesis test to quantify this. Or maybe it could be done via bootstrapping. For example the authors could randomly sample the different datasets and compare them to the EC data and the MPI-BGC data then report an uncertainty on the R values. Or report the fraction of times the different remote-sensing products performed better than each other.

Response: We thank the reviewer for this suggestion and we agree that this could be an interesting approach if one wanted to create a ranking of different VI's and their correspondence to towers. Then again, as agreed with the reviewer an agreement to the MPI-BGC GPP is perhaps not the strongest metric and might not lead to a new conclusion. To show our commitment to the reviewer's remark, we do present here a comparison of NIRv, SIF, NDVI, and EVI with GPP combined from the five EC-tower used in this study. Because none of all proxies showed a correspondence to EC-GPP from GH-Ank site, we exclude values from this site. What we see is that interpreting the R-squares are indeed favorable to SIF and NIRv, but these also show a stronger linear correlation and lower root mean squared deviation than the MODIS Vegetation indices (EVI and NDVI) (See Fig. 1). Moreover, it suggests that the SIF-GPP and NIRv-GPP relationship is possibly less dependent on the vegetation type than the NDVI-GPP and EVI-GPP relations (because we aggregate observations from 5 different towers).

This is an interesting result and we are contemplating a way to look deeper into this,

but given the focus of our current work and the uncertain outcome of the proposed bootstrapping ranking effort, we did not pursue this comparison for now.

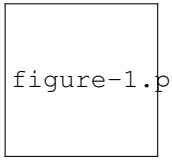

Fig. 1. The relationship of NIRv, SIF, NDVI, and EVI with tower GPP. all correlations have a p-value < 10^{-6}.

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2.2 Are SIF or NIRv capturing those downregulation effects due to water availability?

Comment: As the authors note, the MPI-BGC and other models (e.g., VPRM) include terms for water availability. The authors show that root zone soil moisture is both important for GPP across Africa and strongly coupled to SIF/NIRv. Does this mean that SIF and NIRv are responding to changes in water availability?

Response: Yes, our hypothesis is that remotely-sensed SIF and NIRv reflect changes in canopy-scale photosynthesis that are caused by (or at least very strongly influenced by) changes in water availability. The nuance here is for the tropical broadleaf biome, where moisture levels seem to remain sufficiently high to make this relation weak, or absent in the data we used.

Comment: If so, are they responding in a manner that better approximates GPP than NDVI or EVI? Related to this, does this mean that models using SIF or NIRv would not need a water availability term? Or do they still require one?

Response: The target of our study is to test the usefulness of SIF and NIRv and therefore we did not compare the performance of EVI and NDVI in capturing the water availability. At this stage, we do not suggest that water availability terms need to be included in models for SIF or NIRv, but since these proxies reflect such changes in the vegetation, a model of **GPP** would be required to represent the state of soil moisture well. If not, its GPP is likely to not agree with the remotely-sensed SIF and NIRv that we used.

Comment: The authors mention that the rapid decrease at CG-Tch starting in June is due to water availability, I would be interested to see a time-series for individual years that show SIF and NIRv tracking this decrease and some measure of water availability. This could be a supplemental figure, but it would be nice to see that it's

actually occurring on individual years.

Response: We perform an extra analysis of the timeseries for the years covering 2007-2016 around CG-Tch tower (see Fig. 2). The correlation of SIF, NIRv, and EVI are 0.77, 0.89, and 0.88 with SM and 0.72, 0.64, and 0.64 with precipitation. The lower correlation between SIF and SM is due to SIF responding earlier than the soil gets too dry. Whereas the correlation of EVI and NIRv with SM show the same pattern, this suggests that they respond when the vegetation looses their green color.

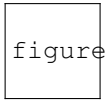

Fig. 2. Time series of SIF, NIRv Precipitation and soil moisture.

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3 Minor comments

3.1 Wang et al study?

The authors may want to discuss the Wang et al. (2020; doi:10.1029/2020JG005732) paper. They provide a nice discussion of what these different remote-sensing measures are telling us.

Response: We thank the reviewer for bringing this interesting new paper under our attention. It nicely highlights differences between NDVI, VOD and SIF and how they could be used complementary. We have included a reference to this paper in our discussion.

3.2 Choice of regions?

Comment: In Section 2.1 the authors mention that they split ecosystems across hemispheres (i.e., NH shrubs and SH shrubs). This reviewer is confused about why this decision was made. The precip and insolation will be out of phase, sure, but wouldn't we expect the response to be similar? Or should we expect a different functional relationship?

Response: We agree with the reviewer that the behaviour of the vegetation in response to environmental drivers should be similar, and that they are thus not fundamentally different. However, the distinction between the NH and SH is for a more practical reason: it allows us to plot the seasonal variation of environmental drivers and the vegetation response as a function of time (e.g. for precipitation in Fig. 1d).

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3.3 Use of multiple MODIS products?

Comment: I see the authors used MCD43C4 for NIRv but MOD13C2 for EVI and NDVI (Page 6, Line 5)? I'm curious why they didn't use the same set of reflectances and then compute the various indices in a consistent manner?

Response: We thank the reviewer for this comment. The reason for doing this, is that MODIS does not provide NIRv in the MOD13C2 dataset, so we calculated it using the BRDF-corrected surface reflectances from MCD43C4, following the steps outlined in (**?**). We have now included a sentence on page 6.

3.4 LUE models

Comment: Not all of the photons emitted will escape the canopy. Shouldn't there be some canopy escape term in the SIF relationship? If I recall, the Dechant et al. (2020; doi:10.1016/j.rse.2020.111733) paper argued that this canopy escape term is where much of the information is coming from (that we're learning something about structure.

Response: We thank the reviewer for this comment. Indeed the photon escape ratio is an important term for the interpretation of the SIF signal. Our LUE framework demonstrate the existence of a linear relationship between SIF and GPP and not to provide a complete empirical relation of GPP and SIF. We define the LUE_f to represent the product of light use efficiency of SIF and fraction of emitted photons escaping the canopy. Now to be consistent with terminology of other literature we re-write our formulation to include the fraction of emitted photons escaping the canopy separately. "where LUE_f is the effective light use efficiency of SIF and f_{esc} is the fraction of SIF photons escaping the canopy (**??**)."

3.5 Flux tower comparison

Comment: Presumably the flux towers can be influenced by different types of vegetation within the footprint of the tower, why do the authors remove those pixels from the satellite data: “The flux towers have a footprint of about 1 km^2 and it is hard to compare them to areas that are 200 km^2 centering the tower which includes many vegetation types. However, we use the vegetation mask to exclude grid cells with different vegetation from the tower’s vegetation”. Seems like it would be more appropriate to keep all of the pixels within the region because they are not systematically removing airmasses that come from certain wind directions.

Response: "We assume that there is one dominant vegetation type within the small footprint of the flux towers ($\sim$ 1-2 km^2). The combination of satellite pixels surrounding the tower cover a larger area and can contain different vegetation types. Therefore, to make the comparison between satellite (with possibly multiple vegetation types) and the flux tower (with a single dominant vegetation type) more representative, the filtering of satellite pixels is required."

3.6 Discussion of COS and $\triangle^{17}$O

Comment: The timing of this discussion seems weird. The authors mention that these measurements exist but do not actually employ them. As such, I don’t feel like this paragraph really adds much value. I’d suggest either removing this paragraph or putting it in the intro.

Response: We move this discussion to conclusion section to recommend it as another alternative for further study.

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3.7 Colorscheme

Comment: As someone who is mildly colorblind, I would prefer the authors use a different color scheme for Figure 1. There's a great discussion on color schemes here: https: //personal.sron.nl/ pault/ and examples of how the rainbow color scheme can distort data (see "Good and bad colour schemes compared" near the end). It appears that the authors are using Matlab, I think the "parula" scheme is fairly safe and should be easy to change to. It should just be a matter of adding colormap(parula) to the code.

Response: We thank the reviewer for the suggestion. We agree and changed the colorscheme as suggested by the referee.

4 Specific Comments:

Comment: Page 2, Line 25: Typo, should be "Congo basin".

Response: Thank you for catching this. Corrected. change was made on page 2 of line 25.

Comment: Page 3, Line 10: Typo? Sentence is confusing: "there is a clear contribution of soil moisture is stress for short vegetation".

Response: Thank you for indicating this, we rephrased the sentence into: "there is a clear contribution of soil moisture stress for the changing photosynthetic capacity of leaves as a function of age in broadleaf vegetation..." change was made on page 3 of line 10.

5 References

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