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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

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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.

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Authors response to anonymous Referee #1 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. The reply to these comments have lead to new analyses of spatial relations between soil moisture and SIF/NIRv, the addition of a new figure to assess the effect of spatial resolution, and changes to the text to reflect the different response of tropical broadleaf forests to seasonal soil moisture variations. We will respond to all comments in detail and indicate the changes made in the revised manuscript as follows.

Comment: The authors compare SIF and NIRv, along with a handful of vegetation indices, against six flux towers located across the African continent. They use these data to build a linear model of SIF and NIRv to estimate GPP across the continent. I have concerns about the spatial mismatch between eddy covariance measurements and the satellite products used for upscaling. The authors use 0.5 degree satellite imagery and take the further step of aggregating up to 4 degrees (filtering 0.5 degree pixels by dominant land cover type). These average observations are then compared against EC-derived estimates of GPP. Figure 3 suggests that this spatial aggregation significantly influences the temporal correlation between the satellite measurements and GPP estimates. In the case of GH-Ank, the 0.5 degree measurements of NIRv are dramatically different from the 0.05 data (e.g., the 0.05 degree data show much more temporal variability). For ZM-Mon, the shape of the NIRv curve is quite different during the middle of the growing season when comparing 0.5 to 0.05 degree imagery. This is a fairly challenging problem to get around. On the one hand, the authors offer a nice proof of concept that SIF and NIRv can be scaled to GPP using continental scale observations. On the other, higher resolution measurements of SIF are rapidly becoming available (e.g., TROPOMI, as the authors mention) and are already available for NIRv. In fact, a more extensive, global scale analysis of the NIRv-GPP relationship, using tower-scale satellite measurements, has been presented elsewhere (**?**).

Response: We share the referee's concern that the spatial mismatch will have some effect on our results and we demonstrated that the use of fine resolution products will improve the relation among these GPP proxies and EC-GPP. Particularly, for sites like GH-Ank and ZM-Mon where the towers vegetation type is different from its surroundings. Despite these limitations, we reverted to the use of GOME-2A SIF for two reasons: 1) Tower GPP data were available for earlier years (for the years before 2014) for most of the towers and therefore the choice of TROPOMI or OCO-2 will not have been good as there were no overlap data between these satellites observation and tower data. 2) Retrieval of SIF from the high spatial resolution of OCO-2 (1.3 x 2 km^2) allows a direct comparison with EC measurements. In contrast, due to its smaller swath, OCO-2 has a large repeat period, which restricts its application in

understanding temporal variation in GPP as a monthly mean is restricted to a few data samples. On the other hand, the swath of GOME-2 is so wide (1920 km per orbit) with a coarse spatial resolution (40 x 80 km^2) that in principle allows a global coverage of once per 2 days. This allows retrieval of SIF possible at 0.5° grid at monthly resolution with more representative data in each month. We acknowledge that new instruments can in the near future, and partly already now, offer the best of both worlds, and see this as a justification for (rather than a weakness of) the work we present here.

Comment: At a minimum, the authors might consider quantifying how the scaling issue affects their modeled estimates of GPP. They could do this by comparing the coefficients of a model derived from 0.05 NIRv data against the 0.5 degree data.

Response: Thank you for the suggestion, now we add a comparison of NIRv at finer resolution (0.05 degrees NIRv) with coarse resolution (0.5 degrees NIRv) at the selected flux towers (i.e., GH-Ank, SD-Dem and ZM-Mon) (Fig. 1). The results show a strong correlation and a slope of $\approx$ 1.0 indicating that there is no significant deviation, but a higher slope for ZM-Mon implies the sampling of coarse resolution including responses from different biomes than the tower biome. To show the effect of this scaling on our GPP estimation we add GPP estimation from 0.05 degree NIRv in Fig. 6 of the main text.

figure-1.pdf

Fig. 1. Time series and scatter plot of fine and coarse resolution NIRv.

Comment: The authors could also be more descriptive about how they construct their model. How is missing-ness handled? How are clouds screened for? When aggregating to 4 degrees, these details are going to be quite important for understanding how the final satellite signal is constructed.

Response: Here we made a direct comparison and thereby we did not apply modifications to these datasets, but we select good quality data from each source (e.g., we selected measured and good quality gap filled data from the EC-tower, and SIF from GOME-2 removes SIF values of high cloud cover and aerosol loading as well as values retrieved for a solar angle greater than 70 degree). Furthermore, we processed the datasets to have the same temporal resolution of XX days/months. Now we add a statement to explain this in the Analysis method section of the main manuscript. "We use good quality data as recommended by each data source, and further we process these datasets to agree in their temporal resolution of **XX** days/months." Change was made on page 6 of line 34.

Comment: I appreciated the authors attempt to use their study to draw inferences about the control on productivity at the continental scale. I think this is a type of framing and analysis that has the potential to make the paper a nice contribution to the literature, as opposed to simply demonstrating that the SIF/NIRv-GPP relationship holds regional.

Response: We thank the reviewer for his kind appreciation.

Comment: Much of the analysis centered on a discussion on the controls of seasonality in photosynthesis. On P15 L2-8 the authors write: "Our analysis showed seasonality of soil moisture strongly controls plant productivity with a weak intervention of available shortwave radiation. . .During saturation, when the soil is very moist, the amount of shortwave radiation significantly impacts productivity, whereas during the growing or

end period of growing seasons vegetation production has a strong proportion to soil moisture." While possibly true, I think this analysis is a little too broad sweeping. Figure 4 shows that broadleaf evergreen forests have a decline in SWR that coincides with declines in precipitation. Personally, I think it would be quite interesting to see if per-pixel anomalies in SIF and/or NIRv track anomalies in SM. I also think that such an analysis would be more informative about mechanism.

Response: We thank the reviewer for this suggestion, which we followed up on. We now provide per-pixel temporal correlation of SIF, NIRv, and EVI with soil moisture and precipitation over the vegetated regions of Africa for the years 2007-2016 (see Fig. 2. Lower correlation was observed over the tropical rainforest region, where the monthly average rainfall always exceeds 100mm/month and covered by a broadleaf evergreen forest. This suggests that the seasonal patterns of GPP may have no correspondence with precipitation/soil moisture over this region, which generally has smaller seasonality in GPP and high soil moisture levels compared to non-broadleaf vegetation types. This additional figure was added to our supplementary figures and discussed in the main text.

figure-2.pdf

Fig. 2. correlation of SIF a) NIRv c) and EVI e) with root zone soil moisture from GLDAS, and SIF b), NIRv d) and EVI f) with precipitation from GPCC for the years 2007-2016.

Comment: Aggregating all the data together across biomes, like in Figure 5, has the potential to hide as much as it reveals, given that averages only reflect the most common SIF-precip/SIF-SWR relationship, as opposed to potentially more complex per-biome or per-pixel relationships.

Response: Indeed, the aggregation does not do justice to many of the spatial differences across the landscape, but we feel that a more accurate and per-pixel estimation of SIF/NIRv based GPP needs a more complex process-based modeling. With the aggregation we only aim to show the possibility of inferring aggregated GPP with less computational cost, while possibly still being of use for larger model-intercomparisons such as TRENDY or CMIP6.

Minor Comments

Comment: P2 L19: "so-called" can have a quite negative connotation. Consider removing.

Response: We thank the reviewer for the suggestion. We remove the word "so-called". change is made on page 2 of line 19.

Comment: P5 L1-2: "Uncertainties in NIRv are largely due to inaccuracy in measurements of canopy architecture, including the leaf projection function and the clumping index, both strongly vary in time and space (**?**)." I believe that Zeng argues that NIRv carries information about the leaf projection function, as opposed to the leaf projection function causing uncertainty in NIRv measurements.

Response: We thank the reviewer for this comment and have removed this sentence.

Comment: P7 LUE framework âĂÅď How appropriate is the LUE framework when you normalize by cosine of solar zenith angle. Doesn't that mean the APAR signal

goes away? How should we interpret what is left?

Response: We understand the point that the reviewer alludes to, but we believe the equations that we showed are still be valid These LUE frameworks are discussed to motivate that we can create a linear fit between SIF and GPP (**?**). However, the temporal mismatch impacts the correlation between instantaneous SIF and daily GPP. By scaling SIF by the cosine of the solar zenith angle we make sure that we are not so dependent on the position of the sun at the time of observation (a way to adjust the instantaneous SIF observations to a common scale) (**???**)

Comment: P13 L3 The manuscript does not address uncertainties in the eddy covariance measurements, so seems unnecessary to spend so much time discussing how the approach is uncertain in tropical context.

Response: The statement is to tell the readers that measurement uncertainties are also responsible for the poor correlation with GPP from the GH-Ank tower.

Comment: P15 L19: Again, the paper does not use COS, making this discussion feel a little out of place.

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

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