Response to comments by Reviewer #2

General comments: This is an interesting paper providing detailed descriptions of spatial and temporal dynamics in canopy light-response parameters at CO_2 flux observation sites across Sahel region. The authors evaluated MODIS GPP, and reported its serious problem. This paper demonstrated the applicability of alternative model to scale up EC flux-based GPP to regional or continental scales, using EO-based spectral vegetation indices. The dynamics of photosynthetic parameters and some interpretations of several vegetation indices presented in this paper are valuable to estimate CO_2 budget in semi-arid ecosystems, which have included large uncertainties so far. Overall presentation is well structured and clear. The purpose of this paper fits well to this journal.

Response: Thank you very much, and also thank you for insightful comments that helped improving our manuscript.

Specific comments:

1. The intra-annual dynamics in F_{opt} and α were well explained with the vegetation indices in relation to the seasonal changes in water thickness and chlorophyll abundance. But the shorter term variations in F_{opt} and α (Fig. 4) do not seem to be explained sufficiently by the regression tree analysis. Some stress events may affect them. Please show the relationships with meteorological variables such as SWC or VPD additionally, and describe more information on the related specific stress events.

Response: We are truly sorry, but we do not completely agree. In Table 3, results from the regression trees are presented and the coefficient of determination (R^2) is larger than 0.9 for most sites; when all sites are combined it was 0.87 and 0.84 for F_{opt} and α respectively. So we would say that the regression trees describe the short term variability in Fopt and α pretty well. To further clarify this, we have incorporated a figure to the supplementary material with both measured and regression tree predicted F_{opt} and α. This indicates that SWC and VPD have a strong influence on the short term variability, since these explanatory variables are included in most regression trees (Table 3). This info is included in the revised manuscript.

2. The result of strong underestimation of ERA Interim PAR against in situ PAR is surprising and important information. Please confirm the ERA Interim PAR data: it is W m^{-2} (Line 157), but μmol m^{-2} s^{-1} (Fig.2). In addition, there seems to be some different tendencies in the relationships in Fig. 2, maybe depending on the periods and sites. Were the PAR sensors calibrated regularly? PAR sensors tend to deteriorate as aging. Please check the deterioration in PAR by comparison with the simultaneously measured Rg.

Response: We completely understand your concern regarding this relationship, and we were very concerned ourselves. 1) Regarding the in-situ PAR data; we agree, two PAR sensors standing next to each other can easily give quite different values, and some minor differences between in-situ PAR and ECMWF could possibly be explained by this issue. However, the sensors have been sent for calibration regularly, and they have been intercalibrated before and after each rainy season. So this should not be a major issue. The different tendencies seen is most likely related to the fact that ECMWF PAR is given in UTC time for each 3h. We converted this to local time when comparing against the in-situ data, and different periods of the day thereby might get slightly different tendencies in the relationship.

2) Regarding the unit conversions: we have been looking at these conversions many times to make absolutely sure that the conversions are correctly done:

The average raw in-situ PAR = 483 µmol m-2 s-1

The average raw ECMWF PAR = 350503 (J m-2 summed for 3 hours)

To get ECMWF PAR to (W m-2): raw ECMWF PAR was divided by (60sec*60 minutes*3 hours) =>
Average ECMWF PAR (W m-2) =350503/(60*60*3)= 32 W m-2.

To convert ECMWF PAR (W m-2) to µmol m-2 we multiplied with 4.57 (Sager and McFarlane, 1997):

Average ECMWF PAR (µmol m-2 s-1) =32*4.57= 148 µmol m-2 s-1

Average in-situ PAR (µmol m-2 s-1)/ Average ECMWF PAR (µmol m-2 s-1) = 483/148 = 3.2

So we think that the PAR conversion is correctly done. We recently found out that the issue is related to a major bug in the code of ECMWF:
"The surface incident value (code 58) seems erroneously low. For example, in locations in the Celtic Sea, surface PAR is typically around 20% to 25% of the clear sky value (code 20), and about a third of in-situ measurement of surface PAR. Cause: We have shortwave bands that include 0.442-0.625 micron, 0.625-0.778 micron and 0.778-1.24 micron. PAR is coded as if it was intending to sum all of the radiation in the first of these and 0.42 of the second (to account for the fact that PAR is normally defined to stop at 0.7 microns. However, PAR is in fact calculated from the sum of the second band plus 0.42 of the third." (ECMWF, 2016).

This indicates that the ERA-interim surface PAR product is actually not PAR, but rather incoming red and near infrared. However, we still intend to use this data source since we relate the gridded ECMWF PAR to in-situ measured PAR and used this relationship to convert ECMWF PAR to the proper level. The relationship should be ok, even if it is relating in-situ PAR to a different part of the spectrum; the final product is still PAR at a reasonable level. The issue is now described in the revised manuscript.

3. This paper aims to provide a model to scale up observed canopy scale GPP to regional or continental scales, using EO-based spectral vegetation indices. The readers will expect a final map of spatial distribution of GPP in semi-arid areas, and the map would make this paper more valuable.

Response: We agree with the reviewer, in the previous version we did not include the full gridded map because the spatial up-scaling requires some very heavy computer processing. However, we have now borrowed computer power from the university, and in the revised version of the manuscript we have included a full gridded map of peak Fopt, peak alpha and an annual sum of GPP.

Minor comments:
Line 184: What do you mean by "air-water interface"?

Response: We agree that the formulation was not clear. This has been corrected in the revised manuscript:

"The NIR radiance is reflected by the leaf cells since an absorption of these wavelengths would result in overheating of the plant whereas red radiance is absorbed by chlorophyll and its accessory pigments (Gates et al., 1965)."

Table 2: Correlation between “intra-annual” dynamics

Response: Thank you for pointing this out. This has been taken care of.

Please unify the descriptions: use $F_{optfrac}$ and $_{\_frac}$ for intra-annual dynamics instead F_{opt} and α in Table 2, 3, as described in the text.

Response: Thank you for pointing this out. The F_{opt} and α were not normalised to F_{opt_frac} and $α_{\_frac}$ for all analysis, they were only normalised when the analysis was conducted for all sites. This has been clarified in the revised manuscript. In Table 2 and 3, it has also been incorporated that it was F_{opt} and α for all single site analysis, whereas it was F_{opt_frac} and $α_{\_frac}$ for all sites analysis.

Fig 3: Some points of ML-Kem are quite low (nearly 0) for MODIS GPP, while around 8 g C m-2 d-1 for EC GPP. Why?

Response: Kelma is an inundated Acacia forest located in a clay-soil depression. These differentiated values are from the beginning of the dry season, when the depression continues to have high CO_2 fluxes since it is still inundated, whereas, the larger area was turning dry. The EC based footprint covers this depression and in-situ GPP was thereby high, whereas the satellite based GPP covering the larger area estimated low values. This info is included in the revised manuscript.

Please unify the descriptions: α instead of QE, as described in the text. Clarify the labels and scales on X-axes.

Response: We have now inserted α into the figures. Scales has been unified on the x-axis.

(f) What is the reason that VI decreased less than 0.15 before the growing season in 2007 at NE-WaM?

Response: There are two possible reasons: 1) Uncertainty in the remote sensing data. The end of the dry season and the beginning of the rainy season is the period of highest uncertainty in the satellite data due to aerosol and cloud contamination. This could possibly affect the VI to a low value. 2) Another possible explanation is that NE-WaM is a millet field. Agricultural practice is that before the rainy season farmers cut the shrubs in their fields. The fields are thereby cleared of vegetation before the sowing, which would decrease the VI substantially.