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Biogeosciences Discussions

Interactive comment on "ENSO and IOD teleconnections for African ecosystems: evidence of destructive interference between climate oscillations" *by* C. A. Williams and N. P. Hanan

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Reviewer 1

Comment: This is a well organized and written manuscript that describes a contribution to the literature for the scientific community, being interested in African ecosystems and climate anomalies. A more detailed understanding of the African carbon cycle is highly needed. Moreover, knowledge on the drivers of photosynthesis and more importantly rainfall (here climate anomalies) are of value, not only for the scientific community, but also for the local living communities - I suggest stressing this little more in the conclusions.

Response: We added the following text to the final conclusions, "Continued efforts are needed to disentangle the independent and joint influences of these climate anomalies on water and carbon dynamics across Africa. This is important not only to clarify the mechanisms driving variability in Africa's carbon cycle but also to inform early warning and decision support efforts aimed at mitigating climate-related disasters."

Comment: In general, remove some of the references. You give 3-5 references for each little fact, choose 1 or max 2 of importance. The reader will thank you, since at the moment this is leads to an interruption in the flow of reading.

Response: To do justice to the broad range of literature that has informed our thinking on the interdisciplinary subject we feel it is appropriate to retain the admittedly extensive citations. The general topic of Africa's teleconnections to remote SSTs has been well studied, and we want to provide a somewhat weighty and expansive review for those readers who may want to pursue additional exploration of the subject. Because we feel that the choice of readability versus breadth of citation is a matter of style, we did not strike citations. We hope that this will be understood and acceptable but are willing to revisit the issue if it is of major concern to reviewers or the editor.

Comment: page 6324, line 5 Abstract: "Africa's carbon sources and sinks" - this is very vague and may not only focus on natural ecosystem, which I assume you do.

Response: We replaced "carbon sources and sinks" with "photosynthesis".

Comment: page 6324, line 11/12 abstract: photosynthesis and vegetation greenness - rephrase, since at the moment this reads as you treat these two variables independently. However from a remote sensing perspective both variables are closely connected whereas from an ecophysiological viewpoint this might not be as clearly the case.

Response: Photosynthesis (a flux) and vegetation greenness (a state) are different and independent quantities, both in the model and in the analysis. The state of vegetation greenness (fPAR) influences photosynthesis in the model, but it is only one of a suite of influences. For these reasons, the current phrasing seems appropriate, stating that the reported index-associated photosynthesis anomalies are consistent with rainfall and fPAR anomalies.

Comment: page 6336, lines 27-30: Is there a clear pattern, so that one can predict possible anomalies in rainfall and photosynthesis? At the moment you mention there are influences of climate anomalies to photosynthesis and rainfall, and also the interaction between ENSO and IOD, but these influences are highly variable, regional as well as temporal. Particularly cancellation or reversal are of interest not only for the scientific community. I suggest writing at least one or more sentences on this.

Response: The page and line numbers do not clearly correspond to the content of the comment, but we suppose that this refers to the conclusions. Unfortunately, the sample sizes of pure vs. coincident events are small and correlations are too weak to support strong statements regarding predictable patterns. Still, as noted above we have added a new ending that emphasizes the importance of continued work that will hopefully reveal clear, predictable patterns: “Continued efforts are needed to disentangle the independent and joint influences of these climate anomalies on water and carbon dynamics across Africa. This is important not only to clarify the mechanisms driving variability in Africa’s carbon cycle but also to inform early warning and decision support efforts aimed at mitigating climate-related disasters.”

Comment: page 6347, Table 2: Please stick to significant only (bold). There might be something vague "close to significant" (italicized) but this is commonly not used in science, and certainly not when modeling.

Response: We have removed all non-significant results.

Comment: page 6351, Figure 2: This is a very doubtful figure. First of all doing regression with 3 or 4 points and than I am wondering why you do regression for photosynthesis SE African, SON, but not for Rainfall (either SE African or Tanzanian). Either you

explain the graph more detailed or you replace it with something more supportable.

Response: The figure has been removed. Table 3’s presentation is sufficient, and we note that it also includes rainfall and fPAR responses.

Reviewer 2 Comment: This paper explores the impact of the two main modes of tropical SST variability – ENSO and IOD – on the vegetation photosynthetic activity over Africa. It aims in particular at identifying their joint influence. The paper offers interesting results about regions/seasons where the two SST modes have a significant influence or noticeable interferences but these results worth to be deeper analysed and discussed, considering in particular the relationship between rainfall and photosynthesis and between photosynthesis and Fpar, the asymmetry between ENSO/LNSO events impacts. In addition given the few number of years taken into consideration for the composites samples, it might be valuable to work with partial correlations for the interference analyses as well.

Response: We have added deeper analysis as recommended in the reviewer’s detailed and constructive critique as described below. We have included additional results and discussion of the relationships among rainfall, fPAR and photosynthesis, seasonal contextualization of anomalies, asymmetry in ENSO impacts, and partial correlation analysis.

Comment: Methods: you are too laconic in this section. SiB3: you should mention clearly here which output variable you use (photosynthesis) and not in the appendix only.

Response: We have added, “In this work we primarily analyze the model’s canopy-scale net photosynthesis.”

Comment: ANOVA and ANCOVA: please explain further these methods referring to previous studies where they have been employed. Additionally, it’s not clear in the paper where the results from the ANCOVA analysis are : Figure 3 ?

Response: ANOVA is a well known statistical tool and it does not seem necessary to refer to previous studies. Both the main text and the legend for Table 2 now present additional information regarding the nature of the ANOVA design: as "...two-way, Type-1 ANOVAs testing for effects of ENSO, IOD, and their interaction on monthly averages of net photosynthesis (Ph), rainfall (R), fPAR (V) for select geographic regions. ENSO and IOD series were treated as grouping variables based on phase (upper and lower quintiles, or neutral)." The ANCOVA results were reported in Figure 3 but this has been removed in response to R1's critique.

Comment: Results: There are several weaknesses in that section mainly because you don't take care enough of (i) the mean rainfall amounts and photosynthesis level involved and (ii) the asymmetry between ENSO and LNSO events. I suggest that (i) you provide for each season, the mean rainfall amounts and photosynthesis level (in new figures or new columns in your tables) and (ii) you don't consider regions and seasons when the dry season occurs (i.e. DJF over the Sahel, Ethiopia, JAS over Namibia ...). For instance in your table 1, it is difficult to evaluate the importance of the anomalies given that you don't provide the mean values. -47mm in DJF for SE Africa is negligible if in mean it rains 470mm . . ..

Response: We have added two figures that present mean seasonality and agree that this provides a valuable context for the assessment of responses, or lack thereof. This also lends itself nicely to discussion of phase-specific responses, or asymmetry. We make mention of asymmetry in various regions, including southern Africa's stronger IOD- response, as well as a stronger Sahelian response to La Nina than El Nino.

Our opinion differs regarding the second suggestion. We think that dry season and dry region results are in fact relevant and important. Anomalies in absolute are meaningful and important in their own right. For example, whether during the dry season or wet season, an anomaly of 10gC m-2 month-1 is equivalent and similarly meaningful for the purpose of understanding carbon cycle variability.

Comment: ENSO association: "A general pattern of negative . . ... Chad and Sudan" : which season are you speaking about ? The seasonal shift: the opposite behaviour in South Africa between spring and summer rainfall has been described as a main mode of variability by Richard et al. (2002). These authors don't explore whether this rainfall mode is significantly related to ENSO or not but this study must be mentioned.

Response: We now note that the southern Chad and Sudan regions show some anomalies mainly during JJA and SON seasons. We have tried to find the Richard et al. 2002 paper but have not been successful. Could a citation be provided? We have found the following but have not been able to obtain full articles and the abstract that we could obtain for the first did not clearly report this particular intraseasonal variation. RICHARD Y., CAMBERLIN P., FAUCHEREAU N., MULENGA H., 2002 : Cohérence intrasaisonnière de la variabilité pluviométrique interannuelle en Afrique du Sud. L'Espace Géographique, 31, 63-72. RICHARD Y., CAMBERLIN P., FAUCHEREAU N., POCCARD I., 2002 : Évolution des précipitations au xxe siècle en Afrique du Sud. Pub. Ass. Int. Climatologie, 14, 134-142.

Comment: "Regarding drivers . . .." : your comment of that table 1 is too laconic whereas there is a lot of interesting information contained: persistence effects for photosynthesis anomalies, delayed answer to rainfall anomalies, asymmetry between ENSO and LNSO. Moreover it is not stated strongly enough that the ENSO, LNSO, IOD+ and IOD- years are the ones reported in figures 1ab, i.e. composites where pure and coincident events are merged. In addition, an insight on the relationships between fPar and photosynthesis (i.e. slope and regression coefficient) would be welcome for each season and region to better understand the intensity of the answer to the rainfall.

Response: We agree that there could be some useful insights gained from more deeply exploring persistence and lags, as well as season-specific relations between P, R, and V, but this quickly gets beyond our intended scope of the current manuscript, which is already rather long. We have added mention of the asymmetries as stated above. The label of Table 1 as been amended to clarify: "Climate-season averaged anomalies for specific regions across Africa associated with all ENSO and IOD events regardless of possible coincidence". The same has been performed for labels for Figures 1ab, "...for (a) ENSO and (b) IOD relations, regardless of possible coincidence".

Comment: IOD association: in DJF and MAM the Sudanian and Sahelian region experience their dry season. Therefore I have doubts about the reliability of the photosynthesis signal produce by SiB3. Moreover the NDVI data over that region during that seasons are known to be contaminated by desert aerosols.

Response: We understand this concern and do not make a main point regarding the signal during these seasons. However, it would be rather awkward and arbitrary to decide which months and seasons are reliable and which are not. Given this ambiguity, we are not inclined to be selective in our presentation of the results, but again do not make a main point out of responses during that season. "Negative phase DJF and MAM responses offer modest exceptions but both are poor representations of pure IOD responses being coincident with ENSO activity as described in a following section."

Regarding aerosol contamination, it is a good point, and also because of fires not just dust. In using the AVHRR NDVI we discovered that this is a significant problem that cannot be easily fixed. Nonetheless, we came up with a best attempt as described in Appendix A. It began with a realization that AVHRR NDVI is anticorrelated with MODIS aerosol optical depth during the period of AVHRR and MODIS overlap. Here's how we worked with the AVHRR NDVI dataset, noting that all of this was reviewed after the fact by Jim Tucker and his team and they support the approach. "While the NDVI dataset contains corrections for satellite orbital drift, differing instrument calibrations, sensor degradation, and volcanic aerosols, we found large negative spikes of NDVI in many areas prone to cloud cover, and therefore replaced the lower twenty percent of NDVI of each biweek across years and at each $\sim$8km grid-cell with the mean of the upper eighty percent. Furthermore, we found unusual seasonal dynamics in NDVI even after this lower-fifth replacement, and discovered that this seasonal pattern is strongly anticorrelated with pyrogenic or mineral aerosol loads measured by the MODerate Reso-

lution Imaging Spectroradiometer (MODIS) Terra Level-3 monthly atmospheric aerosol optical thickness (MOD08_M3). Therefore we performed an ad hoc adjustment to the AVHRR NDVI data so that their biweekly average seasonality matches the average seasonality seen with a filled, 5km MODIS NDVI product covering the five-year period of 2000 to 2004. This approach retains seasonal and interannual variability in the AVHRR NDVI and hence vegetation structure and function, but removes much of the erroneous seasonality associated with aerosol and water vapor contamination." Unfortunately, we do not have information on the interannual variability of aerosol contamination for the 1982-2003 period of record, so we can only correct for this as a mean seasonal effect. At least dust production/transport and fire emissions are strongly seasonal, though the exact trajectory of plumes can be contingent on winds.

Comment: Independent vs Interactive effects: you should recall or provide the evolution along the seasonal cycle of the relationship between ENSO and IOD indexes because it is not stable. Indeed in DJF you have few pure IOD events and on the contrary to SON, DJF and MAM positive IOD events seem coincident with negative ENSO events (LNSO) and not positive ones. This can be a clue for the apparent disappearance of interference in DJF. Moreover, given the few number of years available for compositing (1 or 2 for some seasons) it would worth carrying partial correlation analyses between R, Ph, V and the SST indexes which results could consolidate the composites ones.

Response: Good point, we have added: "Such reversals are less pronounced or absent during the DJF season in both regions. This is likely related to the fact that IOD activity tends to peak in SON and be less persistent than the typical ENSO activity that has broader peaks often centered on DJF. Correspondingly, there are few pure DJF IOD events."

We have added a partial correlation analysis to explore the total variability that can be explained by the teleconnections with each index independently and combined, though given the length of the present manuscript this is not presented for specific seasons but rather in aggregate across seasons. We note: "In part because of the limited sample sizes, but also to explore independent and combined influences, Figure 5 presents results of a partial correlation analysis. As much as 30% to 40% of the interannual variability in photosynthesis, rainfall, or fPAR can be explained by the ENSO and IOD indices combined in select "hotspot" regions. Futhermore, there is some suggestion that ENSO is responsible for more of the variability in the southern African regions, while IOD may explain more of the variability in the Tanzanian region."

Comment: Results for Tanzania are curious for ENSO/LNSO events. I can see the reversal of sign in SON between pure and coincident events for the three parameters but how do you explain that negative (positive) rainfall anomalies are associated with positive (negative) Fpar and Ph ones ?

Response: It is not clear what would cause these inconsistencies as stated in the following: "For example, rainfall increases in Tanzania during SON El Niños are matched with little change in photosynthesis (Table 1) owing to simultaneous fPAR reduction during a time of year when vegetation cover is already relatively low. As another example, in Tanzania and the DRC, MAM photosynthesis increases with El Niño are coincident with little or opposite-signed anomalies of rainfall but slightly elevated fPAR. Such inconsistencies between fPAR and rainfall anomalies may derive from disturbance or management driven changes in vegetation (and fPAR), hydrologic surpluses that buffer vegetation response to rainfall anomalies, or possibly errors in one or both datasets."

Comment: Figure 1ab: for your DJF seasons could you precise if DJF 1983 is "D82" and "JF83" or "D83" and "JF84" Response: The label now includes: "Years reported for DJF refer to the JF calendar year and the previous year's D."

Comment: Table 2: why are you using a monthly time-step and do not work on the four seasons you have defined previously? It would be useful to discriminate these seasons when the interactive effects are present. Please develop the ANOVA in the method section so that we understand fully the results of that table.

Response: We have clarified the nature of the ANOVA design as being a two-way,

Type-1 ANOVA testing for independent and interactive effects of the indices on each response variable and using all events regardless of their possible coincidence.

Comment: Tables 2 & 3: as for Table 1 you must more clearly explain which years and how many years are used in the different composites. In table 2, it is not clear if ENSO and IOD are pure only or pure and coincident (as in fig1ab and table 1).

Response: We now note in the label for Table 2, "This analysis uses all ENSO and IOD events regardless of their possible coincidence." For Table 3, we clarify the years used in the analysis in the label as: "Years included in each composite were as follows: (1) SON–Pure: EN '87; LN '88, '99, '00; (2) SON–Composite: EN '82, '97; LN '98; (3) DJF–Pure: EN '83, '87, '92; LN '85, '89, '97, '99, '00; (4) DJF–Coincident: EN '98, '03; LN '96 '01."

Comment: Technical corrections p7: "satellite or gage based records ..." change for "gauge" p8: "Positive (negative) phase ENSO ..." change for "negative" Figure 2 caption: change "inset" for "insert"

Response: We changed "gauge" but it is unclear what should be modified regarding "negative", and we think "inset" is the appropriate word choice for this case.

NEW Figure Captions:

Figure 2. Monthly average, composite regional series averaged for all years (solid black), for the lowest three ENSO excursions (blue dotted, El Nino phase), and highest three ENSO excursions (red longer dash, La Nina phase) shown for net photosynthesis (Pnet), rainfall, fractional absorbance of PAR (fPAR), relative humidity (RH), and air temperature (Tair).

Figure 3. Monthly average, composite regional series averaged for all years (solid black), for the lowest three IOD excursions (blue dotted), and highest three IOD excursions (red longer dash) shown for net photosynthesis (Pnet), rainfall, fractional absorbance of PAR (fPAR), relative humidity (RH), and air temperature (Tair).

Figure 5. Partial and joint correlations squared (r2) from partial correlation analysis of net photosynthesis, rainfall, or fPAR with the ENSO and IOD indices (MEI and DMI respectively).

Figure 5.

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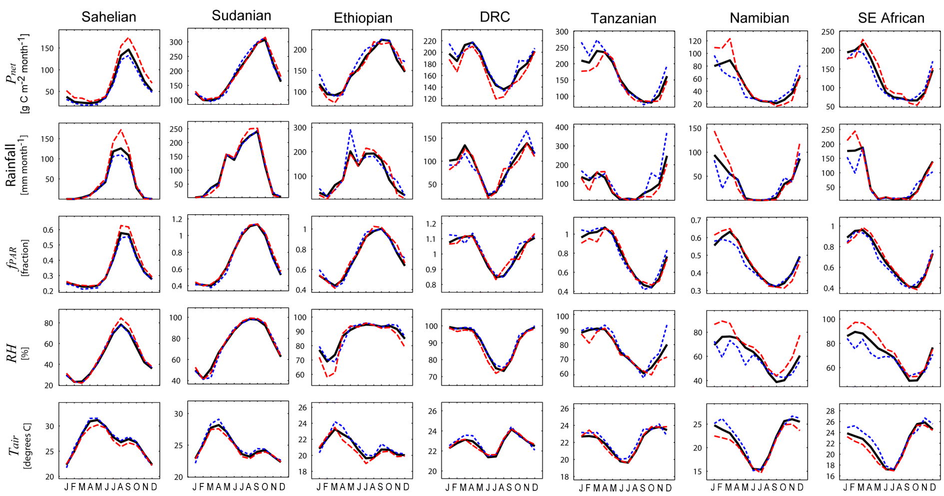

Fig. 1. Figure 2. Monthly average, composite regional series averaged for all years (solid black), for the lowest three ENSO excursions (blue dotted, El Nino phase), and highest three ENSO excursions (red lon

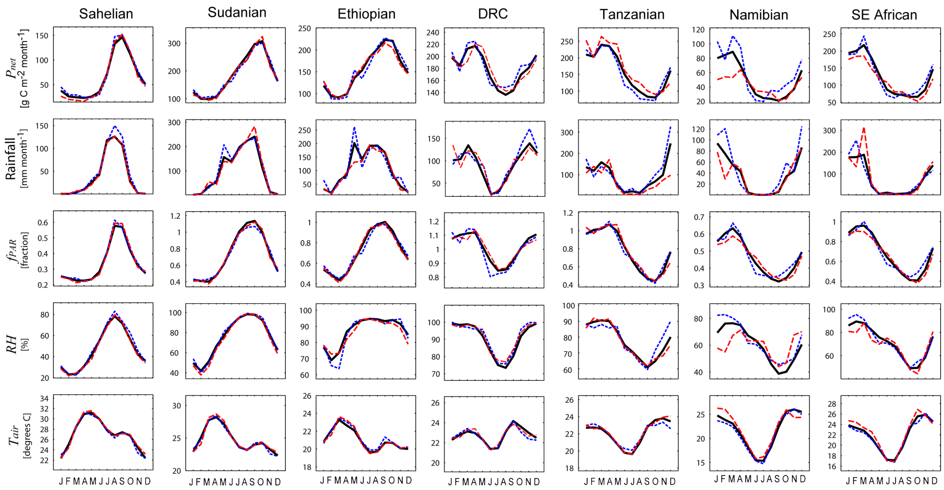

Fig. 2. Figure 3. Monthly average, composite regional series averaged for all years (solid black), for the lowest three IOD excursions (blue dotted), and highest three IOD excursions (red longer dash)

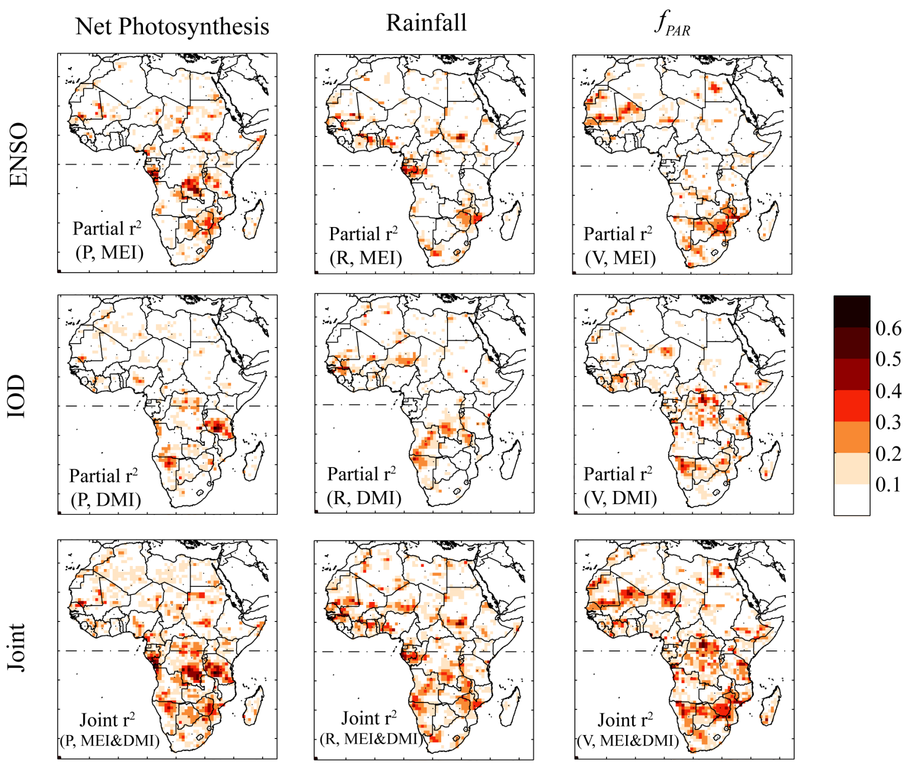

Fig. 3. Figure 5. Partial and joint correlations squared (r2) from partial correlation analysis of net photosynthesis, rainfall, or fPAR with the ENSO and IOD indices (MEI and DMI respectively).