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Interactive comment on "Ecosystem physio-phenology revealed using circular statistics" *by* Daniel E. Pabon-Moreno et al.

Anonymous Referee #2

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General comments: In the manuscript "Ecosystem physio-phenology revealed using circular statistics", Pabon-Moreno et al. used a new method – the circular linear regression to estimate the timing of the maximum gross primary productivity (DOYgppmax) at 52 eddy covariance towers, and further quantified the sensitivity of DOYgppmax to a range of climate variables based on the results from this new regression. The manuscript is relevant to the topics of the journal. While I agree with the authors that circular linear regression has the potential to be a framework of future generalized phenology models, I have some doubts about the advantages of circular regression over the conventional linear regression approach, as well as the interpretation of results. It may need some substantial revisions. I apologize that I cannot be more supportive at this stage. I hope the authors can find this review helpful (please see below).

Specific comments: Major specific comments: 1. The authors introduced two advantages of circular regression 1) it is more accurate than linear regression 2) it can analyze the phenological event regardless of the locations of events, esp. for the southern hemisphere. For 1), I am concerned about circular reasoning, as the authors used two phenological events pre-defined by circular regression to compare the performance of circular regression and linear regression, it is very likely the circular regression can outperform linear regression in this case. In addition, the author used the distance between observed beta and estimated beta to assess the efficiency of two models, and suggested that because the magnitude of distance for beta1 is larger than the distance for beta2, and the results on distance for beta1 favored circular regression, so circular regression is better. But the magnitude of distance for beta is also dependent on beta itself. Beta2 (0.3) is larger than beta1 (0), after normalize the distance of beta by beta, the result based on beta1 does not carry more weight than beta2, and the results on the distance of beta2 in fact favored linear regression. For 2), I am not sure why conventional phenology models cannot be used in the Southern Hemisphere (e.g. L208-209), say the degree-day model can be easily deployed if we know the temperature preceding budburst in Australia (e.g. Webb et al., 2008) and we can also get meaningful climate sensitivity of the event. Overall, I am not sure the circular model is superior to conventional models based on the evidence available in the manuscript.

2. Some questions over the interpretation of the results. First, I am a bit worried about overfitting of the model, as the leave-one-out validation suggest much less robust performance ($r = -0.3 \sim 0.7$) for PFTs compared to the r ($r = 0.7 \sim 0.9$ according to Table S1) we obtained using the training dataset. Second, at seasonal time scale, air temperature, radiation and VPD are all highly correlated with each other, how much can we trust their respective sensitivities estimated by circular regression. Wouldn't the sensitivity of air temperature be account for by the sensitivity of radiation if there is co-linearity between the two? Third, I guess the so-called "memory effect" or "accumulated effect" of past climate is considered in circular regression through equation (1). Is this potentially one of the key differences between circular model and linear

model? Does it mean the climate conditions closer to the event is more important than the climate conditions further back, and different climate variables are prescribed with different half-life here? I hope this part of the method is clearer. Fourth, the authors delegated the complex temperature sensitivity to consumption of available water (L240-). I am not sure there is a clear mechanistic underlying this link as there is no evidence supporting plant water uptake is related to temperature here. Soil water content may directly impact GPP (Stocker et al., 2018), it is not necessarily related to temperature, maybe VPD though. My major concern is about the robustness of the climate sensitivity identified in the manuscript.

Minor specific comments: 1. it is not accurate to say "(DOYgppmax)... is the time the plants reach their maximum potential for CO2 absorption". GPP is the product of vegetation density (i.e. LAI) and the photosynthesis of individual leaves. When leaves have the maximum photosynthetic capacity/potential, it does not mean the whole canopy would be the most productive, as leaf photosynthesis can be downregulated by environment, and it also depends on how many leaves are there in the ecosystem.

2. Figure 1. In figure caption and in the text (L64), you mentioned each line represents the interannual variability. I feel it needs further clarification on how to read the figure. From what I understand, the distance between the line and the circle indicate the frequency of DOYgppmax, and the spread of linear may imply the variability of DOYgppmax.

3. Method. Need more explanation about equation (1), as it not clear the meaning of x, N, N0, and the reason to include this half-life process here.

4. I think the title of the paper might overshoot what in fact was done in the paper, since only one type of phenological event was studied, and I am not sure there is a pattern that really is "revealed" here that we can easily extrapolate for us to understand DOYgppmax due to the reported site-specific sensitivities. The concept of physi-phenology is new to me, maybe the authors can provide a reference? I feel most con-

ventional phenological events (e.g. budburst, leafout, leaf coloring, leaf senescence) are physiological changes of plants, so why they are not qualified as physi-phenology or do we really need this definition here. DOYgppmax sounds like a carbon uptake phenological phase.

Technical comments: 1. “2” in “CO2” is subscript 2. please define “GPPmax” at its first appearance. 3. L201, according to Figure 7, GRA is -0.3 rather than 0? 4. How to interpret the tendency in Figure 7? 5. L150, “leaf” to “leave” 6. Table A1, maybe list the site according to their names or vegetation types. Now it is based on doi and not easy for readers to search sites. 7. It would be helpful to condense figures in supplementary material 2 into a table, showing the sensitivity of each climate variable and significant level indicated by *. And please consider merging two supplementary materials into one.

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