Responses to editor's and reviewers' comments point by point

MS No.: essd-2022-436

Title: A gridded dataset of leaf age-dependent LAI seasonality product (Lad-LAI) over tropical and subtropical evergreen broadleaved forests

Author(s): Xueqin Yang et al.

Comment of Topical Editor:

Topical editor decision: Publish subject to minor revisions (review by editor)

Public justification (visible to the public if the article is accepted and published):

The reviewers are satisfied with the authors' revision and provide few comments/suggestions for the authors' consideration. Please carefully resolve these comments.

Response: *Thanks for your valuable time in handling our manuscript; and thanks also for the constructive comments and suggestions from two excellent reviewers. We discussed the accuracy of leaf-age dependent LAI product generated from CSIF-derived GPP and the performance of NDVI seasonality in representing tropical young leaf phenology. We also added the root-mean-square error (RMSE) to establish the quality control (QC) band. Finally, we conducted a thorough proofreading and corrected some grammar issues to improve the readability of the manuscript. Below, we address each point in detail.*

General Comments of Reviewer 1#:

Thanks authors' work and effort for addressing my questions and comments. The manuscript and figures look better, but I still have few minor issues after I read the new version:

Response: *We sincerely appreciate your thorough review of the manuscript. Your comments and suggestions are invaluable for the revised manuscript. Please see our point-to-point responses to your comments below.*

Minor issues:

Comment 1:

(1) Abstract is too long. It should be highly shortened and simplified.

Response: *Thanks for the comments on the abstract. We have shortened and simplified it as follows:*

*Quantification of large-scale leaf age-dependent leaf area index has been lacking in tropical and subtropical evergreen broadleaved forests (TEFs) despite the recognized importance of leaf age in influencing leaf photosynthetic capacity in this biome. Here, we simplified the canopy leaves of TEFs into three age cohorts (i.e., young, mature and old one with different photosynthesis capacities ($V_{c,max}$)) and proposed a novel neighbor-based approach to develop the first gridded dataset of monthly leaf age-dependent LAI product (**referred to as Lad-LAI**) at 0.25-degree spatial resolution over the continental scale during 2001-2018 from satellite observations of sun-induced chlorophyll fluorescence (SIF) that was reconstructed from MODIS and TROPOMI (the TROPOspheric Monitoring Instrument). The new Lad-LAI products show good* *performance in capturing the seasonality of three LAI cohorts, i.e., young (LAI_{young}) (the Pearson correlation coefficient, R=0.36), mature (LAI_{mature}) (R=0.77) and old (LAI_{old}) (R=0.59) leaves at eight camera-based observation sites (four in south America, three in subtropical Asia and one in Congo) and can also represent their interannual dynamics, validated only at the Barrocolorado site with R being equal to 0.54, 0.64 and 0.49 for LAI_{young}, LAI_{mature} and LAI_{old}, respectively. Additionally, the abrupt drops in LAI_{old} are mostly consistent with the seasonal litterfall peaks at 53 in situ measurements across the whole tropical region (R=0.82). The LAI seasonality of young and mature leaves also agrees well with the seasonal dynamics of Enhanced Vegetation Index (EVI) (R=0.61), a proxy of photosynthetically effective leaves. Spatially, the gridded Lad-LAI data capture a dry-season green-up of canopy leaves across the wet Amazonia areas where mean annual precipitation exceeds 2,000 mm yr^{-1}, consistent with previous satellite-based analyses. The spatial patterns clustered from the three LAI cohorts also coincide with those clustered from climatic variables over the whole TEF region. Herein we provide the average seasonality of three LAI cohorts as the main dataset, and their time-series as a supplementary dataset. These Lad-LAI products are available at https://doi.org/10.6084/m9.figshare.21700955.v4 (Yang et al., 2022).*

Comment 2:

(2) Authors used TROPOMI SIF to produce GPP for decomposing LAI cohorts, why not to use CSIF (doi.org/10.5194/bg-15-5779-2018)? Or whether the results may be different when using different SIF products.

Response: *Thanks for your suggestions and recommendation. We compared the seasonality of RTSIF and CSIF, and found that CSIF data usually had smaller values than RTSIF ones but had greater fluctuation amplitude at Congoflux site, which was likely strongly dependent on incoming solar radiation (Figure R1). Then, as suggested by the reviewer, we used CSIF-derived GPP to generate another version of LAI cohorts product. And we compared the seasonality of LAI_{young}, LAI_{mature} and LAI_{old} products generated from CSIF-derived GPP with the camera-based observation at the 8 sites over the whole tropical forests, respectively. Results showed that the Lad-LAI generated from CSIF-derived GPP performed less well as those from other GPP products. (Figures R2, R3).*

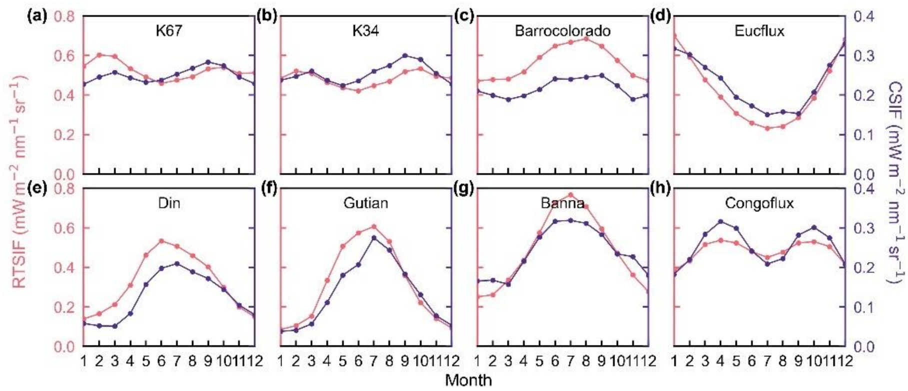

Figure R1. *Comparison of the seasonality of RTSIF and CSIF at 8 sites. (a) K67; (b) K34; (c) Barrocolorado; (d) Eucflux; (e) Din; (f) Gutian; (g) Banna; (h) Congoflux.*

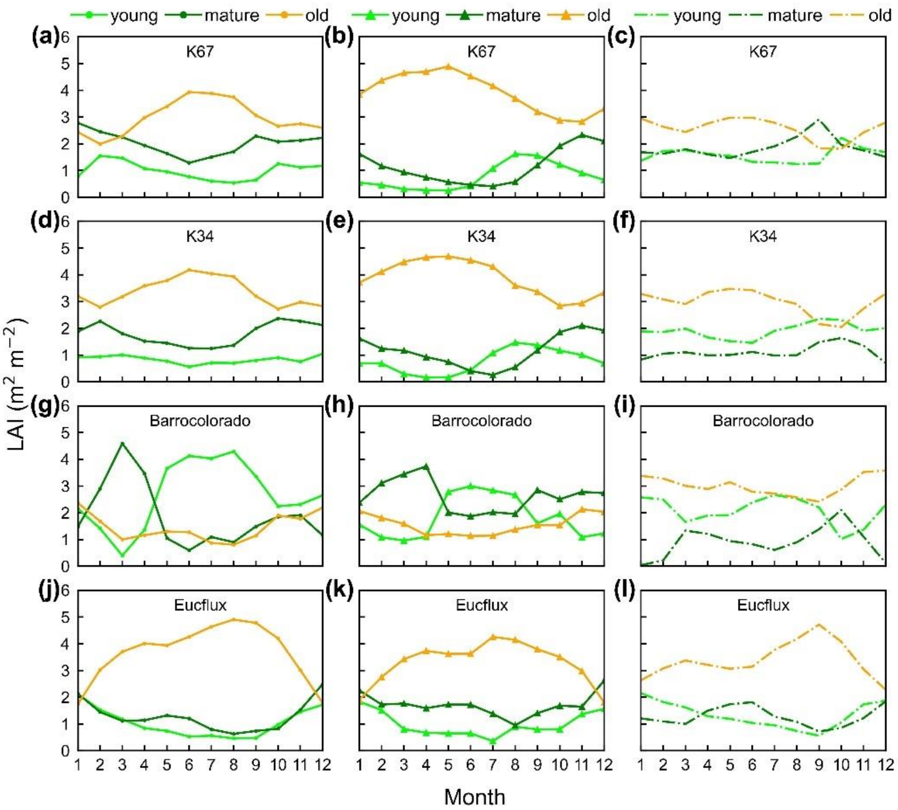

Figure R2. *Seasonality of simulated LAI_{young}, LAI_{mature}, and LAI_{old} in comparison with observed data at 4 sites in south America. (Panels a, d, g and j) simulated LAIs from RTSIF-derived GPP; (panels b, e, h and k) camera-based observed LAIs; and (panels c, f, i and l) simulated LAIs from CSIF-derived GPP*

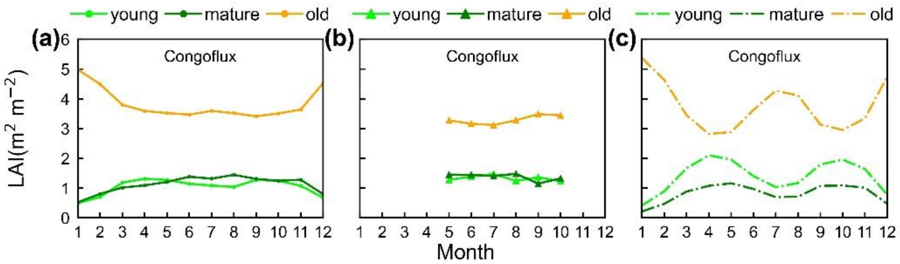

Figure R3. *Seasonality of simulated LAI_{young}, LAI_{mature}, and LAI_{old} in comparison with observed data at one site in Congo. (a) Simulated LAIs from RTSIF-derived GPP; (b) camera-based observed LAIs; and (c) simulated LAIs from CSIF-derived GPP*

Comment 3:

(3) EVI cannot capture greenness seasonality well, particularly for the tropical areas (doi:10.1038/nature13006). Thus, I suggested to add NDVI to analyze the relationship between the LAI seasonality and seasonal dynamics of NDVI.

Response: *Thanks for your comments and recommendation. We compared the seasonality of three versions of NDVI (GIMMS3g NDVI, MOD13C2 NDVI and MYD13C2 NDVI) and EVI (MYD13C2 EVI) at eight camera-based observation sites. Results showed that three versions of NDVI were highly consistent. However, the seasonal dynamics of NDVI at the site level were not as effective as those of EVI for* *representing seasonality of $LAI_{young+mature}$ (Figure R4). And, several studies indicated EVI performs be a better proxy for tropical leaf phenology (Guan et al., 2015). Therefore, we believe that it might not be suitable to add NDVI for validating the results of LAI cohorts.*

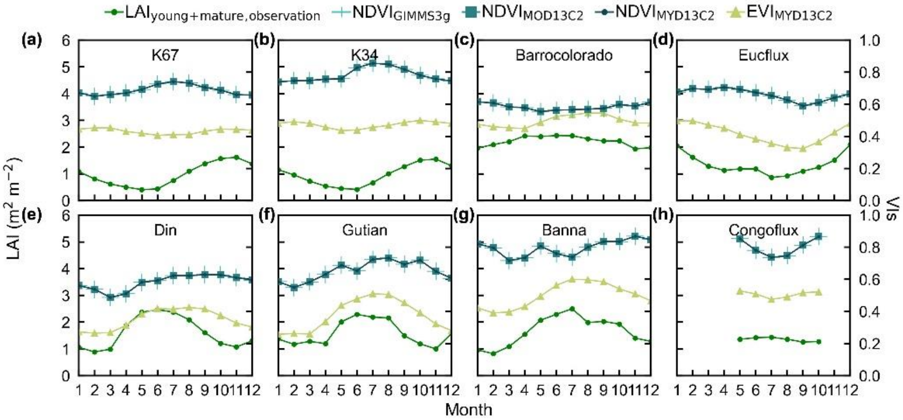

***Figure R4.** Comparison of the seasonality of $LAI_{young+mature}$ observations and vegetation indexs (VIs) at eight camera-based observation sites. Green lines with circle markers present LAI observations; blue lines with short vertical bar markers present GIMMS3g NDVI; blue lines with square box markers present MOD13C2 NDVI; blue lines with circle markers present MOD13C2 NDVI; and olive lines with triangle markers present EVI. (a) K67; (b) K34; (c) Barrocolorado; (d) Eucflux; (e) Din; (f) Gutian; (g) Banna; (h) Congoflux*

Reference:

Guan, K., Pan, M., Li, H., Wolf, A., Wu, J., Medvigy, D., Caylor, K. K., Sheffield, J., Wood, E. F., Malhi, Y., Liang, M., Kimball, J. S., Saleska, Scott R., Berry, J., Joiner, J., and Lyapustin, A. I.: Photosynthetic seasonality of global tropical forests constrained by hydroclimate. Nature Geoscience, 8(4), 284-289. https://doi.org/10.1038/ngeo2382, 2015.

Morton, D. C., Nagol, J., Carabajal, C. C., Rosette, J., Palace, M., Cook, B. D., Vermote, E. F., Harding, D. J., and North, P. R.: Amazon forests maintain consistent canopy structure and greenness during the dry season. Nature, 506(7487), 221-224. https://doi.org/10.1038/nature13006. 2014.

Zhang, Y., Joiner, J., Alemohammad, S. H., Zhou, S., and Gentine, P.: A global spatially contiguous solar-induced fluorescence (CSIF) dataset using neural networks. Biogeosciences, 15(19), 5779-5800. https://bg.copernicus.org/articles/15/5779/2018/. 2018.

General Comments of Reviewer 2#:

I would like to thank the authors for their careful attention to my comments and meticulous efforts in improving the manuscript. I especially appreciate the inclusion of a quality control band associated with the product, which is highly useful. All my concerns and suggestions have been thoroughly addressed, and the manuscript has been substantially improved. I believe this paper and the Lad-LAI dataset have made an impactful contribution to understanding tropical ecosystem dynamics.

Response: *We would like to express our gratitude for your time and expertise in reviewing our work. Your comments and suggestions are very valuable for the revised manuscript. For the minor comments raised by the reviewer, the point-to-point responses are listed below.*

Minor comments:

Comment 4:

1. Figure S11: Note that the x-axis label should probably be LAI. It would also be helpful to indicate the resolution of LAI in the x and y axes.

Response: *Thanks for your carefulness and nice suggestions. We have corrected the x-axis label as "$LAI_{0.25\text{-}degree}$ (m^2 m^{-2})" and revised y-axis label as "$LAI_{0.5\text{-}degree}$ (m^2 m^{-2})".*

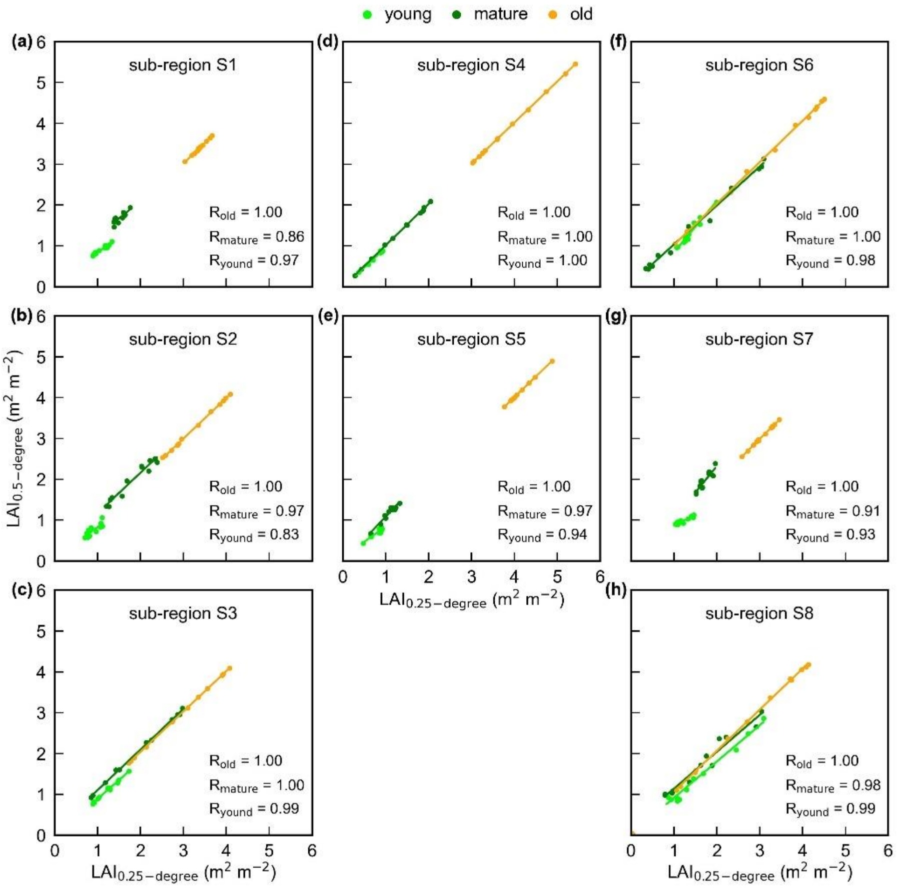

Figure S13. *The scatterplot of 0.25-degree LAI_{young}, LAI_{mature}, LAI_{old} against 0.5-degree LAI cohort datasets in the 8 clustered regions.*

Comment 5:

2. One suggestion for the QC band is to provide an error metric in the unit of LAI, such as RMSE, in addition to RSS. This would make the QC values more easily interpretable and informative.

Response: *Thanks for the valuable comments and nice suggestions. We added the root-mean-square error (RMSE) (Chen et al., 2020) as an error metric in the unit of LAI to establish QC classes with RSS (Melgosa et al., 2008) (Table S7). The new QC band is* *generated according to RSS and RMSE, obtained from the constrained least-squares method that was used to estimate and derive monthly Lad-LAI data. Results showed that more than 92.62% of pixels are with QC at best and gool levels and only less than 5.62% are with QC at level 4 (Figure S5).*

Table S7. *Information of data quality control (QC) for the Lad-LAI product*

QC class	QC value	RSS	RMSE (m^2 m^{-2})
Best	1	0-1	0-1
Good	2	1-4	1-2
Acceptable	3	4-9	2-3
Cautious use	4	>9	>3

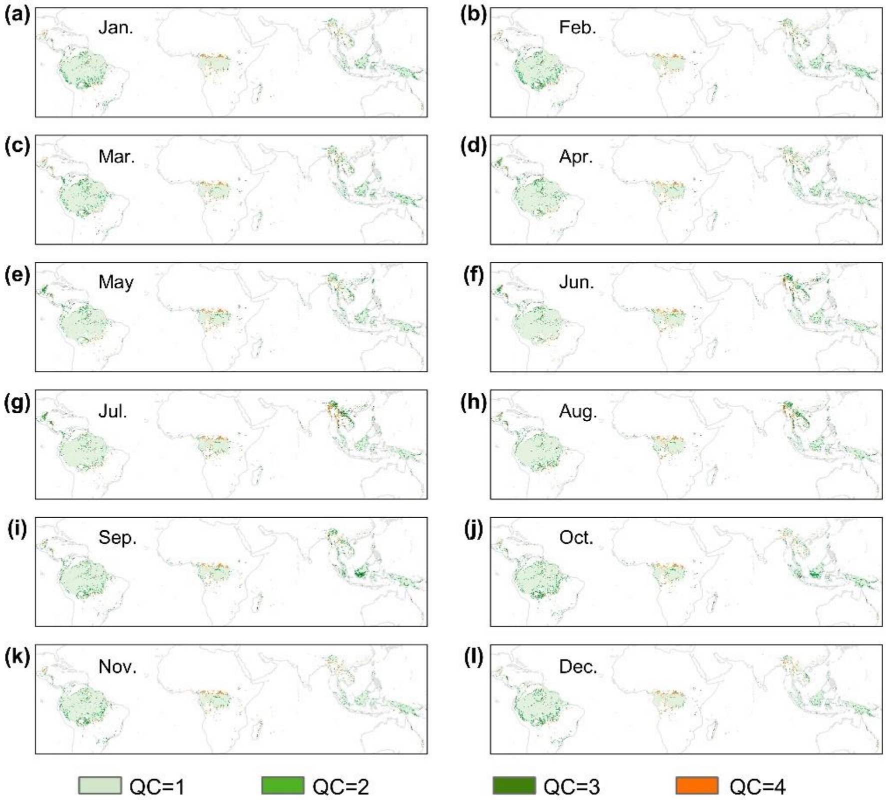

Figure S5. *Spatial patterns of seasonal quality control (QC) datasets.*

Comment 6:

3. The abstract has been greatly improved, but it appears lengthy. I think the authors could consider omitting the discussion about GOSIF/FLUXCOM and the analysis of neighboring window size. These analyses primarily serve as verifications of the methodology rather than the main findings.

Response: *Thanks for the valuable comments and nice suggestions. We agreed with the reviewer's suggestion to omit the discussion about GOSIF/FLUXCOM and the analysis of neighboring window size from the abstract. We have removed those discussions as follows:*

*Quantification of large-scale leaf age-dependent leaf area index has been lacking in tropical and subtropical evergreen broadleaved forests (TEFs) despite the recognized importance of leaf age in influencing leaf photosynthetic capacity in this biome. Here, we simplified the canopy leaves of TEFs into three age cohorts (i.e., young, mature and old one with different photosynthesis capacities ($V_{c,max}$)) and proposed a novel neighbor-based approach to develop the first gridded dataset of monthly leaf age-dependent LAI product (**referred to as Lad-LAI**) at 0.25-degree spatial resolution over the continental scale during 2001-2018 from satellite observations of sun-induced chlorophyll fluorescence (SIF) that was reconstructed from MODIS and TROPOMI (the TROPOspheric Monitoring Instrument). The new Lad-LAI products show good performance in capturing the seasonality of three LAI cohorts, i.e., young (LAI_{young}) (the Pearson correlation coefficient, R=0.36), mature (LAI_{mature}) (R=0.77) and old (LAI_{old}) (R=0.59) leaves at eight camera-based observation sites (four in south America, three in subtropical Asia and one in Congo) and can also represent their interannual dynamics, validated only at the Barrocolorado site with R being equal to 0.54, 0.64 and 0.49 for LAI_{young}, LAI_{mature} and LAI_{old}, respectively. Additionally, the abrupt drops in LAI_{old} are mostly consistent with the seasonal litterfall peaks at 53 in situ measurements across the whole tropical region (R=0.82). The LAI seasonality of young and mature leaves also agrees well with the seasonal dynamics of Enhanced Vegetation Index (EVI) (R=0.61), a proxy of photosynthetically effective leaves. Spatially, the gridded Lad-LAI data capture a dry-season green-up of canopy leaves across the wet Amazonia areas where mean annual precipitation exceeds 2,000 mm yr^{-1}, consistent with previous satellite-based analyses. The spatial patterns clustered from the three LAI cohorts also coincide with those clustered from climatic variables over the whole TEF region. Herein we provide the average seasonality of three LAI cohorts as the main dataset, and their time-series as a supplementary dataset. These Lad-LAI products are available at https://doi.org/10.6084/m9.figshare.21700955.v4 (Yang et al., 2022).*

Comment 7:

4. The introduction has been substantially enhanced and now reads very well! However, I noticed that there are still some minor grammar errors in the abstract, result, discussion and conclusion sections. Therefore, an additional grammar check may be necessary. Here are a few minor issues that I noted. Please note that this might not be an exhaustive list.

Response: *Thanks, we apologize for those minor grammar errors. We have conducted an additional grammar check to rectify these issues.*

Comment 8:

Line 35: “a first grid” -> “the first gridded” dataset

Response: *Thanks, we revised it as suggested.*

Comment 9:

Line 41: specify “R”

Response: *In revision line 47, we have specified R.*

Comment 10:
Line 48: “which is a good proxy” -> a proxy of photosynthetically effect leaves?
Response: *Thanks. We revised it as suggested. (In revision line 55)*

Comment 11:
L192: photosynthetically
Response: *Corrected.*

Comment 12:
L392: Remove “to warn potential uncertainties” or revise it to improve clarity
Response: *Thanks. To be more cautious, we removed this part in the revised manuscript.*

Comment 13:
L547: remove “quite”
Response: *Thanks, removed.*

Comment 14:
L651: potential grammar issue
Response: *We have revised this sentence to avoid potential grammar issues. The revised sentence was as follows:*

It should be noted that over the regions with a large magnitude of annual precipitation nearby the Equator, there are no obvious dry seasons, and thus tree canopy phenology changes are smaller than higher-latitude ones throughout the year (Yang et al., 2021). (In revision lines 652-655)

Comment 15:
L656: “unexpected” -> “additional”
Response: *Done.*

Comment 16:
L701: “convert” -> “start”
Response: *Done.*

Comment 17:
L707: “help” -> “helpful”
Response: *Done.*

Reference:
Chen, X., Maignan, F., Viovy, N., Bastos, A., Goll, D., Wu, J., Liu, L., Yue, C., Peng, S., Yuan, W., Conceição, A. C., O'Sullivan, M., and Ciais, P.: Novel Representation of Leaf Phenology Improves Simulation of Amazonian Evergreen Forest Photosynthesis in a Land Surface Model, Journal of Advances in Modeling Earth Systems, 12, 10.1029/2018ms001565, 2020.

Melgosa, M., Huertas, R., and Berns, R. S.: Performance of recent advanced color-difference formulas using the standardized residual sum of squares index. Journal of the Optical Society of America A, 25(7), 1828-1834. https://doi.org/10.1364/JOSAA.25.001828. 2008

Yang, X., Wu, J., Chen, X., Ciais, P., Maignan, F., Yuan, W., Piao, S., Yang, S., Gong, F., Su, Y., Dai, Y., Liu, L., Zhang, H., Bonal, D., Liu, H., Chen, G., Lu, H., Wu, S., Fan, L., Gentine, P., and Wright, S. J.: A comprehensive framework for seasonal controls of leaf abscission and productivity in evergreen broadleaved tropical and subtropical forests, Innovation (Camb), 2, 100154, 10.1016/j.xinn.2021.100154, 2021.