

Biogeosciences Discuss., author comment AC2
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Reply on RC2

Yujie Wang and Christian Frankenberg

Author comment on "Technical note: Leaf light absorption and electron transport assumptions bias photosynthesis modeling" by Yujie Wang and Christian Frankenberg, Biogeosciences Discuss., <https://doi.org/10.5194/bg-2022-172-AC2>, 2023

The manuscript presented by Wang and Frankenberg presents a leaf photosynthesis modeling simulation to evaluate light absorption features and smoothing curvature (θ) to impact the maximum electron transport rate and photosynthetic rate. The manuscript is clearly written and well presented, the descriptions for the modeling assumptions and the bias are appropriate, and the reasoning that is given for the interpretation of model results is largely sound. Many Earth system modeling studies have shown the importance of the photosynthetic capacity for vegetation carbon assimilation, due to the availability of the photosynthetic capacity estimation from various data sources (e.g., solar-induced chlorophyll fluorescence). The topic in this manuscript is interesting for both leaf- and canopy-level photosynthetic modeling study.

I appreciate the effort of the authors and it is a very interesting and relevant topic for the photosynthesis model, but this manuscript provides the information that the modeler's community may already be familiar with. I would expect to see some analysis and results that show a clear improvement to resolve the bias in α and β . For example, figure 2b demonstrates that the difference between artificial (red and blue light sources form LICOR) and natural light remains relatively stable for $fAPAR \cdot fPPAR$ when chlorophyll contents $> 10 \mu\text{g cm}^{-2}$, and it suggests that this bias may be corrected by using a constant value for most of the chlorophyll conditions. In addition, I think the presentation of the manuscript and the description of some parts should be improved before publishing. Some comments may be taken into account to improve the manuscript (see more detailed comments on these main concerns below).

[Author response]

Thanks for the positive feedback and suggestions. We have revised the manuscript carefully to address the comments. Please find our point-to-point responses below.

1. First, it is better to clarify "JPAR" and "J". In this work, the authors define the JPAR as "potential electron transport in photosystem II" in Lines 17-18, and also define the J as "the potential electron transport rate" in Line 61. In my understanding, these two items

are the same, considering no mention of photosystem I in this study. But they are totally different in context.

[Author response]

Thanks for the clarification. We have clarified the definitions of JPAR and J in the revision that both are for PSII (JPAR is the PPAR that potentially excites electrons in photosystem II, and J is the potential electron rate in photosystem II limited by JPAR and Jmax).

2. The alpha contains information about fAPAR, fPPAR, fPSII, and phiPSII_{max}. The authors investigate the bias in fAPAR*fPPAR but neglect the variation in fPSII and phiPSII_{max}. It is worth noting that significant seasonal dynamics of phiPSII_{max} can be observed in evergreen forests (Mangey 2019, DOI: 10.1073/pnas.1900278116). Porcar-Castell (2021, DOI: 10.1038/s41477-021-00980-4) also mentioned fPSII did not remain constant over time.

[Author response]

Thanks for bringing it up, and it is indeed important to implement these in future land modeling. We have added two paragraphs to discuss how f_{PSII} and Psi_{PSII}_{max} may vary.

Changes

- **Besides fAPAR and fPPAR, assumptions of constant fPSII and $\Phi_{PSII,max}$ may also introduce errors in computed JPAR. The fPSII is rarely measured but often assumed to be 0.5, given that plants are presumed to equally partition the energy between photosystem I and II to mostly efficiently utilize the absorbed photons when plants are not stressed. It should be aware that the partition of photons between photosystems varies with their wavelength, as shorter wavelength photons (below 680 nm) tend to excite photosystem II whereas longer wavelength photons over-excite photosystem I (Hogewoning et al., 2012; Laisk et al., 2014). Generally, as the light harvest complex on photosystem II may detach and reattach to photosystem I to avoid excessive light into photosystem II (Allen et al., 1981), it makes sense to assume fAPAR = 0.5 when PSII takes more photons when shorter wavelength light (below 680 nm) is abundant. However, if the incoming radiation is mostly longwave light (above 680 nm), the assumption of fAPAR = 0.5 and the photosynthesis models which fail to account for photosystem I electron transport will be problematic (Porcar-Castell et al., 2021).**
- **When not being assumed to be constant, $\Phi_{PSII,max}$ is typically computed from the rate coefficients of photochemical yield (KP), fluorescence (KF), and heat dissipation (KD); and in recently years, and rate coefficient of sustained non-photochemical quenching (KS) at low temperatures also comes into play (Porcar-Castell, 2011; Magney et al., 2019; Raczka et al., 2019) [EQ 4 PLACEHOLDER]. However, these rate coefficients are likely temperature dependent. For example, van der Tol et al. (2014) suggested to add a temperature dependency to KD to account for the temperature responses of minimum fluorescence after dark adaptation (F_o) and maximum fluorescence after dark adaptation (F_m); Raczka et al. (2019) found that implementing a dynamic KS term at low temperatures improved the modeled solar induced chlorophyll fluorescence at a subalpine forest during winter time. As a result, it is more reasonable to use a temperature dependent $\Phi_{PSII,max}$ by**

accounting for KD and KS as variables in vegetation modeling, e.g., [EQS 5 and 6 PLACEHOLDER], where T_{leaf} is leaf temperature in °C, [KS,max, b, Ts] are fitting parameters, S is a dynamic acclimation state based on temperature (see Raczka et al. (2019) for more details).

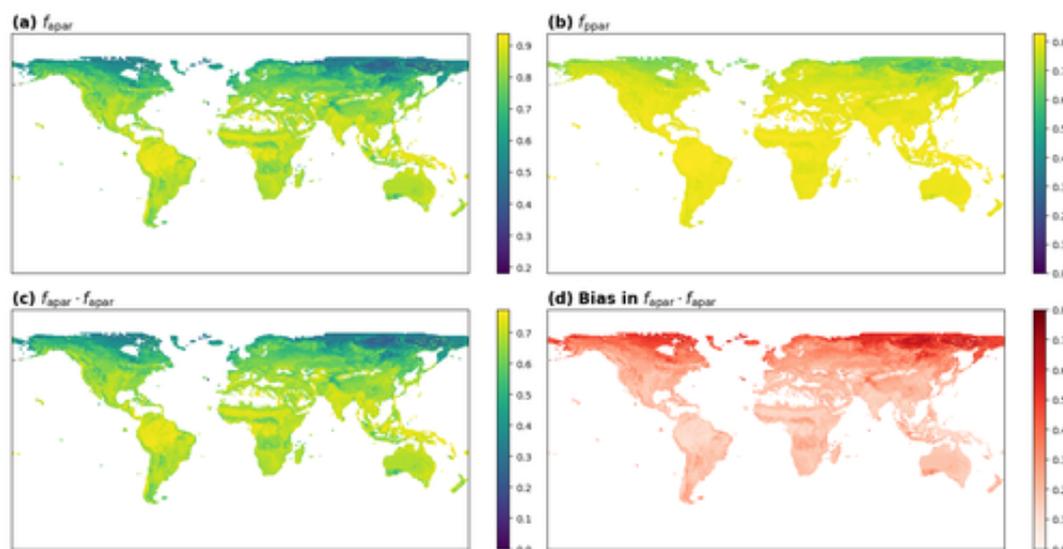
3. Since the manuscript aims to be a type of technical note, the results in this work should provide direct information to help researchers to correct the bias in f_{APAR} and f_{PPAR} , which is caused by the difference between artificial and natural light conditions. A similar study can be found in McClain et al. 2020 (DOI: 10.1111/nph.16255).

[Author response]

We agree that making corrections over the absorption coefficient could help reduce the model bias in photosynthetic rates. Based on the global scale inversion of chlorophyll contents, we will add a new figure (and data product) showing the spatial and temporal variation of the coefficient ($f_{APAR} \cdot f_{PPAR}$), which can be ported to other LSMs. The new figure (pasted below) shows how $f_{APAR} \cdot f_{PPAR}$ varies spatially based on annually mean chlorophyll contents. The dataset based on annually and weekly mean chlorophyll contents, which can be found at Zenodo, would help improve the model parameterizations for other LSMs.

Changes:

- At the global scale, $f_{APAR} \cdot f_{PPAR}$ ranges from 0.1 to 0.75 based on the annually mean chlorophyll content derived from Croft et al. (2020) (Fig. 3a–c). Corresponding bias ranges from 0.11 to 0.76, and is highest in the high latitude regions (Fig. 3d). The $f_{APAR} \cdot f_{PPAR}$ and thus the bias also show seasonal variations because of the seasonality of chlorophyll content (Wang, 2023). The annually and weekly mean $f_{APAR} \cdot f_{PPAR}$ dataset that can be used as prescribed inputs for other land surface models can be found at Wang (2023).



4. A \square C_i curve is generally measured under light-saturated conditions. Thus, it is not

appropriate to say: "Jmax25 is fitted from the light-limited part of A □ Ci curve" in Line 59. "RuBP-regeneration limited part" may be suitable.

[Author response]

Thanks for clarifying it. We have fixed it in our revision.