Response to Reviewer Comments for DOI: 10.5194/bg-2023-163

Anonymous Referee #2*: Neri et al synthesized PAM measurements of ΦPSIImax from literature, and investigated its temperature responses. A model with interpretable parameters is developed, and a tolerance-resilience trade-off is identified. The impacts of PFT and climatological temperature on ΦPSIImax tolerance and resilience are also investigated. While plenty ΦPSIImax measurements can be found in literature, a synthesis analysis as this work is absent. The presented work could be valuable to the community by facilitating our understanding of photosynthesis temperature response and providing information for model parameterizations. The manuscript effectively presented the methods and results in general. Below lists my several concerns and suggestions.*

Response: We thank this referee for appreciating our work and for such a thorough reading of the manuscript. The comments and suggestions made in this review are very helpful in guiding us to improve the text of our manuscript. We have responded to each point as detailed below.

1. *It is not clear to me how the confounding variables (water, light, etc.) were controlled, although that is stated as a selection criterion (L125). Did you select studies where the confounding variables were controlled in that specific study? My understanding is those variables can still vary from one study to another, and may play a role in the analyses. Could you clarify this?*

Responses: We appreciate the reviewer's question about the selection criteria. We selected data with the control of "no other stresses" (e.g., water, light, nutrients). These details are described in the dataset collection document (cited on L130), but we neglected to include the relevant information in the main text. In the appendix dataset, we use "light_status=0", "water_status=0", and "nut_status=0" to label data measured under no light, water, and nutrient stresses respectively. For light status, an additional consideration with some publications was given if the measurement was taken in a climate exposed condition, in which case it may be given a "light_status=1" but still included in the used data for modeling. Among all 2330 measurement data points from the selected 104 studies, 2204 measurement data points met these criteria (Figure 1c), i.e. from PAM monitoring in controlled environments (e.g., greenhouse with no stress of light, water, and nutrients) or field experiments with the description of no other stress condition. To clarify, we will revise the description on lines 123-126, as well as line 150.

On lines 123-126: "To isolate temperature dependence from other external regulators of $\Phi_{PSIImax}$, we mined and selected data from studies that provided cohesive descriptions of temperature for the relevant measurements and excluded the effects of other confounding variables (e.g., water, nutrient, light stress). Following this data selection strategy, we selected PAM observations from the controlled environments (e.g., green house) where nutrients, lights, and water availability have been optimized and only varied temperatures are considered. We also included PAM data from field experiments with the description of no other stress conditions except for temperature. Following these guidelines, a total of 104 studies out of the 380 publications were finally selected."

On line 150: "In total, 2330 measurements from 104 studies were recorded in the final database, with 2104 measurements meeting the criteria for use in modeling."

2. *PFT-specific CTI and percent prediction explained (Eq. 7 and Figure 5): My understanding is that the PFT-specific CTI is still one equation generated for all PFTs, rather than one equation for each PFT. Is this correct? Could you explain the reason for using a general*

equation instead of one equation for each PFT? Presenting the values of the aL parameters might also be helpful.

Responses: This question concerns the description of the three terms about the "CTI" informed parameterization, including "PFT-specific CTI" and "general CTI" shown in Figure 5, as well as "CTI-informed temperature-$\Phi_{PSIImax}$ function" as shown in Figure 6. "PFT-specific CTI" in Figure 5 (green bars) presented the values of estimated aL parameters in Eq. 7. We should have given a clearer legend for this information (e.g., "ART ANOVA results with PFT-specific model residuals"). These values are calculated by performing one ART ANOVA analysis, which determined the residuals (X) between the collected $\Phi_{PSIImax}$ values ($\Phi_{PSIImax,O}$) and predicted $\Phi_{PSIImax}$ values ($\Phi_{PSIImax,P}$) given by each PFT-specific temperature-$\Phi_{PSIImax}$ function. These residuals are integrated to estimate the contributions from different temperature metrics individually as well as from the interactions among them to the overall prediction errors of the 12 PFT-specific temperature-$\Phi_{PSIImax}$ functions (Lines 250-251).

In contrast, "general CTI" in Figure 5 (blue bars) refers to aL values from the second ART ANOVA analysis, which examines the contribution of individual temperature metrics and the interactions among them to the prediction residuals by the general temperature-$\Phi_{PSIImax}$ function derived using all data in the field site sub-dataset (Lines 251-254). Therefore, a clear legend of this second ART ANOVA in Figure 5 should be "ART ANOVA using prediction residuals from general (non-PFT specific) temperature-$\Phi_{PSIImax}$ function."

Comparing the estimated aL values from the two ANOVA analyses in Figure 5 aims to examine whether the contributions of individual temperature metrics and their interactions to prediction errors are consistent, and to provide justification and flexibility for applying either version of aL values for CTI estimations (Lines 459-463).

As the two versions of ANOVA analysis showed consistency, we applied aL values from the PFT-specific prediction residuals-based ART ANOVA (green bars) to estimate CTI values corresponding to each $\Phi_{PSIImax}$ value in the field site sub-dataset, using Eq. 7. Then, these CTI values are incorporated to quantify the dependence of the parameters from PFT-specific temperature-$\Phi_{PSIImax}$ functions (m_1, m_2, s_1, s_2) on CTI, using quantile system approach (QSA) (Section 2.3.4). For each parameter (m_1, m_2, s_1, s_2), we generated one CTI-informed function using all data from the field site sub-dataset. The reason for generating one equation for each parameter using all data from the field site sub-dataset is as follows. (1) A lack of sufficient data covering a large range of CTI values for any one PFT in the field site sub-dataset meant that CTI-dependence of each parameter (m_1, m_2, s_1, s_2) for each PFT could not be determined in a statistically robust way (Lines 285-287). (2) Moreover, the use of a single equation and comparison to the PFT-specific temperature-$\Phi_{PSIImax}$ functions can test the core hypothesis in this study: "climatological temperature regulates the temperature tolerance and resilience of $\Phi_{PSIImax}$, therefore shifts different PFT's temperature-$\Phi_{PSIImax}$ responses toward converged responses to the climatology of their "similar" local habitat. (Lines 209)"

In summary, we accept the reviewer's comments and will clarify this concern by revising the following contents of the manuscript.

1) We will refine the description of the hypothesis and its testing methods.

On lines 209-215: "To test the hypothesis that climatological temperature regulates the temperature tolerance and resilience of $\Phi_{PSIImax}$, and therefore shifts different PFT's temperature-$\Phi_{PSIImax}$ responses toward converged responses to the climatology of their "similar" local habitat, we generated a general

climatology-informed temperature-$\Phi_{PSIImax}$ function and compared its results with the corresponding PFT-specific model results.
In detail, we quantified corresponding climatological temperature metrics for data within the field site sub-dataset (Sect. 2.3.1) and assessed their capacity to explain the prediction residuals from PFT-specific temperature-$\Phi_{PSIImax}$ functions using ART ANOVA (Sect. 2.3.2). Based on the results, we incorporated the metrics via a linear combination into a Climatology Temperature Index (CTI) (Sect. 2.3.3). This index was then incorporated to quantify a CTI-informed temperature-$\Phi_{PSIImax}$ function (Sect. 2.3.4). The fitting results of this CTI-informed model were compared to the corresponding PFT-specific model results. Finally, we identified where prediction deficiency was improved by the CTI-informed parameterization and the climatology's effect on the temperature-$\Phi_{PSIImax}$ relationship was important to consider (Sect. 2.3.5)."

2) We will refine the description of the reasons for generating one equation for each parameter using all data from the field site sub-dataset after lines 285-286.

On lines 285-286: "Ideally, the field site sub-dataset would cover diverse climatological temperature conditions, be distributed consistently across the full global range of CTI values, and contain statistically sufficient data for all PFTs, but this is not the case. The available 709 measurements represent a limited, non-uniform range of climatology temperature metrics (Histogram distribution of data in Fig. 2b). We overcome this data limitation by generating one CTI dependence function for each parameter in Eq. 1 using all data from the field site sub-dataset and the quantile system approach (QSA), which was developed to navigate the small sample size and inconsistent CTI values distribution by performing the following three steps."

3) To avoid confusion about the two versions of ART ANOVA and clarify the specific ART ANOVA finally employed to generate CTI-informed parameterization, we will revise their description in Figure 5 and the corresponding texts in section 3.2.1.

"The green bars" in Figure 5 are defined as "ART ANOVA using prediction residuals from PFT-specific temperature-$\Phi_{PSIImax}$ functions ($ANOVA_{RS\_pft}$)", whereas "the blue bars" in figure 5 are labeled as "ART ANOVA using prediction residuals from the general (non-PFT specific) temperature-$\Phi_{PSIImax}$ function ($ANOVA_{RS\_gen}$)".

On lines 461-462: "This consistency justified that the regulation of climatological temperature on the temperature-$\Phi_{PSIImax}$ relationship can be estimated using the results of either version of ANOVA. Here we will use the aL values from $ANOVA_{RS\_pft}$."

3. Rearranging Section 3.2 and Section 3.3 and putting the CTI map (Figure 8c) before Figures 6 and 7 may help the audience more easily interpret results related to CTI.

Responses: We agree with the reviewer that this rearranging of sections and figures can help to interpret the main results related to CTI and benefit our readers in capturing key points of this study. To address this, we will perform a rearrangement of section 3.2 & section 3.3 and corresponding figures, with more details to be found in the response to **(5)** below.

4. Are the CTIs in the results section the general CTI?

Responses: No, all CTI values after 3.2.1 were generated using the aL weights estimated from ART ANOVA using prediction residuals from the PFT-specific functions. As discussed in our responses to **Comment #2**, this is a point that we should have made clearer, and we will add language to address this around L462.

On Lines 461-462: "This consistency justified that the regulation of climatological temperature on the temperature-$\Phi_{PSIImax}$ relationship can be estimated using the results of either version of ANOVA. Here we will use the aL values from $ANOVA_{RS\_pft}$."

5. *The manuscript is quite long, I suggest cutting the length of the manuscript. Some method and results could potentially be moved to the supplementary. For example, details of ART ANOVA, section 3.2.1, and section 3.2.3.*

Responses: This comment helps us polish our manuscript. We agree that with some re-wording and summary of the main points, section 3.2.1 and section 3.2.3 could be joined into Appendix B. In the meantime, we will combine sections 3.2 and 3.3 and re-organize the text, including three sub-sections:

3.3.1 Global distribution of CTI: This section will focus on the description of the current section 3.3.1 (CTI global pattern) and also include a brief justification of CTI for explaining the prediction errors (a brief summary of the main conclusion from current section 3.2.1).

3.3.2 CTI-informed parameters of temperature regulation on $\Phi_{PSIImax}$ and its latitudinal variation: This section will combine the current section 3.2.2 with section 3.3.2.

3.3.3 Spatial distribution of the differences between CTI-informed and PFT-specific parameterizations: This section will briefly report the "overall improvement of predictions of the temperature-$\Phi_{PSIImax}$ dynamic using CTI-informed parameterization (Figure 7 in current section 3.2.3) and focus on description of Spatial distribution of the differences between CTI-informed and PFT-specific parameterizations (current section 3.3.3).