Responses to the comments by Anonymous Referee #1 on
"Evaluating the carbon and nitrogen cycles of the QUINCY terrestrial biosphere model using remotely-sensed data"

Miinalainen, T., Ojasalo, A., Croft, H., Aurela, M., Peltoniemi, M., Caldararu, S., Zaehle, S., and Thum, T.: Evaluating the carbon and nitrogen cycles of the QUINCY terrestrial biosphere model using remotely-sensed data, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-2987, 2025.

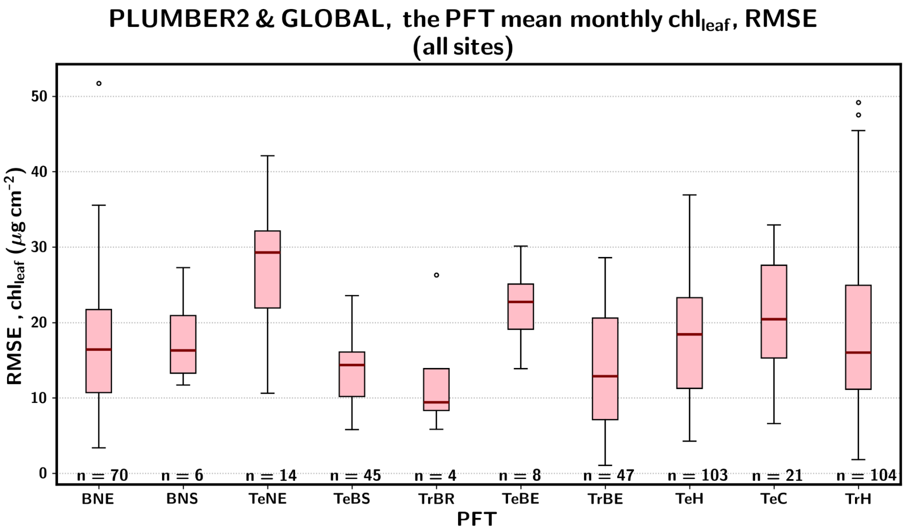
Our responses are written below each comment separately. The referee comments are marked with blue color and italic, and the author replies are marked with black color. The original manuscript text is marked with orange color, and modified text with red. The line numbers refer to the original submitted version of the manuscript which was peer-reviewed.

This study is centered on evaluating the spatio-temporal behaviour of the terrestrial biosphere model (TBM) QUINCY, using mainly a remote sensing (RS) product of leaf chlorophyll content (RS chl_{leaf}). The interest in the use of such a product is motivated by the strong link between leaf chlorophyll and Nitrogen contents. Other datasets are exploited such as RS LAI, and GPP at FLUXNET sites. The study looks at the agreement between simulated and observed chl_{leaf}, evaluating the magnitude and the seasonal cycles across and within plant functional types (PFTs). Alternative algorithms of nitrogen use are also evaluated, and a statistical model is used to look at the main drivers of observed and simulated chl_{leaf}.
The topic is quite innovative. The paper is well structured and clearly written. The methodology is sound, and the results are accurately described. The analysis of the seasonal cycles would gain in clarity from actual figures of the seasonal cycles. To enrich the temporal analysis, the authors could present boxplots of RMSD distribution for each PFT. The Discussion section would benefit from a more clearly defined structure. Even though the model results are not yet fully satisfactory, this paper nonetheless offers a valuable contribution to the field, and paves the way for a larger use of RS chl_{leaf} products among TBMs, both for evaluation and data assimilation purposes.

We thank Anonymous Referee #1 for the encouraging and constructive feedback which certainly helps us to improve the quality of our analysis and representation of the results. We have done our best to address the comments.

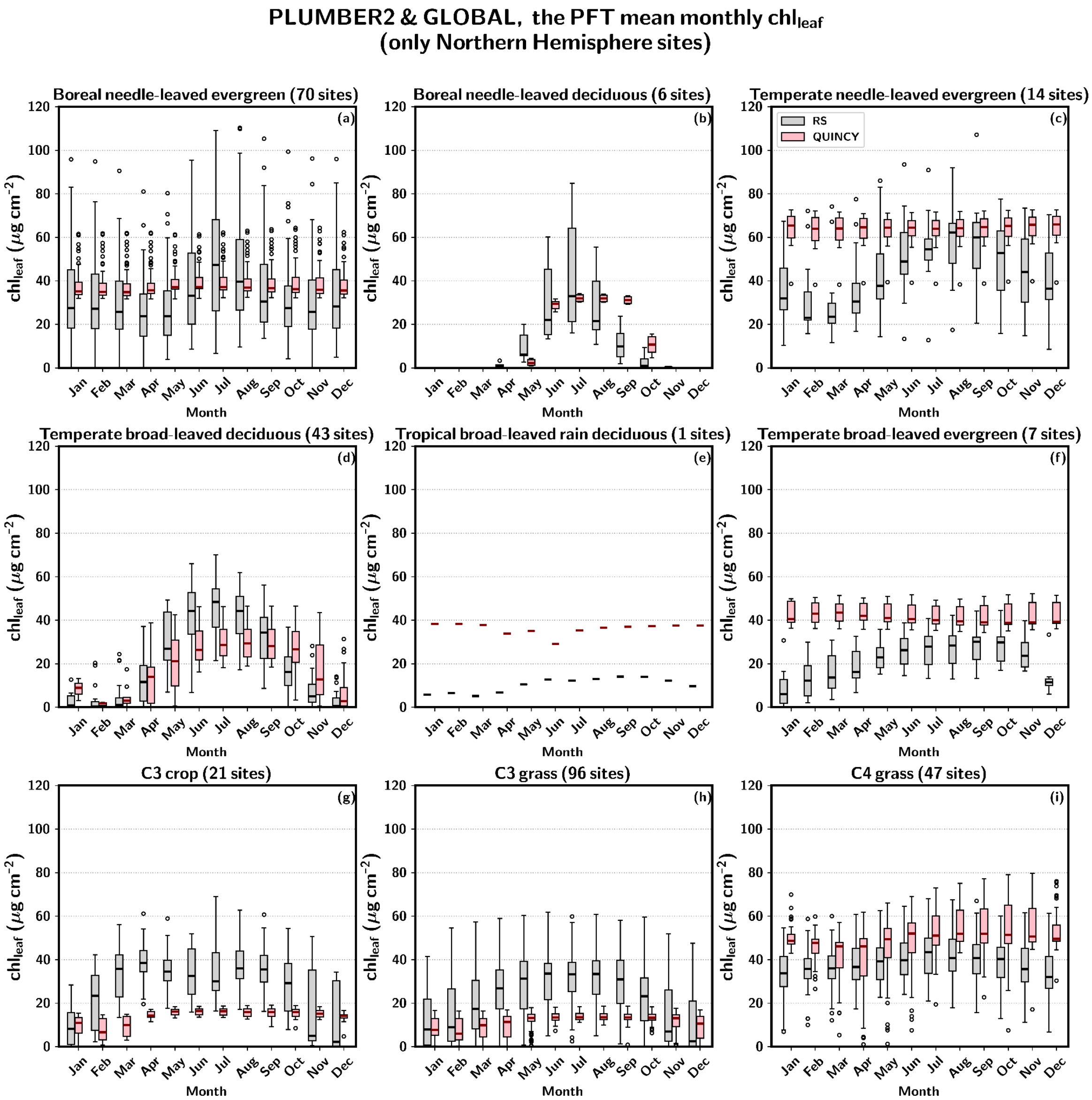
We have now added additional figures to show the PFT-averaged seasonal cycles. We will also revise the Discussion section to be more concise and readable.

In addition, we tested two different options for the boxplots that the referee suggested. Below is a box plot showing the root mean square errors (RMSE) for chl_{leaf} for each PFT. The RMSE values are calculated between QUINCY and RS chl_{leaf}, using the averaged monthly values over years for each site. The boxplot boxes and whiskers indicate the distribution between sites' RMSE.



The lowest RMSE median of monthly chl_{leaf} averages is seen for the TrBR sites, but the median represents only four sites. The highest RMSE median values are seen for TeNE and TeC sites. For the evergreen needle-leaved sites (TeNE and BNE), the QUINCY chl_{leaf} during winter time is much higher than RS_{chl}, as QUINCY is showing a stronger seasonal cycle than RS_{chl}, which affects the RMSE values. For the TeC sites, the magnitude of RS chl_{leaf} is much larger than QUINCY, and the seasonal cycle of QUINCY is delayed, which leads to high RMSE. The TrH sites show a high range of RMSE values. However, the median RMSE of TrH is at a similar level as for other PFTs.

Furthermore, we drew a boxplot showing monthly averaged chl_{leaf} values. The boxplot whiskers and boxes indicate the distribution of site-level mean monthly chl_{leaf} values for QUINCY and RS.



The boxplots of the monthly mean chl_{leaf} values show that there is a larger deviation between sites in RS chl_{leaf} compared to QUINCY chl_{leaf}. Especially needle-leaved sites show a larger spread in monthly chl_{leaf} values in RS than in QUINCY.

After consideration, we decided that we present only the PFT-averaged seasonal cycles with the standard deviation shown in the same plots in the manuscript, including the RMSE values.

Main comments

Abstract.

-L14-16: 'Our results also show that compared to the original leaf nitrogen allocation scheme of QUINCY, the revised scheme produced a more reasonable sensitivity of gross primary production to increases in chl_{leaf} '-> Where is this demonstrated in your results?

We referred here to the analysis and results presented at L502-509. To better communicate our conclusion, we will modify and improve the manuscript text in Section 3.3 and describe this in more detail. We have also updated the manuscript text in Discussion to clarify this aspect (See detailed response below in replies to another comment.)

1 Introduction

- L54: Krinner et al., 2005 -> The N version of ORCHIDEE is described in Vuichard et al. (2019).

Vuichard, N., Messina, P., Luyssaert, S., Guenet, B., Zaehle, S., Ghattas, J., ... & Peylin, P. (2019). Accounting for carbon and nitrogen interactions in the global terrestrial ecosystem model ORCHIDEE (trunk version, rev 4999): Multi-scale evaluation of gross primary production. Geoscientific Model Development, 12(11), 4751-4779.

Many thanks for pointing out the correct citation. We have fixed this in the updated manuscript, and also added another reference.

- L55-56: 'evaluating and validating' -> What's the difference for you?

We have now updated the sentence at L55-56 from:
"..remote sensing (RS) of the Earth's vegetation provides comprehensive data for evaluating and validating TBMs." to
"..remote sensing (RS) of the Earth's vegetation provides comprehensive data for evaluating TBMs."

2 Materials and methods

2.4 Remote sensing data

2.4.3 Post-processing of the RS data

- L241-243: 'In addition, the RS chl_{leaf} for the needle-leaved sites was multiplied by π/2. This was done to account for the half-hemispherical needle geometry in the remote sensing retrieval (Stenberg et al., 1995).' -> This is weird, why was this correction not applied in the native algorithm of Croft et al. (2020)? How can the users of chlorophyll products know whether this has been considered? For example, what about the OLCI product, do you know if such a correction is integrated in the processing chain?

In the Croft et al. (2020) RS chl_{leaf} processing chain, the leaf-level reflectance spectra is derived with the 4-Scale model, which assumes hemispherical shape of needles. The geometry correction, i.e. multiplying by π/2, is done in order to have the RS chl_{leaf} data corresponding to the projected area of needles. This way, RS chl_{leaf} is comparable to QUINCY chl_{leaf}. There are multiple options for geometry correction available, and we decided to go with the option recommended by Stenberg et al.

OLCI chl_{leaf} product by Reyes-Muñoz et al. (2022) is derived using the SCOPE radiative transfer model, where the needle-leaved trees are treated in a similar manner as other leaf types. Therefore, RS chl_{leaf} for conifer trees already corresponds to the projected needle area, and does not require a correction.

2.5 In-situ observations

2.5.1 Eddy covariance flux observations

- L256: 'Data from all years were used, and therefore, the GPP time series are not from the same time interval as RS chl_{leaf}.' -> Can you comment on this discrepancy? What are the possible implications regarding the accuracy and robustness of your findings?

Our aim was to simulate and evaluate standard, average behaviour of each PFT, and also conduct analysis over some specific PLUMBER2 sites. Therefore we aimed to use as much data as there was available. Taking the average over all available data years enables us to compare the average seasonal cycle. If we'd have used only the years for which we would have both RS chl_{leaf} and eddy covariance GPP data, the analysis of the seasonal cycle might not have been representative for each site due to lack of data.
The discrepancy in time intervals between RS chl_{leaf} and eddy covariance GPP observations might cause differences in the seasonal cycle development for individual sites, for instance, due to extreme drought years. However, as most of the analysis is carried out over several sites and years, the impact of single drought years is likely to be minimized. The RS chl_{leaf} shows stronger interannual variability than QUINCY chl_{leaf} when analyzed over all sites. This indicates that the RS chl_{leaf} is potentially more sensitive to the choice of years compared to QUINCY simulated data.
For the GLOBAL sites, the QUINCY simulations were for a 30 year period, while the RS chl_{leaf} data was available only for nine years. To maintain comparability, for each GLOBAL site we filtered out QUINCY simulation data for those years where there were no RS chl_{leaf} data available. This was not described clearly enough in the original manuscript text, and we will modify the text to highlight this data processing step.

2.6 Feature importance analysis

- In this section we need more information on your training/test/evaluation datasets and the scores of your statistical models to trust your further analyses.

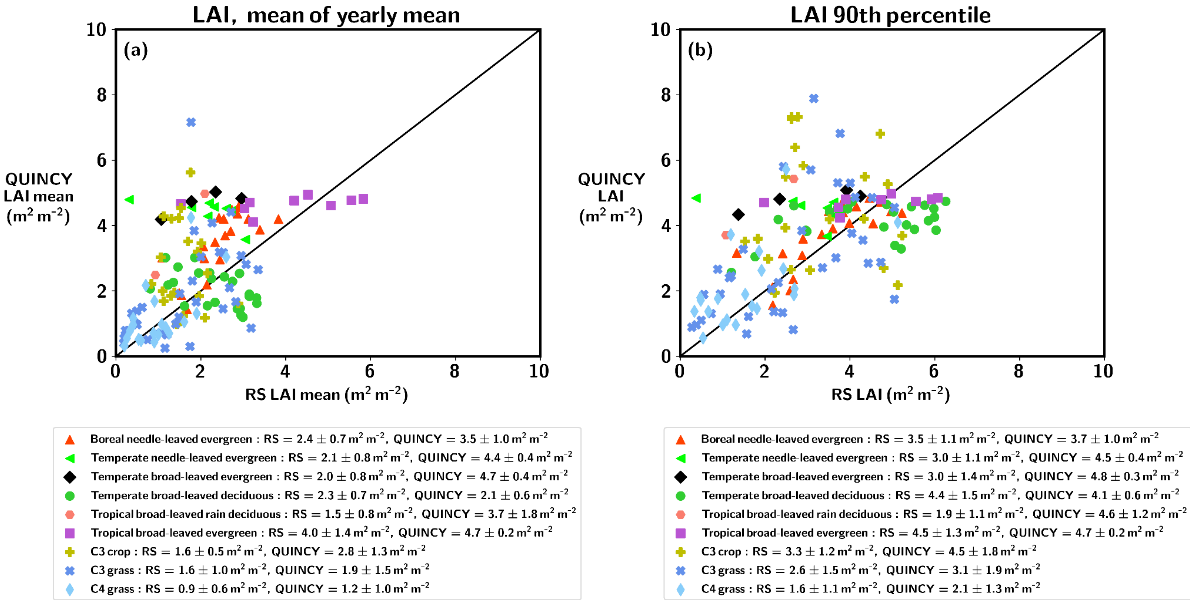
We have updated the manuscript text to better describe the machine learning evaluation. In addition, we have added a supplementary table S6 to present the R^2 scores of each PFT-specific random forest model.

2.7 Data-analysis

- L326-327: 'We used the 90th percentile of LAI instead of the mean values to reduce the effect of seasonal variation.' -> This is not clear, how is the mean value more impacted by the seasonal variation? What would be the impact on your study if you considered the mean LAI?

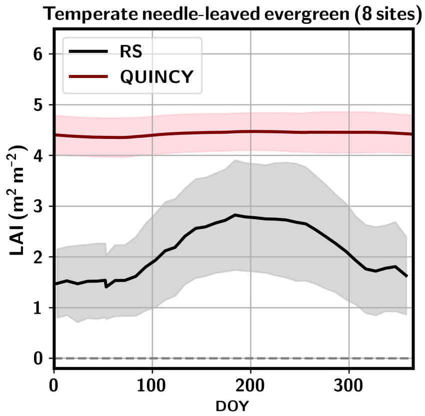
The motivation to choose 90th percentile instead of mean values is due to the fact that QUINCY and RS LAI show different seasonal behaviour (such as differing growing season length or overestimation of seasonal amplitude in evergreen needleleaves) for some of the PFTs. In this part of the evaluation, our aim was to compare the magnitude of the growing season LAI between QUINCY and RS. The seasonal cycle will be analyzed separately, and here we wanted to focus on PFT-specific LAI magnitudes. As there are sites from both hemispheres (NH and SH), the growing season can not be narrowed to a certain period (JJA, for instance). We chose to use the 90th percentile instead of the maximum values, as the 90th percentile is less sensitive to outliers and anomalies, which are often present in the RS data.

Below is a figure comparing the mean LAI and 90th percentile LAI for the PLUMBER2 sites:



For instance, the PLUMBER2 temperate needle-leaved evergreen (TeNE) sites show a larger difference between QUINCY and RS LAI if we would use yearly average as a metric, compared to the 90th percentile. Using the averages as metric would therefore lead to a conclusion that QUINCY LAI is greatly overestimated (>100%) for TeNE sites, while using the 90th percentile, the overestimation of QUINCY is moderate (~50%).

Here are the PFT-averaged seasonal cycles of the PLUMBER2 TeNe sites for QUINCY and RS LAI:



As the figure above shows, QUINCY shows very little variation throughout the year for the TeNE sites, while RS shows a distinct seasonal pattern. The difference in seasonal pattern leads to larger differences in the mean values, while the 90th percentile values are closer to each other compared to the means.
To clarify this, we have modified the text in L326-327 from:
"We used the 90th percentile of LAI instead of the mean values to reduce the effect of seasonal variation." to
"We used the 90th percentile of LAI instead of the mean values. This was done in order to reduce the effect of differences in seasonal amplitude and timing variation between QUINCY and RS, and to focus on the growing season LAI values."

- L330 : 'We analyzed the seasonal cycle of chl_{leaf}, LAI and GPP for one specific site, Hainich in Germany (DE-Hai, 51.08◦N, 10.45◦E)' -> Why not show mean seasonal cycles per PFT? This would be justified as many parameters are PFT-dependent.

Thank you for the suggestion. We have now replaced the analysis of the seasonal cycle focusing only on Hainich with an analysis over the PFT-mean seasonal cycle for the temperate broad-leaved deciduous sites of the PLUMBER2 site set. In addition, we have added the estimations of start of season (SOS), end of season (EOS) and length of season (LOS) for these sites. The SOS and EOS values are calculated using a similar approach as in Thum et al. (2025), and we have added the description of the calculation in the Methods section.

- L334-336: 'In addition, we calculated the average values over April, May, October and November for the PLUMBER2 TeBS NH sites for the QUINCY results and observations, to study the differences in seasonal development'. -> Again, why not study the complete seasonal cycle?

As mentioned above, we have updated the manuscript analysis to cover the PFT-mean seasonal cycles.

3 Results

3.1 Evaluation of simulated chl_{leaf}, LAI and GPP against observations

- These first paragraphs should be grouped under a first subsection '3.1.1 Mean values' (as opposed to the following subsection dealing with seasonal cycles).

This was a good point, we have added a subsection title for these paragraphs. We decided to use a subtitle of "Yearly values" to avoid confusion with the 90th percentile of LAI and the annual GPP sum.

- L353: 'For chl_{leaf} in all cases apart from TrBE and TrH, there is a lack of variation in the QUINCY chl_{leaf}' -> Looking at Table S5, TeBS seems to be quite good with QUINCY's statistics being close to those of the RS product.

Again a good observation, we have added TeBS in the list. We updated the sentence at L353 from:
"For chl_{leaf} in all cases apart from TrBE and TrH, …" to
"For chl_{leaf} in all cases apart from TeBS, TrBE and TrH, …"

3.1.1 Seasonal cycle

- The whole description of Figure 3 is too vague, please provide some quantification to support your assertions.

We have now replaced the analysis of Hainich with assessment over the PFT-mean seasonal cycle for the PLUMBER2 Northern hemisphere TeBS sites as suggested earlier in the comments, and added the Pearson correlation and RMSE statistics. Furthermore, we calculated the start of season (SOS), the end of season (EOS) values and length of the season (LOS) values for chl_{leaf} , LAI and GPP. Those will be shown in a new supplementary table.

- L383-384: 'The annual cycle of chl_{leaf} at the Hainich site (Fig. 3) is very similar when comparing QUINCY and RS' -> This seems somewhat optimistic, even accounting for the delay, as the shapes are different. Please provide some statistics.

We have now added the Pearson correlation r and RMSE values for the PFT-mean cycle of PLUMBER2 TeBS NH sites.

- L384-385: 'the simulated LAI increases approximately 20 days later in spring compared to the RS LAI. The delay is even more pronounced for chl_{leaf}' -> This is not what is seen on the subplots of Figure 3: RS chl_{leaf} and LAI seem to be starting around DOY 80, and QUINCY chl_{leaf} and LAI around 120, and we don't see any delay regarding chl_{leaf} as compared to LAI, the delay vs the RS products seem to be around 40 days for both variables. To settle this, explain how you determine the start of season for model and observations, provide the dates, and add the corresponding lines on the figure.

Thank you for pointing this discrepancy out. We have now added the calculation of SOS and EOS values using the PFT-averaged seasonal cycle of the PLUMBER2 NH TeBS sites. From this analysis, we see that the start of the season for TeBS-averaged cycle is during the same DOY for both simulated and observed chl_{leaf}, while the SOS for LAI shows a difference of 13 days. We have now added the SOS and EOS lines in the updated figure, and added a supplementary table for the SOS and EOS values for QUINCY and observations.

- L388-390: 'However, despite the fact that QUINCY chl_{leaf} and LAI remain higher, their winter level is reached almost at the same time as in the Hainich observations, because the senescence occurs more rapidly in QUINCY than in the observations' -> That might be overstated, explain how you determine the winter levels for model and observations, provide them and the dates when they are reached, add all the corresponding horizontal and vertical lines on the figure.

This part of the text is now modified to correspond to the PFT-mean seasonal cycle. We modified the text in L388-390 from:
"However, despite the fact that QUINCY chl_{leaf} and LAI remain higher, their winter level is reached almost at the same time as the observed, because the senescence occurs more rapidly in QUINCY than in the observations."
to
"However, the senescence occurs more rapidly in QUINCY than in the observations."

- L390: 'Therefore, the overestimation in GPP is not as pronounced.' -> Why "therefore"? I don't see the link. Your later sentence on L395-396: 'In addition, although the simulated LAI remains at the summer level until DOY ~280, the simulated GPP decreases due to the environmental conditions' is more convincing.

The referee is correct that the reasoning is not logical in this section. What we meant was that as GPP depends on the LAI in QUINCY, the delayed end of the season in the simulated GPP is partly minimized by the sharp decline in the LAI. In order to avoid confusion, we have removed from L390 the sentence:
"Therefore, the overestimation in GPP is not as pronounced."

- L397-398: 'For the TrH sites (Fig. 2i), the lowest PFT mean for QUINCY is in April, suggesting that the phenological cycle for these sites needs further tuning in QUINCY' -> It's not clear from the scatter plot what the seasonal cycles look like. It would be much easier to see the mean seasonal cycles for both model and observations than trying to imagine them from the scatter plot. Please add them, at least in supplementary, otherwise it's very difficult to follow this paragraph. Also, you could add the corresponding RMSD and r.

We have now replaced Figure 2 with three new supplementary figures (S6, S7 & S8), showing the PFT-averaged seasonal cycles of chl_{leaf}, LAI and GPP. The figures include the RMSE and Pearson correlation values, calculated between PFT-averaged seasonal cycles of QUINCY and observations.

- L402-403: 'could be due to a drought' -> Do you mean a modeled water stress? Please check whether this is the case in your simulations. Plus, wouldn't that be the standard phenology for a tropical deciduous PFT, to be limited by water availability rather than temperature?

This was an important point. We have now analyzed the simulated soil moisture levels for NH TrH sites. We observed that the soil moisture at the 1st and 2nd QUINCY soil layers were in the same magnitude when comparing DJF and MAM averages over sites. Therefore, we decided to remove the speculation of the role of potential drought affect chl_{leaf} magnitude.

The potential cause of the low spring chl_{leaf} magnitude of the TrH sites could be due to delay in autumn LAI, as the senescence occurs rather late in QUINCY for the NH TrH sites.
In QUINCY, the growing season of TrH sites is determined using three threshold values (soil moisture, air temperature and whether the weekly carbon balance is positive).
Phenological triggers in herbaceous systems are more varied than in forests, due to higher species diversity so models such as QUINCY often struggle to capture start or end of season. For seasonally dry sites it is also possible that the simulated soil moisture does not match the PFT-level threshold parameters.

We will update the manuscript analysis and add some discussion points regarding the delay in the Northern Hemisphere TrH sites seasonal cycle.

- L408: 'The mean IAV' -> Why do you present the mean IAV in the "Seasonal cycle" section, and not in the former one which presents the mean annual values?

This was a good suggestion, we have now moved the text in lines 410-414 after the line 378.

3.2 Nitrogen limitations in QUINCY

- L455: 'indicating that chl_{leaf} is more influenced by other factors than leaf N levels, compared to BNE and TeBS' -> Provide a few examples of these other potential factors.

We noticed that there was a small typing error: the purpose was to discuss leaf C:N levels as a factor, not leaf N. We have updated the sentence at L455 from:
"indicating that chl_{leaf} is more influenced by other factors than leaf N levels,"
to
"indicating that chl_{leaf} is more influenced by other factors, such as water availability, temperature and precipitation, than leaf C:N levels,"

- L478:479: 'The US-MMS QUINCY leaf C:N is close to the lower leaf C:N threshold '-> You could provide the leaf C:N low and high thresholds per PFT in the supplementary material.

Thanks for the suggestion, we have added a new supplementary table (S4) where the QUINCY lower and upper leaf C:N boundaries are listed. In addition, we have modified the sentence in L112 from:
"The ratios are constrained to an empirically derived range based on the TRY database (Kattge et al., 2011)."
to
"The ratios are constrained to an empirically derived range based on the TRY database (Kattge et al., 2011), and the lower and upper boundaries are presented in Table S4."

4 Discussion

4.1 QUINCY's ability to reproduce chl_{leaf} magnitude

- This section spans over two pages and lacks clear organization. Please add subsection titles to better guide readers through the logic of your argument.

We will re-organize the discussion section based on the comments by Referee #2, and add more subsection titles as suggested.

- L569-570: 'Overestimation of LAI can lead to too strong shading, which can result in too small GPP in lower canopy layers' -> I'm not sure about that, it will depend on the radiative transfer model.

We have now updated wording at L569-570 to be more speculative. The sentence is modified from:
"Overestimation of LAI can lead to too strong shading, which can result in too small GPP in lower canopy layers."
to
"Overestimation of LAI can potentially lead to too strong shading, which could result in too small GPP in lower canopy layers."

- L570-571: 'In addition, the radiative transfer model might play a role in the underestimated GPP' -> Why 'in addition', as this has a direct link to your former sentence?

Thanks for pointing this out, we have removed "in addition" from the sentence.

- L596-598: 'This indicates that the alternative N allocation scheme produces more in line with our current ecophysiological understanding of plant dynamics: increasing leaf N in chl_{leaf} does not decrease other photosynthetic fractions , but more structural part ($f_{N,struct}$)'
-> I'm not sure what 'this' refers to. While you argue that your new model is more realistic, it is unclear how this is supported by your results.

Here we had "this" referring to emerging understanding from the current literature, and also to the increase of GPP due to changes in $f_{N,chl}$ and $f_{N,Rub}$. We will clarify the manuscript text in Section 3.3, and also the text in Discussion.

We have modified the text at L596-598 from:
"the advanced N allocation scheme provided a more realistic mechanism when $f_{N,chl}$ was increased. This indicates that the alternative N allocation scheme produces is more in line with our current ecophysiological understanding of plant dynamics: increasing leaf N in chl_{leaf} does not decrease other photosynthetic fractions, but more the structural part ($f_{N,struct}$)."
to
"the advanced N allocation scheme provided a more realistic mechanism when $f_{N,Rub}$ was increased, by resulting in an increase in both $f_{N,chl}$ and in GPP. This indicates that what the alternative N allocation scheme produces is more in line with the literature (Onoda et al., 2017; Evans and Clarke, 2019) of the relation between $V_{c(max)}$ and chl_{leaf}: increasing leaf N in chl_{leaf} does not decrease other photosynthetic fractions, but rather the structural part ($f_{N,struct}$)."

- L600-601: 'QUINCY chl_{leaf} for evergreen sites was driven by N deposition, with other environmental variables contributing less. The same was true for the RS chl_{leaf} for BNE and TrBR, but not for TeNE' -> Why is TrBR mentioned here, it's not an evergreen PFT. Do you

mean TrBE?

Many thanks for pointing this out, indeed we were referring to TrBE. This is now corrected in the text.

Code and data availability

- L774: 'RS chl_{leaf} by Croft et al. (2020) will be available by request from the authors.' -> Why not make it available on a public repository? This would ensure broader use.

The RS chl_{leaf} product data has limited access due to intellectual property rights. However, the data is available by request from Dr. Holly Croft. To promote broader use of the data, we are looking for a possibility to share the postprocessed RS chl_{leaf} data for the PLUMBER2 sites via the METIS data repository.

Technical comments

- L77-78: Evans and Clarke, 2018 -> Evans and Clarke, 2019. To be corrected also L79, 155, 862.

This is now fixed accordingly.

- L155: 'Site description -> Description of the sites'

A good suggestion, this has been updated.

- L355: 'for TeC and TeH sites, which gives' -> 'for TeC and TeH sites, which give'

Thanks for pointing this out, it is now corrected.

- L359: 'PFTs.Whilst' -> 'PFTs. Whilst'

The typing error is now fixed.

- L378-379: 'for the boreal and temperate evergreen sites (Fig. 2a,b,c,d)' -> That would rather be 'Fig2. a, c, f'.

Thanks for pointing this out, we have now corrected this when referring to the new supplementary figures.

- Figure 2e: 'TrBR (1 sites)' -> 'TrBR (1 site)'

Figure 2 has been replaced with new supplementary figures, and we have taken this comment into account while formatting the figures.

- L395: 'between years the 2003–2011' -> 'between years 2003–2011'

This correction was not needed as the text was updated to cover all PLUMBER2 TeBS sites.

- L401: 'compared rest of the year' -> 'compared to the rest of the year'

This part of the text was removed due to updates in the manuscript analysis.

- L405: 'The April and May chl_{leaf} values are mostly underestimated by QUINCY for chl_{leaf} , LAI and GPP' -> 'The April and May values are mostly underestimated by QUINCY for chlleaf, LAI and GPP'

This part of the text was removed due to updates in the manuscript analysis.

- L435: 'Fig. S7 and S6' -> 'Fig. S7 and Table S6'

Thank you for indicating this, we have corrected this in the text.

- L454: 'p< 1×10−40' -> 'p < 1×10−40'

Added the missing white space.

- L458: 'For the TeBS site'-> 'For the TeBS sites'

Fixed the sentence accordingly.

- Legend Figure5: 'Teh' -> 'TeH'

We have corrected the PFT abbreviation in the figure caption.

- L486: '3.3 Alternative leaf N allocation scheme' -> '3.3 Alternative leaf N allocation schemes'

We decided to change the subsection 3.3 title from
"Alternative leaf N allocation scheme"
to
"Leaf N allocation schemes"

- L496: 'PFTS' -> 'PFTs'

This is now revised in the manuscript text.

- L567: 'the QUINCY mean chl_{leaf} is underestimated at majority of the the TeBS sites' -> 'the QUINCY mean chl_{leaf} is underestimated at the majority of the TeBS sites'

A good remark, we have fixed the text accordingly.

- L579-580: 'Another missing processes in are fertilization and management of croplands' ->' Other missing processes in QUINCY are fertilization and management of croplands'

Corrected the sentence in the text.

- L596-598: 'This indicates that the alternative N allocation scheme produces more in line with our current ecophysiological understanding of plant dynamics: increasing leaf N in chl_{leaf} does not decrease other photosynthetic fractions , but more structural part (fN,struct)' -> 'This indicates that what the alternative N allocation scheme produces is more in line with our current ecophysiological understanding of plant dynamics: increasing leaf N in chl_{leaf} does not decrease other photosynthetic fractions, but rather the structural part (fN,struct)'

Many thanks for the suggestion, the manuscript text is now updated accordingly, with slight modifications based on comments earlier.

- L599: 'Our machine learning based analysis' -> 'Our machine learning-based analysis'

Fixed the typo in the text.

- L626-627: 'The Sentinel-3 chl_{leaf} shows the strongest seasonal cycle for the US-NR1 compared to other products' -> 'The Sentinel-3 chl_{leaf} shows the strongest seasonal cycle at the US-NR1 site compared to other products'

This is now revised in the manuscript text.

- L633: 'one of the state-of-the art TBMs that includes' -> 'one of the state-of-the art TBMs that include'

Corrected the sentence.

- L653: 'overestimated at the certain sites' -> 'overestimated at certain sites'

We have fixed this accordingly.

- L679-680: 'RS observations from the Sentinel-3 satellite could be included as it was tested for two sites' -> 'RS observations from the Sentinel-3 satellite could be included as they were tested for two sites'

This is now corrected in the updated manuscript.

- L692-693: 'the low elevation angles of the sun, which limits the reliability of the measurements throughout the winter months and, in mid-winter, results in polar night' -> 'the low elevation angles of the sun, which limit the reliability of the measurements throughout the winter months and, in mid-winter, result in polar night'

Thank you for pointing this out, we have corrected the sentence text.

- L708: 'Similarly, RS inversion algorithm does not consider' -> 'Similarly, RS inversion algorithms do not consider'

Updated the manuscript text accordingly.

- L710-711: 'In addition, PFT can be a very broad category' -> 'In addition, a PFT can be a very broad category'

This has been corrected in the text.

- L711-712: 'different tree species may have different characteristics, which is taken into account in our PFT-based modeling scheme and parameterization' -> 'different tree species may have different characteristics, which is not taken into account in our PFT-based modeling scheme and parameterization

An excellent remark, the sentence is now corrected.

- L738-739: 'However, this would be possible only if other TBMs to provide' -> 'However, this would be possible only if other TBMs were to provide'

We have implemented this suggestion in the manuscript text.

- L743: 'near-time' -> Do you mean 'near-real-time'?

Indeed, this was our intention. Fixed the sentence.

- L768: 'las access' -> 'last access'

Thanks, this is now corrected.

Supplementary material

- 'Table S2. Lanc cover' -> 'Table S2. Land cover'

Fixed this in the caption text.

- Table S5. chl_{leaf} (μg cm−2 -> chl_{leaf} (μg cm−2)

We have added the missing parentheses.

- Table S7: ("Qdef."-> ("Qdef.")

Similarly, we have added here the missing parentheses.

- Legend Figure S2: 'Subplot (h) has a different scale on the x- and y-axis than the other subplots' -> Why h and not b or e, where values also are not higher than 60 mg cm-2?
This was a good point. We have adjusted the subplot scaling, and updated the tick label coloring to have pink color indicating higher ranges. We have modified the caption in Figure S2 from:
"Subplot **(h)** has a different scale on the x- and y-axis than the other subplots." to
"Subplots **(a)**, **(c)**, **(g)** and **(i)** have a different scale on the x- and y-axis than the other subplots."