Answer to the Anonymous Referee #2

The reviewer comments are in bold, and the replies in regular font.

This manuscript describes a new model of biogeochemical and biogeophysical cycles. The motivation for the model is to build (from the bottom-up) a comprehensive model of these cycles that incorporates the latest ecophysiological understanding, rather than bolting new processes onto an old/existing TBM. This is an ambitious (and worthwhile) task, and the new model has some exciting aspects and functionality compared to the present generation of models. The authors highlight the major/novel advances in QUINCY as: source/sink dynamics enabled through fast and slow non-structural carbohydrate pools; including N and P limitation in initial model development; lagged responses to instantaneous variations in climate; explicitly resolved vertical soil processes affecting litter and soil organic matter; and novel diagnostics to enable model Evaluation.

We thank the reviewer for this assessment and for the recognition of this work's importance.

After reading the manuscript, I still have some questions about how the model performs, and the results section could better highlight these core processes and developments and their emergent behaviors in the model. I think the manuscript would benefit from re-organizing the results around these 5 themes. I'm sure each of these could warrant a whole study on their own, so I'm only suggesting some simple plots to exhibit the model behavior in these areas. This is already done for the nutrient limitation (although further displaying the process-level results mentioned on Page 11 Lines 13-16 would be informative) and an example using isotopes. It seems to fully document the model, the other major advances included in QUINCY should be illustrated. For example, when does down-regulation of photosynthesis due to sink-limitation occur (Also as mentioned in the SI Page 8 Line 9-12: under what conditions are severe C deficit likely to occur to down-regulate respiration?)? What is the impact of the temperature acclimation on photosynthesis and respiration (some plots of GPP and Ra vs average temperature)?

We thank the reviewer for these suggestions that will help to illustrate the characteristics of the model. We will add an example from a case study where the down-regulation of photosynthesis due to sink limitation occurs and demonstrate its magnitude and importance in the down-regulation to the next version of the manuscript. This takes place under nitrogen or phosphorus limitation. We also show a case study from a grassland site to demonstrate where C deficit is down-regulating respiration. To illustrate the impact of the temperature acclimation, we will add the figure the reviewer suggests. This figure will make use of the modular structure of QUINCY, allowing to easily change model hypothesis, and will show differences in simulation with and without the temperature acclimation in a GPP and Ra vs average temperature plot.

The re-organizing of the results section along the five mentioned topics seems challenging, because we do not have evaluation data for all the aspects mentioned by the reviewer. We therefore prefer to keep it this way, as it is currently organized by evaluation data source and we find this order logical and easy to follow.

However, we will revise the Results and Discussion sections of the manuscript taking into account these suggestions as well as the ones from Reviewer #3 to illustrate the effect of these topics on the behaviour of the model. These will also include demonstration of the lagged responses to instant climate variations. In order to show the importance of the vertically resolved soil processes, we make again use of the model's modularity and show the differences in the fluxes for a model version with and without vertically resolved soil layers.

Also I can see the benefit of the uncertainty analysis but it is hard to put these results into context when most of the variables or the parameter values shown in Figure 8 are not otherwise discussed in the text.

We will expand the discussion about the parameters, bringing them more clearly to the context of the different processes and also highlight what are the likely causes for these results. To further clarify the presentation of the results, we add color coding to the variable names which links them to certain processes and add the rank-transformed partial correlation coefficients to the table.

Specific Comments

Page 4, Line 26: Are the leaf chlorophyll and N concentrations updated variables in the model?

Yes, these are state variables. This is presented in the SI section 2.1. We will expand the model description in the new version of the manuscript and will also clarify this point in the main manuscript part, and not only in SI.

Page 8, Line 24-25: It's not clear to me how the short-term uptake is not affected, if the mid-day GPP values are lower with nutrient limitation? This is also mentioned on Page 11 Lines 16-17.

What is meant here, is that the short-term dynamics are not affected in these cases with the nutrient limitation, but there might be differences in the LAI for example, which would of course also affect GPP. We will clarify this further in the new version of the manuscript (to answer this point also to Reviewer #3).

Page 8, Line 25-26: Which experiments do these rˆ2 values refer to?

The r2 -values here refer to C and CN(P) experiment values (CN and CNP experiments have identical r2 values) and what improvements took place between these two. We will make this part of the text clearer.

Page 9, Lines 19-24: It's interesting that the P cycle is not having an impact on the tropical sites, as would be expected. What is the reason for this?

We have explained the causes for this in the discussion section, p. 11 l. 30-34. The reasons include efficient recycling of the P in the litter layer, as well as unknown initial soil concentration of plant available P and uncertainties in the rate of P weathering.

Table 2: This is a lot of information which is difficult for the reader to evaluate what it means in terms of model performance. I'm not sure it's all necessary to include here. Do each of these stocks and fluxes have corresponding representation in Figure 1? It could be possible to show these results graphically, reproducing Fig. 1 for each site but to add the observed values when they are available.

Taking into consideration also the comments from Reviewer #3 to this table, we will change it so that it will show the observed and modelled values for GPP, TER and leaf C:N -values for these sites. The reason to show the whole CNP budgets in this table was to highlight that the model is giving realistic and reasonable values for all parts of the nutrient cycles. However, now with the added plots that were suggested by the reviewers, we believe that this will be shown through those.

SI

Equation 1: Could you provide examples of where these lag effects occur later in the set of model equations?

These lag effects take place e.g. in labile pool dynamics and phenological processes. We will add examples to this part.

Equation 6: What is the reason for using Tair to model leaf photosynthesis instead of leaf or canopy temperature?

At the moment, QUINCY does not calculate leaf or canopy temperature in the model, but only the bulk surface temperature (as do other land surface model such as ORCHIDEE and JSBACH). We will separate the canopy and soil energy balance in a future version of the model.

Page 4 Line 8: Should this be "excessive soil moisture stress constraints"?

Yes, thank you, this will be corrected.

Equation 46: Is there an equation for S somewhere that I have missed?

We will clarify that S is updated according to this equation starting from a set initial value.