Response to anonymous referee # 1

The concept for this study is strong, using TLS to constrain forest structure and function in the ED2.2 model, follows a decade and a half's work on using remote sensing to constrain predictions made by ecosystem models (in reducing process and initialization errors). While this idea is worth publishing, the execution is not clear, the structure of the study needs improvement, and the actual constraining of the ED2.2 model is adequately done. Concerning this last point. Essentially you want to know how well your TLS-constrained ED2.2 simulations has fared compared to Ground-based-initialized ED2.2 simulations and compared to bare-ground simulations. To assess the improvement you need to compare all 3 of these simulations to observed data (like GPP, plot basal area changes, and/or growth and mortality dynamics). You need to do this for both TLS-structure and TLS allometric improvements.

We first would like to thank Reviewer #1 for their positive review of our work. We were pleased to see that he/she shares our opinion that TLS has strong potential to successfully constrain forest models and that such an idea is worth publishing In Geoscientific Model Development. After reading both reviews, we decided to reshape our study in order to improve the structure of the manuscript and enhance the execution of the research idea. The concepts, data, and methods will remain essentially the same but will be reshaped, used and presented in a different manner.

As highlighted by both reviewers, what we are interested in at the end of the day is (i) the sensitivity of the ED2 model to parameters and processes that can be constrained/defined via TLS-derived observations and (ii) how model simulations constrained to TLS data compared to ground-based initialized simulations, bare-ground model runs and independent observations. In order to investigate this, we propose to replace the current

set of analyses by an overall global sensitivity and variance decomposition analysis applied to different model configurations (default and TLS-informed). This new, large analysis will encompass the previous three analyses and extend them. For each model configuration, we will run large ensembles of the Ecosystem Demography model and decompose the total uncertainty into its components (initial conditions, model structure and model parameters). This will allow us to answer three types of research questions that were somehow already present in the previous version of the manuscript but only partly identified and answered. Those research questions are:

(i) What is the total model uncertainty of the ED2 model for the specific site that we try to mimic in silico? What are the contributions of the different sources of uncertainty? And how do they change along the simulation?

(ii) Is the total model uncertainty reduced when constraining the model with TLS observations? Do the primary sources of uncertainty remain the same?

(iii) Does the use of TLS data improve the model performance?

Model ensembles will be started from TLS-derived inventories (TLS-informed configuration) or from near bareground conditions/field inventories (default configuration). The importance of the model structure will be tested in the different configurations by changing the crown representation (finite or infinite) and the number of simulated PFTs (see below for details) while the impact of model parameters will be quantified by changing a larger set of parameters than just SLA and V_{cmax} as suggested by the second reviewer. We propose to include all parameters that were shown to drive a significant fraction of the model uncertainty in previous studies (see e.g. Dietze et al., 2014 and Shiklomanov et al., 2019) and not only the ones for which we have trait data available. In the TLS configuration, the allometric parameters will be constrained to TLS

data while the prior distributions of those parameters will remain uninformed in the default configuration.

Once achieved, those ensembles will directly serve to quantify the total model uncertainty and partition it into its components (initial conditions, model structure, and parameters). A simple comparison of TLS-informed *vs* default model configurations will allow us to estimate the benefits of TLS to reduce the total model uncertainty and how its drivers change when some processes and parameters are constrained by TLS data. Finally model outputs will be compared to the datasets previously used to calibrate some of the model configurations (eddy covariance fluxes, LAI and light observations). Doing so, we will now be able to compare the performance of the different configurations as well as some of their subsets (e.g. TLS-structure and TLS allometries).

There are many more comments in the text attachment below.

We thank reviewer #1 for this detailed review, which is very useful to correct all minor points. As we expect the manuscript to change significantly (as explained above), we do not provide here a detailed response for every single comment. Instead, below we only repeated and answered the comments that will remain relevant for the new version of the manuscript and the new analyses. Should some of those comments that we left open appear to be relevant during our revision, we will of course take the reviewer's suggestion into account.

<u>Detailed comments and response</u>

L25: "... at a temperate forest site" As it is a single site, isn't it meaningful to say what it is?

We will name the site (Wytham Woods Forest, UK) starting from the abstract

L27: "... productivity ..." gross primary productivity? net primary productivity? leaf area production?

The global sensitivity and variance decomposition analyses will be performed on several model outputs, including gross and net primary productivity, as well as the total leaf area.

L29: “the imposed openness” do you mean the gap fraction here?

By “imposed openness” we meant “the representation of the canopy (infinite or finite crown areas)”. That will be clarified in the new version.

L35-39: “We conclude … and reduce their overall uncertainties” Have you validated you new TLS-configured ED2.2 runs? Do you have tested reductions in uncertainty?

As explained above, validating the TLS-informed runs with independent datasets (including eddy-covariance data, basal area changes, etc.) is one of the objectives of the new analysis and will be presented in the new version of the manuscript.

L165-166: “All trees inventoried in Wytham Woods were classified as mid-successional temperate deciduous trees” Are you sure. Sycamore can be considered a shade-tolerant tree (late successional), maybe hazel. You need to go through each and every species to see which are early, mid and late successional species. Identifying them all as mid-successional needs a good explanation.

As the manuscript was initially seen as a simple sensitivity analysis of the ED2 model to the parameters and processes that could be constrained to TLS data, we wanted to simplify the analysis as much as possible and hence decided to simulate a single PFT. Incorporating more than one PFT would have made the whole analysis way more complicated to present, as well as for rendering the outputs to the readers. Yet, with the new global analysis that we foresee, it will be possible to take this complexity into account by simulating one or several PFTs. The tree species mapping to the model PFT will be achieved using trait data of SLA and wood density, the allometric relationships derived from TLS, as well as previous classifications from the literature.

L191: “i) near-bare ground initial conditions (i.e. seedlings only” Is this with Mid-Successional Hardwoods seedlings only?

In the previous runs, it was indeed with Mid-Successional Hardwoods only. In the new runs, it will be Mid-Successional Hardwood trees or a combination of several PFTs (see comment above).

L191-192: “the DBH distribution available through the field inventory” Why not just call this the 'ground-inventory initialization'? Up to you.

That is what we will call it in the revision.

L193-194: “that were allowed to fuse along the simulation” Unclear. Delete?

This will be deleted.

L194-195: “Simulations were run … dataset (Viovy 2018)” We need more information on the initializations. How long was the bare-ground simulation run for? How did you cycle the years of the met data? Which PFTs did you use? What soil data were used at the site? What is the resolution of your met data? What are the structural attributes of the ground vs TLS initial forests...i.e. Basal Area, DBH, LAI, TLS occlusion etc.

Those pieces of information will be provided in the new version of the manuscript.

L214-216: Can you have results for this analysis and comparisons to ground-inventories?

In the revised version, all near bare-ground runs will be compared to ground inventories as an independent validation.

L231: “Parameter data assimilation and model equifinality (Analysis III)” Rather than equifinality, this method appears to be about parameter optimization. Perhaps I am wrong.

Yes, you are correct. Yet analysis III will no longer be included in the new version of the manuscript.

L261-264: I can't find these numbers in the figures

Those numbers will be added in the new version of Figure 3.

L265-271: These results are not clear. It is assumed you are describing Figure 3, but numbers comparing TLS and ED2 are not clear.

Figure description will be improved in the new version.

L273-275: TLS and ground differences are important here and should not be in the supplement. Valuing the use of TLS in ED2.2 needs a rigorous comparison to ground-inventory data and initializations.

We will add a proper comparison of the TLS and ground inventory in the main text in the new version.

L277-278: Figure 6 has the IC- parameter optimization results!

This issue will be corrected.

L287: Start off making reference to the Figure you are about to explain

We will make sure we properly start off making references to the appropriate figures in the new version of the manuscript.

L304: It is still unclear why you are doing this step, and why you are not including the new optimized results in the sensitivity analysis (Figure 5). Also it seems counter-intuitive that IC-Default Vcmax value of 47.3 compared to 17.5 would not largely affect GPP!

The V_{cmax} definitely influenced the modelled GPP but the effect of the parameter was compensated by the reduction in SLA resulting from the optimization, which eventually led to similar GPP. In the new analyses we will no more perform optimizations but rather run a global sensitivity analysis and compare the (sub-)ensembles with the (now) independent eddy-covariance datasets.

Figure 7: Confusing figure. What this tells me is that the TLS and FC initial conditions are not that close, especially with the results in SLA. How useful is this optimization, and why do this

if you are not going to use it in the sensitivity (Figure 5), or in ultimately comparing the improvements of TLS vs ground-inventory initializations against carbon fluxes?

The optimization analysis will not be repeated in the new version of the manuscript.

Figure 7 (bis) What does this mean?/What is this dot?

The dots were the data from the TRY database. Yet, this figure is likely to disappear in the new version.

L355: There is no Table 5

We are sorry that Table 5 was missing in the manuscript. It disappeared somewhere in the submission process. We will make sure those data are available in the new version.

L359-365: It may be expected that better site level descriptions of BLeaf allometry will affect the LAI and GPP, and that better descriptions of Bdead will affect Woody biomass. Rather than sensitivity, what about overall improvement to LAI, GPP, Biomass??

That is going to be the goal of the new analysis according to your and reviewer #2' suggestions.

L379-380: Have you done model calibration effectively using TLS?

That is indeed what we did in the previous version of the study but we will not do this step in the next version as explained above.

L383-384: Not sure you have done showing the effective improvement in model performance.

We hope that the new analysis will allow us to conclude about the effectiveness of using TLS data to constrain the model uncertainty and improve model performance. Based on the model sensitivity and the results presented in this first version, we expect a strong reduction in uncertainty and a significant improvement of model performance thanks to the TLS data.

L397-398: From your results, this 'equifinality' issue could be demonstrated without TLS, just by optimizing using bareground and ground-inventory initializations. Furthermore, the usefulness or added value of this equifinality/optimization excercise is still not clear.

The optimization exercise will no longer be present in the new version of the manuscript and equifinality will definitely emerge from the large ensemble runs (especially in the default configuration).

L403-L404: You could use recurring forest inventories collected at your site as an additional calibration dataset

We did not use successive inventories from Wytham Woods in the first version of the manuscript but these data will be added as an additional validation dataset in the second version if we can get access to it.