

Response to reviewer comment RC2 for

“Leveraging leaf-level optimality processes with explicit acclimation improves global GPP representation in an individual-based DGVM (LPJ-GUESS v4.1.1)”

M. Forrest et al., egusphere-2026-3273 (under review for GMD)

We thank the reviewer for taking the time to review our manuscript. The comments are copied verbatim below, our responses are in blue, suggested revision to the text are in green.

The authors applied an eco-evolutionary optimality (EEO) approach for calculation of assimilation rates in the LPJ-GUESS DGVM. Additionally, an acclimation process was implemented. This alternative approach has two major advantages: It saves computation time and gives better agreement between observed and modelled GPP. They used for LPJ-GUESS mode in individual mode and see an improvement in model performance and better agreement with observational data. In general, the paper is well written and structured and fits into the scop of the journal.

The model is run with modelling individual trees. it might be interesting to see the performance in run time and quality of the average individual model mode. This mode is significantly faster and is best suited for coupling to Earth system models. `The authors state, however, that acclimation must be calculated on an individual level. A short discussion how this approach can be applied to average individual models should be added.

Yes, we didn't consider the “population mode” (so named because one average individual represents the whole population in a gridcell). This mode is now very rarely used, even coupled configurations use the cohort mode (confirmed for EC-Earth, RCA-GUESS, EMAC-GUESS, LPJ-GUESS-LSM). The logic is that although cohort mode is computationally heavier, it is still a very small fraction of compute time compared to a full atmospheric simulation and so worth including for the added realism. Furthermore, all model development and tuning is done with cohort mode and the mostly recently integrated fire model, SIMFIRE-BLAZE, doesn't run in population mode.

To satisfy the reviewers curiosity we did run the model in population mode (with the GlobFIRM fire model). It indeed very much faster, around 10x (from a little over 5 hours on 384 AMD 7763 CPU to only 30 mins). Global GPP increased modestly 143 PgC/year in the EEO configuration but to a rather large 196 PgC/year in Standard config. Interestingly the spatial NME was unchanged for the EEO config (0.41) but was very much worse for the standard configuration (0.65). This is actually pretty interesting and useful. Based on this, we propose to add the following text on how the approach might be applied to average individual models.

“Although LPJ-GUESS's “population mode” (which uses a single average individual per PFT instead of the full cohort structure) is now very rarely used and has not been developed for

quite some time, we tested it with EEO configuration to give some indication of how the EEO formulations might work with average-individual type models. The global total GPP increased moderately to 143 PgC/year and the spatial NME remained unchanged at 0.41 (data not shown). This rather good performance indicated that the EEO approach works well with an average individual representation, which is perhaps to be expected as the EEO formulations were mostly developed and tested at the ecosystem, as opposed to individual plant, level.”

The authors compare the LPJ-GUESS model with EEO photosynthesis and acclimation to the unchanged model. It would be interesting to see the impact of different acclimation times on the model performance to see how important the addition of acclimation is.

Yes, that could be interesting to see how time plays out in the DGVM. However, such an exercise would be confounded by other model processes and errors, such as errors in phenology and soil moisture, and would thus be rather specific to LPJ-GUESS. The cleaner studies and more broadly useful studies are the (Mengoli et al. 2022) and (Ren et al. 2024) papers, especially as they use higher quality site data, and we don’t feel we would be able to usefully add to those results.

More specific remarks:

Line 292: Soil moisture is denoted as Theta, identical to the co-limitation parameter Theta in Table 1.

Ah, yes, that is inconvenient. The original sources both use Theta and we would like to be consistent with both. We propose to add change the “(θ)” on line 292 to:

“(θ , distinct from the parameter in Table 1)”

Line 279: One question. Does this correspond to the original photosynthesis model setting the co-limitation factor $\Theta=1$? Are there any justification to assume this?

Essentially yes, but they apply at different time scales and for slightly different purposes. The colimitation factor Θ is applied to daily or monthly average rates. The minimum at line 279 applies to the instantaneous rates (although these do happen to be daily average rates in this case). The P-model avoids the need for a Θ by using the Coordination Hypothesis, which is well supported (Maire et al. 2012) and essentially assumes that the two rates are equal under typical growth conditions. The (Mengoli et al. 2022) approach goes further and assumes the rates are equal specifically under midday conditions and separates the acclimation timescale from the instantaneous timescale. The minimum term is then applied as instantaneous conditions *deviate* from the midday conditions. In contrast, the Θ is used to co-limit using the two average rates under average conditions without invoking the Coordination Hypothesis.

Please add unit of GPP and R_d in the figure captions.

Yes, done.

The authors use 500 yrs of spin up of the model. The carbon and nitrogen pool should be in equilibrium after the spin up period. It might be in particular for the boreal and polar regions that the pools are in disequilibrium because of the low temperatures leading to very low decomposition rates. This might not be important for evaluation of GPP values but for soil pools it is important. Also nitrogen limitation might change.

Ah yes, we didn't mention in the description that LPJ-GUESS has a soil pool extrapolation functionality which acts during spinup and uses 200 years of modelled fluxes to extrapolate C and N pools for 40,000 years to a long term equilibrium specifically to address this. We propose to remedy this by adding the following the end of section 2.5:

"Following standard LPJ-GUESS protocol, soil C and N pools were extrapolated to an estimate of their long-term equilibrium using 200 years of modelled fluxes recorded during spin up."

The author claims that an error in the fAPAR values propagate directly to the GPP value due to its linear relationship. The fAPAR dynamics is also affected by the phenology. LPJ-GUESS has an annual update of the carbon pools distributing the assimilated carbon to all vegetation carbon pools. The phenology function determines the intra-annual the intra-annual variability of leaf carbon changing the fAPAR value. A discussion should be added.

Yes, we were a little brief on the fAPAR and phenology discussion, although we do mention the role of phenology at line 574. We proposed to add additional text discussing the role of fAPAR and phenology at line 626 in the discussion:

"Dynamics of fAPAR are controlled by LAI in LPJ-GUESS and LAI in turn has two controls; the allometry scheme, which determines the carbon allocated to leaves and therefore seasonal maximum leaf area, and the phenology scheme, which determines how leaf area responds to soil moisture and temperature. Both of these could be targeted to improve LAI and consequently fAPAR and GPP. Recent EEO theory about the controls on LAI (Zhou et al., 2025) may prove informative for both aspects."

The authors claim to have a faster model using the EEO approach. Please give some numbers for a typical configuration on an HPC cluster.

Happily. We propose to modify the text at line 683 to:

"Model runtime was reduced by ~23% for the global simulations presented here, from 7 h for the standard simulation to 5 h 22 min for the EEO simulation on 384 AMD 7763 CPU cores."

15 patches are normally considered sufficient for LPJ-GUESS, so the 30 patch simulations used here are computationally heavier than strictly-speaking necessary.

References

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