Review “A general physiologically driven representation of leaf turnover in grasslands in the QUINCY land surface model (revision: 974a6b7f)”

General remarks

The manuscript presents the land-surface model QUINCY for the grassland model. It extends the dynamic leaf-turnover formulation for herbaceous vegetation in the QUINCY land surface model. The manuscript indicated that the proposed formulation improves model performance at several sites, particularly in seasonally dry and cold environments. This work is promising and has the potential to enhance ecosystem and climate simulations, but major substantial revisions are required before the manuscript is suitable for publication and it requires a thorough language check (e.g. improvements in clarity, structure, and language are needed). The Discussion section would benefit from revision after the major comments have been addressed.

I hope that the specific comments below help to improve the quality of the manuscript.

Major comments

1. The manuscript introduces an advanced consideration of dynamic leaf turnover in the QUINCY model. However, the explanation for why they chose QUINCY over other land surface models is missing in the introduction. Moreover, the additional explanation of how reliable QUINCY has been evaluated in previous studies (e.g., detailed photosynthesis mechanisms, carbon-nitrogen cycle) is important to align with the manuscript's aim.
2. The authors tested the model by using broad climate variability for grassland and relied mainly on environmental drivers. However, the authors stated that they don’t consider plant functional type (PFT; C3 or C4 grass), but instead use a more generalised model. Or do authors consider different PFT? If yes, please explain it more clearly in the methods and show it in the results. If authors don’t consider PFT and want to use general physiology for the grassland, it is not clearly justified why a generalized and PFT-independent approach is adequate to represent the autumn phenology. Additional information on the discrepancy between site-level and PFT-level performance will be more convincing.
3. The term “dynamic turnover” is central to the manuscript but is not clearly defined in terms of the plant mechanism. Please provide a concise definition of “dynamic” in this context, explain how the turnover rate responds to environmental drivers, and explain how this formulation differs from the default approach. Please specify the terms “dynamic turnover” and “senescence” for more precision. Is it only leaves or other parts too? In addition, the term “autumn phenology” also needs similar explanation. Please give a brief explanation about both the first time they appears, and the underlying mechanism could be included in the Methods section.
4. Eq. A1–A4: The description of the growing season is a central component of the model, it would be helpful to include a brief explanation of the equations in the main text rather than relying on the Appendix. Eq. (A1) is missing the GDD calculation. Eq. (A2) is missing

the explanation of β_{soil}^{flush}, $\beta_{soil_{\tau_{pheno}}}^{gs}$ in the body text and then refer to Table 1. What is the meaning of this paramater "$\beta_{soil_{\tau_{pheno}}}^{gs}$"? Please simplify the formulation by separating variables and dependencies. For example, $\beta_{gs,soil}(\tau_{pheno})$ would be clearer than $\beta_{soil_{\tau_{pheno}}}^{gs}$ and also for $\beta_{soil,flush}$. Eq. (A3) is introduced without sufficient explanation of its underlying assumptions or rationale. Please clarify the origin and logic of these formulations. The abbreviation "sen" is used for the end of the growing season, but it is not clearly introduced and may not be immediately intuitive. Please define it at first use and consider using a more explicit or consistent notation (for example: EOS).

5. L118: Please provide an explanation of the mechanism by which carbon allocation to roots increases under water and/or nutrient limitation, or provide a reference supporting this assumption.
6. Eq. (1) – (7) is incomplete. Mathematical formulation of the end of season and dynamic turnover model are crucial in the model itself. The manuscript does not clearly explain the origin of the assumptions underlying the dynamic turnover formulation. Please provide the information of each equation about whether the formula is derived from previous studies, default setting or calibration choices?
7. Eq. (11) needs further justification. Its mathematical or conceptual basis is not evident in the manuscript, please explain the function is based on what assumption and mechanism. Please also provide the definition of f_{turn}^{temp} and so on (also for moisture and light effect) after the equation and refer that this parameter is coming from Eq. (7), (8), and (9). What is the time step used in this equation?
8. While the manuscript focuses on GPP and EOS, the implications for net primary production (NPP) remain unclear because respiration is not evaluated. Therefore, it is unclear whether the proposed phenology formulation improves net biomass production rather than only gross carbon uptake. If such outputs are available, including NPP or respiration, they would strengthen the ecological interpretation of the model's changes across different ecosystems. If not, this limitation should be acknowledged more explicitly.
9. L129: The authors explained soil temperature and moisture simulated in the model in a brief way, but it is insufficiently detailed on how this variable is simulated affecting the GPP or EOS. It is recommended to specify the equations/models and assumptions, such as heat diffusion or soil water transport, and to provide relevant references to ensure reproducibility.
10. L182: The authors also mention soil water content (SWC). Please provide the explanation of the equations/models and the assumptions used. Does it consider the irrigation condition or assume all grassland is rainfed-based?
11. Eq. (7) is incomplete. Was leaf water potential also simulated in this study? Please explain the equations/models used with citation (if using parameters from other studies).

12. Eq. (9) is incomplete, what kind of rate of change? The explanation in L215 is insufficient where authors can specify the variable and its unit. Please write the unit every time introducing a parameter/variable. Authors may change the 'rate of change' with mathematical symbol with subscript 'i-1' or 't-1' to indicate the time. Please also be clear about the time step (hourly or daily).
13. L238-L250: The naming of sites (e.g., ES-LMa, CGE, US-Tol, IE-Dri) is not clearly explained and appears inconsistent. Please provide a clear description of the naming convention (for example: the three acronyms of the country + the soil-weather condition).
14. Figure 1: It would be helpful if the authors could provide more explanation for the assumed relationship between temperature, soil moisture, and light with the leaf turnover and provide the reference of this assumption (whether it was calibrated in this study or citing other study/mechanism). The term 'temperature response' might be slightly ambiguous, a more explicit phrase such as 'leaf turnover response to temperature' would improve clarity (also for moisture response and light response). The caption of Figure 1 for right bottom figure also needs to be explain into separated figures (d) and to state clearly that the full-range plot is shown alongside the zoomed-in plot for comparison.
15. Table 5 and 6: Please clarify why the dynamic model shows improvement at the site level (Table 6), but not at the climate level (Table 5). Are the results in Table 5 derived from site-level data (Table 6)? If yes, this suggests that the model performance is inconsistent across sites, and improvements may not be robust when aggregated. Please clarify the reason for this discrepancy and what it implies about the robustness of the proposed model in the discussion.

Minor comments

1. Title: what is 'revision: 974a6b7f'? Please explain or refer to the reference version.
2. L73: Please briefly explain the meaning of End of Season Date (EOS) and the impact of simulating EOS in this study.
3. L77 and L265: The authors mentioned Green Chromatic Coordinate (GCC), but they failed to further explain the meaning of the number, its relevance, and how to calculate this index. This explanation could also be included in the method section. It would be beneficial for the authors to elaborate further on the advantages of comparing GCC, as this is a particular strength of this study.
4. L83 and L131: It is not clear whether the permafrost freeze-thaw is also included in this study or only in the QUINCY default? This is particularly relevant for colder sites, where soil freezing can affect water availability and plant stress. Please clarify how these processes are handled and whether they may influence the results, specifically in cold sites.

5. L86: Please clarify why this study does not consider the phosphorus availability. Since QUINCY by Thum et al. (2019) included the phosphorus processes, it is unclear whether phosphorus is assumed to play a limited role in autumn phenology or is implicitly represented through other mechanisms. A brief justification would improve the clarity.
6. L87-L88: Please refer to which version of QUINCY has the 14 PFT and briefly explain what the term 'labile' means in the first time it appears.
7. L89: Authors may remove the 'second' as the authors have not introduced the first one. Please either define both pools or revise to "non-structural long-term reserve pool".
8. L97: "$k_{reserve}^{target}$" is used only once in the Table 1. There is no need to shorten this parameter unless the authors need to define it in the equation. Please define this parameter and explain its implications for the model. Moreover, the definition of $k_{reserve}^{target}$ in Table 1 "Fraction of annual leaf + fine root biomass that is the target size of the long-term reserve pool" is unclear, which one is the numerator and which is the denominator?
9. L122-123: Please consider combining this sentence about the litter into the fine roots in the previous paragraph.
10. L124: Please specify the 15 layers of thickness in which depth of soil.
11. L134: The "low, constant rate (1/Tleaf) to simulate a basic level of herbivory" is ambigious. Do the authors mean a loss rate? And please specify the definition and value.
12. L135: Please define T_{air}^{sen} when it first appears.
13. L150: Please define $f_{shed,max}$ in the first time it appears in Eq. (5)
14. L175: Please define the difference between λ_{temp} and k_{temp} and the supporting reference.
15. L195: Please separate the sentence about how to calculate day length into a new paragraph, as it no longer relates to the previous topic where the authors were talking about the reason for considering day length (in the previous sentences).
16. L198: What is 15 h? Please write in the first occurrence.
17. L230: It will be helpful if authors added a new parameter/threshold in this study (for example: the snow depth threshold for the end of growing season) into Table 1, so it will be clear what this study improves compared to the previous version.
18. L254: Please briefly explain what FLUXNET2015 is and cite the reference. Current manuscript has no supporting reference.
19. L255-257: Please also specify the annual GPP is calculated from which year to which year? Or is it only for one year?
20. L281: Add 'flux' after EC to maintain consistency when the term first introduced.
21. L285 and Figure B3: Which method is Kong et al. (2029, 2022). Derivative (DER) is only mentioned once in the paragraphs. It would be better to use the acronym when mentioning DER and other thresholds in Figure B3. Figure B3 shows some value, is it the

Day of Year of the EOS? It may be clearer to present these results in a table to show how this study improves EOS relative to the EC flux calculation.

22. L317: How do you conclude that the dynamic runover model improves responses of grasses to the environmental conditions in the first sentence? It would be better to conclude after showing the evidence of the result. In addition, please mention quantitative values in L320-321 about GPP to support the statement, so that the improvement can be clearly evaluated.
23. Figure 2f: Why is the standard deviation of LAI dynamic turnover (shown in orange shade) really large compared to the default model?
24. Figure 6: Please explain the acronym meanings of each column title and use consistent acronym.
25. L446: Please indicate the specific values of EOS in US-Tol (or refer to which figure/table) that show the improvement of the model.
26. L455: Do authors mean Fig. 2f instead of Fig. 2? The onset of senescence prediction is not shown in other sites in Fig. 2.
27. L476: Change “apriori” to “a priori” and please define what the three triggers.