Geoscientific Model Development Discussions

Geosci. Model Dev. Discuss., referee comment RC2
https://doi.org/10.5194/gmd-2022-126-RC2, 2022

Comment on gmd-2022-126

Anonymous Referee #2

Referee comment on "Accelerated photosynthesis routine in LPJmL4" by Jenny Niebsch et al., Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2022-126-RC2, 2022

General comments:

This manuscript describes an implementation of Newton's method to speed up the computation of the solution to the photosynthesis scheme in the LPJ DGVM. This topic is generally appropriate for a report in Geoscientific Model Development, but as currently written the manuscript is likely to be relatively low impact. Primary concerns are: (1) the application of Newton's method to this problem while logical is not novel; (2) while it speeds the solution, the marginal improvement is modest (only on the order of ~16%); (3) the focus on the acceleration of the photosynthesis scheme overlooks substantial underlying problems with calibration and evaluation of this scheme. To increase the impact of this manuscript, I would suggest: (a) including a concise review of the numeric methods used to implement the Farquhar-Collatz style photosynthesis schemes in land surface models; (b) better contextualizing the importance of computational efficiency relative to other priorities for the development of the photosynthesis scheme; (c) condensing the figures down to one or two key visuals, summarizing the magnitude of the impact of Newton's method.

Specific comments:

Line 30, The current text should be updated to accurately describe the pathway that the Farquhar-style model took into large-scale applications. The Farquhar et al. (1980) photosynthesis model was originally coupled to a stomatal model by Collatz et al. (1991; 1992). The coupled photosynthesis-conductance scheme was then integrated into the Simple Biosphere Model developed by Sellers et al. (1992; 1996a, b, c, d). These initial applications were then built on by Haxeltine and Prentince.

Farquhar, G.D., von Caemmerer, S.V. and Berry, J.A., 1980. A biochemical model of photosynthetic CO2 assimilation in leaves of C3 species. Planta, 149(1), pp.78-90.

Collatz, G.J., Ball, J.T., Grivet, C. and Berry, J.A., 1991. Physiological and environmental regulation of stomatal conductance, photosynthesis and transpiration: a model that includes a laminar boundary layer. Agricultural and Forest meteorology, 54(2-4), pp.107-136.

Collatz, G.J., Ribas-Carbo, M. and Berry, J.A., 1992. Coupled photosynthesis-stomatal conductance model for leaves of C4 plants. Functional Plant Biology, 19(5), pp.519-538.

Sellers, P.J., Berry, J.A., Collatz, G.J., Field, C.B. and Hall, F.G., 1992. Canopy reflectance, photosynthesis, and transpiration. III. A reanalysis using improved leaf models and a new canopy integration scheme. Remote sensing of environment, 42(3), pp.187-216.

Sellers, P.J., Randall, D.A., Collatz, G.J., Berry, J.A., Field, C.B., Dazlich, D.A., Zhang, C., Collelo, G.D. and Bounoua, L., 1996. A revised land surface parameterization (SiB2) for atmospheric GCMs. Part I: Model formulation. Journal of climate, 9(4), pp.676-705.

Sellers, P.J., Tucker, C.J., Collatz, G.J., Los, S.O., Justice, C.O., Dazlich, D.A. and Randall, D.A., 1996. A revised land surface parameterization (SiB2) for atmospheric GCMs. Part II: The generation of global fields of terrestrial biophysical parameters from satellite data. Journal of climate, 9(4), pp.706-737.

Randall, D.A., Dazlich, D.A., Zhang, C., Denning, A.S., Sellers, P.J., Tucker, C.J., Bounoua, L., Berry, J.A., Collatz, G.J., Field, C.B. and Los, S.O., 1996. A revised land surface parameterization (SiB2) for GCMs. Part III: the greening of the Colorado State University general circulation model. Journal of Climate, 9(4), pp.738-763.

Lines 37-38, I recognize that some of this will be presented later, but it would help to set up the manuscript to summarize the runtime analysis here and state what fraction of the total time was originally required by the photosynthesis routine.

Lines 42-45, Suggest to review and summarize here the literature on the numeric methods that have been used to implement the Farquhar-Collatz style photosynthesis schemes within land surface models. Newton's method has been implemented in many different modeling frameworks to solve the coupled photosynthesis-conductance-energy balance schemes, but I am not aware of a review that provides a concise overview of these applications.

Lines 99-129, Section is difficult to follow without having the mathematical symbols defined at first use and the flow of the equations explained in narrative form. To improve readability, suggest defining each mathematical symbol in text at first use and also explaining what each equation represents in physical terms rather than just presenting the mathematical derivation.

Lines 174-184, The argument developed here is a bit confusing. The lack of an impact of Newton’s method on modeled pools and fluxes does not imply anything about the accuracy of the pool/flux calculations. The “accuracy of the photosynthesis scheme” must be defined relative to skill at explaining observations. Recent work by Walker et al. (2021) has highlighted the challenges in rigorously confronting the Farquhar-Collatz style schemes with observations due to the empirical coefficients that have been used as tuning knobs. One path forward is updating the current Farquhar-Collatz schemes with the Johnson and Berry (2021) scheme which eliminates empirical coefficients, reduces the total number of free variables, and permits calculation of both gas-exchange and chlorophyll fluorescence.

Walker, A.P., Johnson, A.L., Rogers, A., Anderson, J., Bridges, R.A., Fisher, R.A., Lu, D., Ricciuto, D.M., Serbin, S.P. and Ye, M., 2021. Multiâ□□hypothesis comparison of Farquhar and Collatz photosynthesis models reveals the unexpected influence of empirical assumptions at leaf and global scales. Global change biology, 27(4), pp.804-822.

Johnson, J.E. and Berry, J.A., 2021. The role of cytochrome b6f in the control of steady-state photosynthesis: a conceptual and quantitative model. Photosynthesis Research, 148(3), pp.101-136.

Figures D1-D12, The current figures simply summarize differences in model output across a variety of metrics; they add relatively little to the impact of the paper and it would be useful to distill them down to a smaller number of key visuals.

Technical corrections:

Line 38, ‘fracture’ should probably be ‘fraction’