Geosci. Model Dev. Discuss., 7, C1164–C1173, 2014
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Geoscientific Model Development Discussions
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Interactive comment on "A model using marginal efficiency of investment to analyse carbon and nitrogen interactions in terrestrial ecosystems (ACONITE Version 1)" *by* R. Q. Thomas and M. Williams

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We thank the Anonymous referee for comments that have improved the quality of the manuscript

Comment: In this manuscript the authors present a new model (ACONITE) to analyse terrestrial carbon and nitrogen interactions, that uses theory on plant economy and optimisation. The paper is generally well-written, includes a full code description in the supplement, and stands out with its novel approach. I really appreciate the use of a simple model, which requires a relatively small number of parameters and inputs. This combination makes ACONITE easy to apply, and of great benefit to the modelling community. Developing a new model is always a tremendous amount of work, especially when building on novel concepts, as is the case here. The latter requires a careful introduction and description of the involved processes, in which I think the authors are successful. But high information density plus complex sentence structures, in combination with the enormous amount of equations and tables, makes the first half of the paper a bit of a 'tough read'. Contrastingly, the results and discussion are presented in a clear and concise manner. I think the manuscript could be improved in readability by breaking down the larger and complex sentences into shorter ones (examples in specific comments).

Response: We have substantially edited Section 2.1 in the manuscript to improve readability. All the changes cannot be listed here. As suggested, we have used shorter sentences, and added some clarification in parts.

Comment: Also, many difficult words are used that could easily be replaced by more common ones.

Response: We have replaced difficult words with more common ones. For example "amortized" has been replaced with "time-integrated"

Comment: But section 2.1 of the manuscript suffers from (many!) missing parameter descriptions and appropriate references to tables and equations. I suggest a careful check of all parameters, equations, in-text references and corresponding tables (see specific and technical comments for details).

Response: We have checked parameters and adjusted equations accordingly. Also, we have reordered the parameter tables alphabetically so that parameters are easier to find

Comment: p. 2526, l. 8-13: This is a very long and complex sentence explaining the

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theory be- hind ACONITE. I strongly suggest breaking this up in smaller fragments to improve readability. The final part of the sentence is complex, with terms as “emergent constraints” and “marginal returns”. Why not use a description more like based on the text in the introduction (p. 2528, l. 6-20) which I find much more comprehensive.

Response: We changed the sentence to be clearer based on the comment. The new sentence is: “Here we describe a new, simple model of ecosystem C-N cycling and interactions (ACONITE), that builds on theory related to plant economics in order to predict key ecosystem properties (leaf area index, leaf C:N, N fixation, and plant C use efficiency) based on the outcome of assessments of the marginal change in net C or N uptake associated with a change in allocation of C or N to plant tissues”

Comment: p. 2526, l. 24: The non-linear relationship performed better how, did it perform better in describing leaf C:N, and compared to what?

Response: We changed the sentence to define that the non-linear relations performed better at simulating leaf C:N, compared to the trait database, than the linear relationship. The sentence now states: “Also, a widely used linear leaf N-respiration relationship did not yield a realistic leaf C:N, while a more recently reported non-linear relationship simulated leaf C:N that compared better to observations”.

Comment: p. 2527, l. 1: what sort of challenges do we face in ecosystem earth system models, and how do the constrained LAI and variable leaf C:N ratios in ACONITE help to address these challenges?

Response: We modified the sentence to define the challenges as simulating LAI and leaf C:N ratios in models. The sentence now states: “Overall, our ability to constrain leaf area index and have spatially and temporally variable leaf C:N can help address challenges simulating these properties in ecosystem and Earth System models”

Comment: p. 2528, l. 15-18: And a recent addition by Smith et al. (2014). doi:10.5194/bg-11- 2027-2014

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Response: This citation has been added

Comment: p. 2532, eq. 1: parameter store_propC is set to 1%, what is the rationale/reference for this value? E.g. Zaehle and Friend (2010) have set the maximum size of the storage pool to be almost ten times larger and made this term PFT-specific, based on Friend et al 1997. In their approach, the maximum pool sizes are based on data, with evergreen PFTs having a lower maximum storage pool size than deciduous trees because the fraction of live sapwood is smaller.

Response: From Zaehle and Friend (2010) Supplementary Material: "The Clabile pool is assumed to be distributed throughout the living plant tissue (foliage, roots, and sapwood) and, if C is not limiting, is limited to a maximum of 1% of the living plant tissue mass, or 10x current daily GPP (Clabile_max)". We choose to set store_propC to be 1% so that it is similar in magnitude to Zaehle and Fiend (2010). Since ACONITE does not separate sapwood from dead wood we use total wood plus root C rather than leaf C plus root C plus sapwood C to define the pool size. Based on table 8, the steady-state properties of ACONITE (the focus of this manuscript) are not strongly sensitive to the store_propC parameter (a 10% increase in the parameter alters LAI and NPP by 5% or less). We agree with the reviewer that store_propC parameter will be an important area of future model development and comparison to observations, particularly non-structural carbohydrate observations.

Comment: p. 2532, l. 8: Is this leaf or atmospheric temperature? In the latter case, I do not agree with this statement. Plants - needleleaf evergreens in particular - are known to continue photosynthesis at atmospheric temperatures up to -10 (-7) âŮęC in temperate (boreal) regions, e.g. see Linder and Troeng (1980); Suni et al (2003); Sevanto et al. (2006). Photosynthesis shuts down only after a prolonged period of freezing temperatures.

Response: We agree that there is not an absolute air temperature threshold for photosynthesis to cease. We do know that frozen soils restrict water uptake- Linder and

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Interactive Comment

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Comment: This paper tried to propose a new C/N model that based on the carbon return with nitrogen investment. The C/N coupling is an active research area and this paper fills a nice gap by provide an advanced optimization approach that well predicted the C:N ratio. While the paper is well written, I do have a few important concerns. First, the author seems omitted an important earlier publication on this area [Fisher, J. B., S.

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Sitch, Y. Malhi, et al(2010), Carbon cost of plant nitrogen acquisition: A mechanistic, globally applicable model of plant nitrogen uptake, retranslocation, and fixation, Global Biogeochem. Cycles, 24, GB1014]. What is difference between author's research compared to Fisher's research is not clear to me.

Response: We agree that not including discussion of Fisher et al. 2010 was an important oversight.

The primary difference between the FUN model in Fisher et al. 2010 is two-fold: 1) ACONITE is a full ecosystem model that mechanistically calculates NPP, along with LAI and foliar C:N, while FUN uses a specified potential NPP (i.e., NPP without nitrogen limitation) and calculates how this NPP is allocated to additional respiration for the uptake of nitrogen, 2) ACONITE only allocates excess respiration (i.e., respiration beyond growth and maintenance respiration) to N fixation while FUN uses the costs of N acquisition to determine the allocation of respiration to the retranslocation of foliar N, active N uptake, and N fixation. ACONITE and FUN are complementary and can help inform each other. For example, ACONITE demonstrates how to calculate the N return on allocation to root construction. FUN demonstrates how to calculate N return on allocation to root respiration. Future research could potentially combine the two approaches to build a model that mechanistically predicts LAI and leaf C:N based on ACONITE and the allocation of respiration to N uptake based on FUN.

We have now added the following paragraph to the discussion:

"In the current version of ACONITE, the respiration of excess labile C is used for N fixation when N is limiting. Future model extensions can more mechanistically allocate this respired C to different forms of N, based on the uptake cost of each form. For example, the Fixation and Uptake of Nitrogen (FUN) model provides an example how to allocate C respiration to N uptake based on the comparison costs of N of fixation, active N uptake from inorganic forms in the soil, and retranslocation (Fisher et al., 2010). The FUN model could be further expanded to include marginal returns N on C

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allocation to soil microbes (soil priming) or mycorrhizal allocation. Combining elements of ACONITE and FUN would allow for more mechanistic predictions of both LAI and leaf C:N from ACONITE and the allocation of respiration to N uptake from FUN."

Comment: Second, for the methodology section, it is very dense with equations. Because most of the equation comes from ACM model, it will be difficult for the readers to identify what is the new components proposed by this paper. I would suggest that the author move the description of ACM model into appendix and derive a general description of the ACONITE. This will help the reader easier to follow and also make it easier to implemented ACONITE in other models.

Response: We appreciate the need to improve the readability of the model description section and have included edits throughout in response to this comment and the comments provided by reviewer 1.

We included the ACM model in the main text for two reasons: 1) our goal was to include all equations in the text so that a model user could find all equations in a single location and 2) there was a modification to the ACM model in ACONITE that is important to clearly describe. We believe this rationale warrants the inclusion of ACM in the main text.

Comment: Finally, it is not clearly to me how the authors designed their numerical experiment for model evaluation. One paragraph describing that will be helpful.

Response: We modified the description of the model simulations to more clearly define the numerical experiment. The paragraphs now state:

"Next, using the full ACONITE model, we performed three numerical experiments to analyse the qualitative functioning of the model using two different sets of climate forcing, one tropical and one temperate. For the temperate forcing, two separate simulations were performed using a deciduous forest (leaf lifespan <1 year) and evergreen forest (leaf life span > 1 year). The model was run to steady state using a 2000 year

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simulation that cycled through climate data from Harvard Forest (Munger and Wofsy, 1999), at 42.5°N, 72.0°W. Steady state was evaluated by testing the stationarity of Csoil, the longest residence time pool. The tropical simulation paralleled the temperate simulation with tropical tree parameters and climate data from Manaus (Kruijt et al., 2004) at 2.6°N, 60.2 °W.

The three simulations evaluated the model capacity to resolve seasonality in climate and phenology. We examined the annual GPP, annual carbon use efficiency (CUE; ratio of NPP to GPP), foliar C:N, maximum annual LAI and compared to representative ecosystem data. Intra-annual patterns in LAI, GPP, net primary production (NPP), leaf C allocation, wood C allocation, and root C allocation at steady-state for the temperate deciduous and tropical forests are described in the supplemental material (Figure S2)."

Interactive comment on Geosci. Model Dev. Discuss., 7, 2525, 2014.