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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 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

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

Troeng (1980) note that “as soon as soil temperature increased above 0°C the supply of water was sufficient” to maintain photosynthesis. We rely on simple met drivers, and use air temperature as a proxy for soil temperature. Our use of daily minimum temperature is reasonably conservative - Linder and Troeng (1980) note that it took time “to reestablish full photosynthetic capacity after the damage. . ..caused by low temperatures”. While our rule is crude, it does produce reasonable annual productivities for the evergreen temperate forest simulations. We have adjusted the text to note this caveat:

“This function is required because photosynthesis relies on a water supply from soil that is restricted when soil moisture is frozen, and also because photosynthetic apparatus is damaged by freezing conditions (Linder and Troeng 1980). We use an air temperature threshold for simplicity, but acknowledge that soil temperature would provide a more reliable forcing.”

Comment: p. 2532, l. 11-15: Please be clear on the definition of photosynthesis. It is first defined as GPP (previous page, line 6), and set as a values between 0 and G*Xc (eq 2) which is fine. Then, photosynthesis is said to be “G” in eq. 4, which is ok when one is familiar with the Farquhar type of models, but might confuse other readers.

Response: We now define GPP as the photosynthesis after down-regulation by freezing temperatures and labile C saturation. We replaced G in eq. 4 with GPP* to more clearly define it as the photosynthesis before down-regulation.

Comment: p. 2533, l. 2: to which temperature is Itemp related: soil, atmospheric? Also please refer to equation 19, because I went looking for a definition in Table 4.

Response: Based on the comment, we changed the text to state “adjusted by average daily air temperature (Ta, °C)" (Itemp; see Equation 19)”

Comment: p. 2536, l. 1: Why is the maximum daily growth potential set to 0.07? I wonder what the rationale is for using only 7% of the labile C for growth each day, can you provide a reference? In case this is a ‘tuning parameter’, this should be made clear

to the reader.

Response: We added the following text to the parameter justification column in table 5: “Approximates a 2-week turnover time for labile pools; a balance between buffering the labile pools and allowing for responsive growth at realistic time scales”

Comment: p. 2537, l. 23: Only here the authors mention that Cstore is a variable in itself and refer to eq. 42. Why not do so when the parameter is first introduced, in section 2.1.2? Also, qeuation 1 equals equation 42? Please explain the difference, or remove one of the two.

Response: This was a duplicated equation. We removed the equation for defining the maximum store of C and now reference equation 1.

Comment: p. 2539, l. 9: what scalar is applied here? It is not directly clear from equation 33 below.

Response: The scalar is the 86400 in the equation (the number of seconds in day). To reduce confusion we modified the sentence to state: “The respiration is multiplied by the number of seconds in a day (S=86400) to convert respiration from per second to per day units”

Comment: p. 2539, eq. 34 and 35: Again, which temperature is used? This is unclear throughout the whole manuscript (g(T) functions for soil processes in section 2.1.10.

Response: Daily average air temperature is used throughout. To reduce confusion we have redefined T as Ta and have specified throughout that air temperature is used.

Comment: p.2543, l. 24/25 – line 1-5 on the next page: What is shown where? It is unclear what is meant with “below” and “above”. Instead, refer to the appropriate equations.

Response: We now refer to Eq. 33.

Comment: p. 2550, l. 9: CUE is used without explaining the acronym and its meaning.

A full description is not provided until late in the discussion. Response:

We now define CUE as the annual carbon use efficiency (CUE; ratio of NPP to GPP).

Comment: Parameter acm11 is discussed in quite some depth in the results and discussion. therefore, a description of this parameter and the shape of the LAI-N leaf relationship in section 2.1 would be extremely useful for interpretation of the results.

Response: We added the following text describing the acm11 parameter in more detail to Section 2.1.2:

“In the ACONITE version of ACM, photosynthetic capacity is reduced when the ratio of LAI to Nleaf falls. Thus, a canopy with a given Nleaf is more productive with a larger LAI. To achieve this, GPP is adjusted by a monotonically saturating function on the ratio LAI:Nleaf (Equation 7), introducing a new parameter to ACM. When LAI:Nleaf is large, the adjustment tends to 1: as this ratio declines, the adjustment factor falls slowly at first, but then increasingly fast as Nleaf becomes concentrated in a smaller and smaller total leaf area.”

Comment: Fig. 1: Autotrophic respiration flux Rax is not explicitly defined in either the figure caption or model description. Presumably it represents increased respiration after the maximum labile pool size is exceeded (Raexcess, Table 2)?

Response: To address this confusion, we modified the names of the boxes and arrows to directly correspond to the names in Tables 1 and 2. The figure caption now states: “Figure 1. Structure of ACONITE, showing pools (boxes) and fluxes (arrows). The gray boxes are pool with C:N ratios. The top panel shows the C cycle, and the bottom panel shows the N cycle. All pools and flux correspond Tables 1 and 2. Rh includes both litter (tlitterC_atm) and soil C (tsoil_atm) respiration fluxes. CWD = coarse wood debris”.

Comment: Fig 1: Is any excess C allocated to mycorrhiza? This would influence the uptake of N. If this is not handled within the model, the authors should briefly adress this topic in the discussion.

Response: In the current version of ACONITE, excess C is only allocated to N fixation. We now include discussion of the potential allocation of respired C to mycorrhiza in a paragraph that also addresses reviewer’s 2 request for discussion on the Fixation and Uptake of Nitrogen model (Fisher et al. 2010). The new paragraph is: "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 of how to allocate C respiration to N uptake, based on the comparison of C costs of N 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 of N on C 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: Table 8: bold values are hardly visible in any printed version of this document. Shading might be more appropriate.

Response: The originally submitted manuscript used shading rather than bold text but the publishers changed to bold text during typesetting. If accepted for publication in GMD, we will work with the publisher to insure that the highlighting is clearly visible.

Comment: p. 2533, l. 2: alpha is also not listed in table 4, so please refer to equation 14.

Response: We added the reference to equation 14. The text now reads: “Uptake rate of N (UN) is a function of the root surface area (rsurfarea), root absorbing power (α; Eq. 14), the air temperature (Ta) adjusted maximum rate of uptake (Itemp; see Equation 16), and the degree of down-regulation of uptake (XN; Equation 20), multiplied by the number seconds in a day (S = 86400) to provide daily mass values.”

Comment: p. 2533, l. 3: Z is not specified in any Table or the text, yet it is used as a linear scalar in equation 12. What is its value and/or reference?

Response: Z is the number of seconds in a day. We have removed reference to Z and replaced Z with a scalar S, that is clearly defined. The text now states: “Uptake rate of N (UN) is a function of the root surface area (rsurfarea), root absorbing power (α; Eq. 14), the air temperature (Ta) adjusted maximum rate of uptake (Itemp; see Equation 16), and the degree of down-regulation of uptake (XN; Equation 20), multiplied by the number seconds in a day (S = 86400) to provide daily mass values.”

Comment: p. 2536, l. 16: Insert a reference to parameter ReturnleafCNInstant in line 16.

Response: The references has been added

Comment: Raexcess and RaexcessC are used intermittently in the document. For example, com- pare equation 37 and Table 1+2.

Response: We now define it as Raexcess throughout

Comment: - p. 2526, l. 6: replace “However” with “However,” - p. 2531, l. 1: replace “describes” with “describe” - p. 2531, l. 22: replace “Therefore” with “Therefore,” - p. 2531, l. 24/25: replace “... sub-model listed in” with “... sub-model are listed in” - p. 2531, l. 26: remove “the” before maximum and actual photosynthesis - p. 2533, l. 13: overly complex language, replace “extant” with “existing”

Response: The above textual comments have been changed in the text

References:

Fisher, J. B., Sitch, S., Malhi, Y., Fisher, R. A., Huntingford, C., and Tan, S.-Y.: Carbon cost of plant nitrogen acquisition: A mechanistic, globally applicable model of plant nitrogen uptake, retranslocation, and fixation, Global Biogeochemical Cycles, 24, GB1014, 2010. Linder, S. and Troeng, E.: Photosynthesis and transpiration of 20-year-old Scots pine, Ecol. Bull., 32, 165-181, 1980. Zaehle, S. and Friend, A. D.: Carbon

and nitrogen cycle dynamics in the O-CN land surface model: 1. Model description, site-scale evaluation, and sensitivity to parameter estimates, Global Biogeochemical Cycles, 24, GB1005-, 2010.

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