

## ***Interactive comment on “On constraining the strength of the terrestrial CO<sub>2</sub> fertilization effect in an Earth system model” by V. K. Arora and J. F. Scinocca***

**Anonymous Referee #3**

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Comments:

Overall comment: This is an interesting study and asks an important question: how can we constrain an emergent property such as the global responsiveness to elevated CO<sub>2</sub> based on global transient observational records? The authors are careful to emphasize the contingent nature of their answers, and emphasize that such answers cannot be unambiguously identified by this approach due to the presence of large amounts of model and forcing uncertainty that determine the response. I would personally go further and ask whether it makes sense at all to try to "tune" emergent model properties to match transient data in such an explicit manner. The more widely-followed approach is to test model components at scales where process-level

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understanding can be gained, in hopes of removing some of the dependence on overall model behavior that may influence results, for example by comparing at FACE sites (e.g. the various FACE-MIP papers), or by systematically benchmarking multiple aspects of the model in order to better understand the structural control on emergent behaviors. So while I do see this paper as a valuable contribution, I also feel that, in the end, the answer to the problem posed in the title is that it very much depends on what is in the ESM itself, and so without understanding how accurate the model is across a wide range of predictions, it is impossible to know whether the specific answer inferred by the comparison is informative of the real world or not.

page 5, lines 7-14: I don't see how, from the perspective of the terrestrial biosphere, the information content of the first three of these tests are different. So if the focus is just on the land, why include the total CO<sub>2</sub> growth rate at all since the answer is effected by the uncertainty in ocean and fossil fuel emissions?

page 14, discussion on "relaxed CO<sub>2</sub>" approach. This seems to be a side point that isn't fully explained here, and I suggest either going into a bit more detail of what you mean (with figures or schematics) or else delete. Is the point that when you run it with relaxed CO<sub>2</sub>, you are able to assess whether or not the model is in equilibrium? Or is the point that the 3D structure and seasonal variation of the CO<sub>2</sub> matters from a radiative perspective and therefore leads to a different baseline climate than in the specified CO<sub>2</sub> case?

table 1: It might be useful to add a row here with the purpose of each scenario.

figure 1: Why is this functional form of the downregulation factor chosen? Assuming that the downregulation is meant to capture progressive nutrient limitation, it doesn't actually seem very progressive—the initial slope is quite high and then lessens at higher CO<sub>2</sub>, but wouldn't one expect a priori that nutrient limitations ought to become stronger only at higher CO<sub>2</sub> levels? Secondly, I can imagine that part of this phase space in this figure would be effectively excluded in that it would actually cause GPP to decrease

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under elevated CO<sub>2</sub>, but it isn't apparent from the figure where that boundary would occur. have you performed sufficient sensitivity studies to identify where that transition is? Thirdly, the minimal downregulation case is quite close to the standard model, why was that chosen?

page 28, last paragraph. Implicit in this argument seems to be the idea that the degree of historical growth and the response of the terrestrial biosphere over the historical period ought to be informative of an idealized 1%/yr forcing. But to the extent that downregulation is progressively driven by nutrient limitations, it ought to be expressed differently based on the rate at which CO<sub>2</sub> increases. So it may be just as informative to consider an extremely rapid CO<sub>2</sub> increase even if not at global scale, as in a FACE experiment, as it is to consider the slower-than 1%/yr forcing that has been applied globally over the historical period.

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