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Interactive comment on "African biomes are most sensitive to changes in CO_2 under recent and near-future CO_2 conditions" *by* Simon Scheiter et al.

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Anonymous Referee #2

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General Comments

This paper considers the lag between a transient and committed vegetation state under changing CO2 and due to the disturbance effect of fire, using the aDGVM. In my view the paper is well written, clearly structured, and presents relevant and interesting results. The study is structured around 4 hypotheses which consider the current

vegetation state, the impact of rate of change, the extent of change, and the effects of fire, which are novel and useful. The methods are explained clearly. The definition of equilibrium presented in equation 1 appears logical, although I wonder if there is already a published method for this that has been used in other studies. The results are presented in a logical way, and the text supports the figures throughout. I believe the conclusions are a valid interpretation of the results and that they are substantial and useful. I have some small comments on specific sections as outlined below, but otherwise I think the paper is of very good quality.

RESPONSE: Thank you for the positive feedback. Regarding the equilibrium conditions, please see our response below.

Specific Comments

Line 19 – Include the time period for the Devonian period to give context

RESPONSE: We will add the period (419.2-358.9 Ma).

Line 28 - Paleocene-Eocene Thermal Maximum (PETM), a period with high carbon emissions some 56 million years ago – It would be nice to see a little more about this period and explain why the carbon emissions were high

RESPONSE: We will modify the text and add "During the PETM, temperature increased by approximately 5-8K due to massive carbon release likely caused by volcanic activity. As temperature increased by 6K within the 20ky period, the PETM is often considered as best analogue for current and future climate change (Zeebe 2016)".

Line 50 – is there a reference for this definition of equilibrium? I wonder if there is another method available which has been used in already published studies that can be referred to. I can see the logic of this method but some extra reference to existing methodology, and why it has been altered if necessary, would make this stronger

RESPONSE: We screened the ecological and land surface modeling literature, particularly the papers cited in our manuscript, but we did not find a similar mathematical definition. Essentially, our approach reflects steady state conditions as used in calculus, i.e., the first derivative has to be zero. As simulated variables are stochastic, we relax this condition by requiring that the first derivative (approximated by the difference between values of subsequent years) has to be smaller than a predefined value for a certain period.

Section 2.1 Line 110 – There aren't many PFTs represented in aDGVM. However it is mentioned in the discussion that this may cause an underestimation in lag time in forests, and as the study is focused on one savanna location I think it is enough for this study

RESPONSE: aDGVM only simulates two tree PFTs, savanna trees and forest trees and as mentioned by the referee and in the discussion, this prevents a detailed representation of successional dynamics and changes in the community composition. Therefore, our simulations may underestimate lag size in forests. However, despite the low number of PFTs, simulated communities and functional diversity may change in terms of population dynamics (i.e., number of trees, height and age structure), and in terms of phenology and carbon allocation patterns. These features are dynamic in aDGVM and allow simulated plants to adjust to changing environmental conditions. Note that most of our analyses were conducted for Africa at the continental scale, only in Fig 10 we used a site that is currently a savanna (but grassland or forest under low or high CO2, respectively).

Line 136 – the performance of aDGVM has been evaluated in terms of vegetation, but what about fire? It would be good to see some evidence that the fire model is reliable, at least for the location picked

RESPONSE: In Scheiter and Higgins (2009) GCB and Scheiter et al. (2015) New Phytologist, we showed that aDGVM can reproduce broad patterns of fire activity in Africa and Australia. At local level, Governder et al. (2006) states that natural fire return intervals in Kruger National Park, South Africa, are between 4 and 5 years,

and previous aDGVM simulations show that simulated return intervals are in the same range. We did, however, not compare simulated fire activity with paleo records to assess if aDGVM can simulate fire regimes at pre-industrial or even lower CO2. We will add a statement: "In Scheiter and Higgins (2009) and Scheiter et al. (2015) we showed that aDGVM can simulate broad patterns of fire activity in Africa and Australia, respectively."

Section 3.6 Line 300 – can you give an explanation as to why the carbon debt continues to increase when the tree cover debt decreases?

RESPONSE: Both in Fig 7 and Fig 9 tree cover debt saturates because tree cover is limited by 100%, i.e., full canopy closure. As CO2 increases, more and more grid cells reach closed canopy. Hence, tree cover debt is constrained and saturates. In contrast, even if canopy closure occurs in a grid cell, biomass can further increase, for example by higher tree numbers and taller trees. Therefore, tree biomass debt continues to increase. We will add a statement: "Tree cover debt decreases at higher CO2 mixing ratios because tree cover in a grid cell is constrained by canopy closure. At higher CO2 mixing ratios large fractions of Africa reach a forest state and canopy closure. Tree cover debt in these areas is zero. In contrast, biomass in a grid cells and hence biomass debt can further increase even if canopy closure occurs."

Fig 3 Bar plot – if fire is suppressed in forests (L384) would you not expect the forest results in figure 3 a and b to be the same, or would there still be some fire?

RESPONSE: Yes, there would still be some fire, especially in forest areas with lower tree cover. However, fire return intervals are low in these regions. We will reword: "Fire rarely occurs in simulated forests, and therefore they reach equilibrium faster than other biome types. Fire activity in forests is, however, sufficient to slightly increase times to reach equilibrium in comparison to simulations with fire suppressed."

Also from figure 3, I think it would be worth quantifying the lag time and noting in the abstract how much longer it takes to reach equilibrium per X increase in CO2, which is an important result

RESPONSE: Note that Fig 3 shows times required to reach an equilibrium state and not lag size. As suggested we calculated the relation between CO2 and times required to reach equilibrium, specifically we calculated averages across all biomes for simulations with fire and without fire. We will add in the results and the abstract: "When averaged across all biomes and simulations with and without fire, times to reach an equilibrium state increase from approximately 242 years for 200 ppm to 898 years 1000 ppm."

Line 256 – Lags are larger at low and intermediate CO2 mixing ratios and decrease at higher CO2. How does this fit with 'The time until vegetation reaches an equilibrium state. . .. Increase[s] with CO2' (L236)

RESPONSE: We do not see a contradiction in these statements as they describe different results. L236 describes times to reach equilibrium states in different biome types (Fig 3), whereas L256 describes lags between transient and equilibrium simulations (Fig 4).

Line 270 / Figure 5 and 6 – It follows that the time taken for the transient simulations to reach equilibrium is measured, but how is the time taken to reach equilibrium in equilibrium simulations measured? In other words what is the equilibrium simulation initialised from?

RESPONSE: It is initialized with the 'standard' method of initializing aDGVM, i. e., 100 trees with random biomass below 150 kg (uniform random distribution) and grass biomass of 0.01 kg/mˆ2. See also L167, section 2.4. We will add grass and tree biomasses used for initialization in the Methods section.

Line 289 – I think specifying that the debt is "larger" would be better than "higher" given the values are increasingly negative

RESPONSE: We will reword as suggested.

Technical Comments

Line 18 – Earth's history?

RESPONSE: We will modify and add the s.

Line 25 – Define RCP (Representative Concentration Pathway)

RESPONSE: We will write out RCP as suggested.

Line 91 – Does the a in aDGVM stand for anything?

RESPONSE: adaptive Dynamic Global Vegetation Model, it is defined in l. 112, sec 2.1 but we will write it out in l. 91.

Line 116 - "This approach allows to model how herbivores" – allows us to model?

RESPONSE: We will correct as suggested.

Line 228 – "C4 or C3-dominated vegetation if fire is present or absent" respectively. In most of the figures C4 grassland and savanna is labelled, but woodland and forest is not labelled as C3 despite being referred to in the text as C3

RESPONSE: We use two different notations: the different biome types (e.g. C3 grassland, C4 grassland, forest) and C3/C4 dominated biomes where we aggregate several biomes. We do not label woodland and forest explicitly as C3 woodland or C3 forest, because these biomes are always dominated by C3 trees; a C4 dominated forest state is not possible. We will check the manuscript to ensure that there is no ambiguity.

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