

## ***Interactive comment on “Biogeophysical feedbacks trigger shifts in the modelled climate system at multiple scales” by S. C. Dekker et al.***

**S. C. Dekker et al.**

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1) The method of this study is close to that in Brovkin et al. (2009), but the ocean is fixed in this study. Therefore, it is not valid to compare results in this study with those of Brovkin et al. (2009) and some others that considers the ocean processes. The multiple equilibria found in this study are for the vegetation-atmosphere system and not the whole climate system. This should be emphasized in the title and paper.

Reply: We agree with this and suggest changing the title in “Biogeophysical feedbacks trigger shifts in the modelled vegetation-atmosphere system at multiple scales”. We already did emphasize this point in the first paragraph of the discussion (P 10992) but we will also add this later on in the revised manuscript when comparing our results with other studies. We will opt to use the term prescribed SST, and not as suggested

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by the referee fixed SST, because our used SSTs are not fixed in time but describe seasonality.

2. Section 3.1, last paragraph. The negative correlation between biomass and temperature does not necessarily indicate a cooling effect of biomass on atmosphere. The correlation itself can not indicate any causal relationship. Actually, the correlation should have regional differences. In Sahel, the biomass is largely controlled by rainfall, which is negatively correlated with temperature. In Amazon forest, the biomass strongly relies on the amount of solar radiation, which has a positive correlation with temperature (Nemani, et al. 2003).

Reply: We agree that the plotted correlation of Fig4b is not a causal relationship and does not indicate a causal cooling effect of biomass on the atmosphere. Indeed as suggested by the reviewer there are regional differences although the examples mentioned by the reviewer (Amazon and Sahel) were not found in our simulations. Largest anomalies are found in Central Africa. Therefore we will change the last sentence to (pg 10990): At low and mid latitudes (45N–45S) a negative correlation is found between biomass and temperature anomalies ( $r=-0.5$ ). The largest positive biomass anomalies are found in Central Africa caused by higher precipitation which in turn is negatively correlated to temperature.

3. Section 3.3. It is not clear how the S index is calculated for the Fig. 6 (a) and (b). Are perturbations from Deq to Geq and from Geq to Deq? I know this can not be right, because it will lead to the same result for (a) and (b).

Reply: Indeed we agree that the sentence In Fig. 6 two maps are presented, from perturbations of the D towards the G equilibrium (Fig. 6a, with positive perturbations) and from G towards the D equilibrium (Fig. 6b, with negative perturbations) (L8-10, pg 10991) is confusing. We have calculated Si with equation 1 by using the positive perturbations from the D equilibrium and the negative perturbations from the G equilibrium. Therefore we will change this sentence to: As a final step we calculated

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the susceptibility index ( $S_i$ ) of the vegetation-climate susceptibility to perturbations with equation 1. In Fig. 6 two maps are presented, Fig 6a with positive perturbation from the D equilibrium and Fig 6b with negative perturbations from the G equilibrium.

3b. I also agree with another reviewer's comment to use percentage biomass perturbations instead of absolute biomass values. It may lead to very different results.

Reply: See point 1 of referee 1.

4. According to this study, the African Sahel is a region with high resilience and there is no sign of multiple equilibria. However, some previous studies have shown the possible existence of multiple equilibria over this region (e.g., Wang and Eltahir 2000a, b). Studies also show that climate variability or noise may force the climate to an intermediate state between two equilibrium states (Zeng and Neelin 2000; D'Odorico et al. 2005). The authors need to consider these previous results in their introduction and discussion.

Reply: Indeed our results did not show multiple equilibria (the result was not significant in the perturbation runs, fig 6) for the Sahel/Sahara although differences were found between the D and G run (Fig 3). This can be caused by lower monsoon strength due to the fixed SST's: We have shown that more vegetation resulted in lower surface temperatures meaning that the gradient between ocean and land is decreased subsequently leading to a decrease in the monsoon strength;

In the first paragraph of the introduction we will add the references of Wang and Eltahir and Zeng and Neelin as their study area is the Sahel. Further we will change L4-8 at page 10994 from the discussion into: In our experimental set-up, with prescribed SST's and sea ice, there is no feedback to the ocean, and therefore lower land temperatures directly decrease the gradient between ocean and land and subsequently decrease the strength and length of the monsoon. This can be the cause that multiple equilibria for the Sahel Sahara were not found in our study while it was simulated by e.g. Wang and Eltahir (2000a, b) and Zeng and Neelin (2000).

5. Page 10994, lines 6-7. “lower land temperatures directly increase the gradient between ocean and land and subsequently increase the strength and length of the monsoon”. This statement is not right. Summer monsoon is caused by warmer land and cooler ocean.

Reply Indeed lower land temperatures will decrease the gradient between ocean and land and subsequently decrease monsoon strength. See at point 4. The first part of the paragraph will be changed into: In the monsoon areas of Africa and Asia multiple equilibria were also found. Here clear positive correlations are simulated between anomalies in biomass and precipitation and negative correlations between anomalies in biomass and temperature. Although the albedo effect would lead to warming, an overall cooling of up to 3K is found. This cooling effect by the vegetation is caused by increased moisture recycling resulting in increased evapotranspiration (Barry and Chorley, 2003) and in turn increased precipitation (up to 0.5 m/y) for some grid cells in Central Africa. A general cooling in the tropics (up to 4K) due to vegetation was earlier found by for instance Fraedrich et al. (1999;2005).

Minor comments 1. Foley et al. we will include the reference. 2. Typos: see also referee 1

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**BGD**

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