Reply to anonymous referee #3

We would like to thank our referee for the very helpful comments which will improve our manuscript! If not stated otherwise, our references to pages, figures, etc. are based on the submitted, not the revised manuscript in order to match the references of the reviewers. In the following, we quote the referee's comments one by one, each followed by our reply in italic font.

1.
p690 line 21: "the bifurcation parameter B...". This is quite an obscure definition of B. It becomes clear afterwards that B is simply time. Please just say so.

We have added the following explanation at this point:
„The bifurcation parameter B is the time (in kiloyears before present) that corresponds to a certain orbital forcing. Decreasing B implies an orbital forcing that evolves forward in time. This in turn tends to decrease P during the late Holocene due to the impact of orbital forcing on northern hemisphere summer insolation and thus convective precipitation.“

2.
p691 line 11: there are here 2 options to generate noise (additive of multiplicative). This point is not mentioned anymore in the following of the text, and it seems that RM1 and RM2 are based only on one option (additive noise ?). This point is not clear at all: if only additive noise is used in the following, please say so explicitly. There is a comment in the conclusion (p700 line22) stating that large multiplicative noise is in conflict with this methodology (this also appears in Part 1). I would like the authors to discuss this point in more depth.

As explained on p694, l6-7 we do every analysis for additive as well as multiplicative noise. As the results (qualitatively) do not depend on the type of noise (p695, l10-11) we do not discuss the noise properties in more detail.

Regarding the inconsistency between EWS and PlaSim-VECODE-tr, in addition to the explanations in Sect. 3.1 (points 1-3) we now elaborate on the problems of large multiplicative noise in Sect. 6:
„In the case of PlaSim-VECODE-tr, we have documented before that the large multiplicative noise is in conflict with this concept (Bathiany et al., 2012). In particular, the small noise approximation breaks down under such conditions: higher-order terms would become important so that the linearization around an equilibrium and thus the link between EWS and local stability would not be strictly valid anymore. Even more importantly, the multiplicative nature of the noise leads to a noise-induced transition. The Tipping Point then depends on properties of the noise and does not coincide with the deterministic bifurcation point. Variance would be a particularly unreliable indicator under such conditions. If it depends on the forcing (directly or indirectly through other variables), variance can decrease towards the Tipping Point if these effects overcompensate the influence of slowing down (Dakos et al., 2012).
Although the green equilibria in PlaSim-VECODE-eq disappear due to an instability at the corresponding hotspot, we therefore cannot draw a conclusion regarding the causality of the collapses in PlaSim-VECODE-tr. There, the large variability eliminates the complex deterministic stability properties and the hotspots of the model are probably much less focussed.“

3.
p691 line22: the orange area in Fig1 is red

Corrected.

4.
p692 line8: "Vi*(P)... is constant in time". Well, since P varies with time, Vi*(P) should also change through time. Again, this is very confusing... May be it would be useful to add time t as a discrete index in equation (2) in the same way as in equation (3). Or may be I did not understood the regression model at all...

What we refer to as constant here is the function V(P). Different values of P are related to different equilibrium vegetation cover fractions, but the functional relationship does not change over time because we have fixed δ in time. To clarify this we now write:*
„The function Vi(P) ...“.*
We have also added the time index t to the variables in Eq. (2) as suggested.

5.
p695 lines5-10: The authors are mentioning parameters of the hotspot detection algorithm that are not described here (but only in Part 1). This appear quite awkward...
First, this should be mentioned at the beginning of the paragraph (eg. "The detection algorithm developped in Part 1 requires some parameters.... We will use x and y values... because ..."), but not at the end ("...mysterious notations and numbers... For explanations of these parameter options see Part 1"). Second, it is necessary to specify the choice of these numbers if these are not "default" or "standard" options defined in Part 1. If they are, what is the point of mentioning them ?

We mention all parameter settings in order to provide comprehensive and transparent information on our analysis. On the other hand, as it turns out that these options hardly influence the results, we refer to Part 1 instead of explaining all these options in detail. Having said this, we go along with the referee's suggestion to make the paragraph more readable and to provide more explanations at an earlier point in the manuscript.
We now write in Sect. 4: „The detection algorithm developed in Part 1 requires some parameters and options, in particular the definition of a signal (SD 1 or 2), the choice of an elimination rule (ER 1 or 2), the construction of the EOFs from covariance or correlation matrices and the use of autocorrelation or relative variance as an EWS (relative here means relative to the first value most distant from the Tipping Point). Here, we test all possible combinations of these options which are discussed in Part~1 of our article. To keep the algorithm sufficiently fast, the system under analysis is repeatedly divided into parts with a maximum number of elements prescribed by n_max. Here, we use values of 3, 5 and 8 for n_max. For the successive removal of elements during the procedure, a relative threshold is applied which starts at an initial value t_ini and is increased in steps of t_inc. For both parameters we use the standard values from Part 1: t_ini = 5 % and t_inc = 5 %. “
When discussing the robustness of results in the later paragraph (previously p. 695) we write: „To investigate the robustness of these results, we compare the results for all possible combinations of our parameter options as listed above (SD, ER, EOFs, EWS, n_max). We find that the determined hotspots are always the same for all combinations of these parameter settings. ...“

6.
p695 line 25 typo "emergef rom"
Corrected.

7.
p696 line 12: Reference to Fig8. Previous figure was Figure 4. Maybe Figure 8 should be renumbered to Figure 5? Again, this kind of jump between figures does not help the reader ....
We thank our referee for this suggestion. We have now placed Fig. 8 after Fig. 5.

8.
p698 line10-11: Fig.8d is not the difference between green and desert state as mentionned (should be Fig8f probably).
Corrected.

9.
p709 Fig4. When reading the text (p694), I spend some time trying to understand what the colored areas meant... This is explained only much later (p698). Maybe these colored areas should defined on another figure, or at least, some explanation should be given in the Figure legend....
We have now inserted the following comment in Sect. 4: „The significance of the coloured areas will be explained in Sect. 5.2.“. Also, we have added to the caption of Fig. 4: „The coloured areas are the areas of our perturbation experiments explained in Sect. 5.2.“.
As we want to show the relation between the obtained weights and the vulnerability of the full model to land cover changes in different areas, we still show both, areas and weights, in one and the same figure although the meaning of the areas is explained in a later section.

10.
p710 Fig5: Here again the Figure caption is very elliptic. Something like "The five equilibrium states obtained in paragraph 5.1..." would be more appropriate than "Fixedpoints...". In order to help the reader, figure legends should be "almost" selfexplanatory... This is not the case here.

We have changed the figure caption which now reads: „The five equilibria of Eqs.~(1), (2), and (3) for 4.5 k conditions as obtained in Sect. 5.1. ...“.

11.
p713 Fig8: The difference between panels a-b and panels c-d is not clearly stated....Please say more clearly that the vegetation cover is the same, but the moisture transport is in the lowest levels (a-b) and integrated vertically (c-d).

We have changed the caption which now reads: „Vertically integrated horizontal moisture fluxes (arrows) and vegetation cover (colours) in PlaSim-VECODE-eq.
Left column ((a), (c), (e)): 8 k conditions; right column ((b), (d), (f)): 4.5 k conditions.
(a)-(d): green equilibrium; (e)-(f): difference between green and desert equilibrium.
(a)-(b): moisture fluxes are integrated over the two lowest atmosphere levels only; (c)-(f): moisture fluxes are integrated over the whole atmospheric column. Vegetation cover fractions in (a) and (c) as well as in (b) and (d) are the same.
*Fluxes are in kg ms**-1, vegetation cover fractions in %. Numbers 4 and 5 denote the individual grid cells referred to in the text.“*