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Climate of the Past Discussions

Interactive comment on "Simulating sub-Milankovitch climate variations associated with vegetation dynamics" *by* E. Tuenter et al.

E. Tuenter et al.

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The instructive and useful comments of both referees are gratefully acknowledged. Their comments significantly improve our manuscript.

Ref. 1.

Major point A.

We agree that the occurrence of the sub-Milankovitch periods in the vegetation may be related to the simplicity of the vegetation model. VECODE computes a tree fraction and a desert fraction, while the grass fraction is a dummy variable (i.e. grass fraction = 1 minus tree fraction minus desert fraction). This is now explained in section 2. We also give some more information about how VECODE computes the tree and desert fraction in section 2, and a reference to a study comparing VECODE to other vegetation models and observations (Cramer et al. 2001). However, the simulated succession of climate and biome seems realistic (maximum precipitation results in grass mixed with trees with a relatively large water holding capacity, while minimum precipitation results in desert combined with grass area which has a relatively low water holding capacity). Further research is obviously needed to test this hypothesis using more sophisticated vegetation models, which simulate biomes types directly in terms of climate. This caveat is given in the discussion section of the revised paper as well as in the abstract.

We have tried to verify our results by running LPJ forced by the output of CLIMBER2-3. Unfortunately, this is not as straightforward as we anticipated and due to numerical problems we did not succeed. Also, such an exercise would not include the feedback from vegetation to climate which would result in a somewhat ambiguous outcome. For these reasons we now emphasize that our results provide only a hypothesis for the origin of sub-Milankovitch periods, but do not carry out additional experiments.

Concerning the significance test of the power spectra for vegetation we note first that the desert and tree fractions are computed independently in CLIMBER-2,while grass is determined as 1 minus (trees and desert fractions). The 10 kyr period in the desert and tree fractions seems to be an artificial period, resulting from clipping (see also specific comment 3). This 10 kyr period is absent in the time series. Therefore we do not regard it as significant, although it passes the lowest significance test. For the grass fraction the computed 10 kyr period is present in the time serie, as can be seen by eye (Fig. 3). This visible evidence together with the absence of this period in the tree and desert fraction leads to the conclusion that the 10 kyr period in the grass fraction is real, in addition to the significance test. The statistical significance is computed for the grass fraction time series, without taking its dependency on the tree and desert fractions into account. This is explained in the caption of (the old) Fig. 4.

Major point B.

Ref 1. was not convinced by the hypothesis that changes in runoff could significantly affect the ocean circulation. We agree with the referee that the sub-Milankovitch signal in the runoff seems too small to affect the ocean thermohaline circulation. At least the variations in runoff are much smaller than the values used for the standard hosing experiments. However, in the oceanic gridboxes in which the monsoonal runoff is dumped the model does simulate a sub-Milankovitch signal in the annual salinity. This is particularly strong for the Mediterranean Sea (35 degrees North, sector 2, Fig. 1) and for the northern Indian Ocean (15 degrees North, sector 3, Fig. 1). Therefore, sub-Milankovitch signals in the salinity as recorded in sedimentary records could be induced by sub-Milankovitch signals in the runoff. There might be implications for the wind-driven ocean circulation (and maybe the thermohaline circulation), but we agree that the evidence from the present model results is not very strong. Rephrased in the revised paper at the end of section 4.

Specific comments.

(1) We explain now in more detail in section 2 how VECODE computes the vegetation fractions, especially emphasizing that the grass fraction is a "left-over" after the bare soil and tree fractions are computed.

(2) In section 2 we added a reference to Cramer et al. (2001) who compared the present-day results of a high-resolution version of VECODE to other vegetation models as well as to satellite measurements. From this study it appeared that VECODE agrees reasonably well with other models and observations, as stated in the revised section 2.

(3) With "artifact" we refer to the occurrence of sub-harmonics of the precession forcing in the spectra of the desert fraction (Fig. 4 upper panel) and tree fraction (not shown). The desert (and tree) fraction only show a "pulse" every 20 kyr (Fig. 3 middle panels). This should not result in higher harmonics. However, due to the sharpness of the peaks caused by the non-negativity of the vegetation fractions, higher harmonics are introduced. This is an example of "clipping", resulting in an artificial 10 kyr period in

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the spectra. Such a period is not visible in the time series. Therefore, the "artifact" originates in the spectral analysis, not in the CLIMBER-data. In the real world this clipping can also occur leading to artificial periods. In contrast, the 10 kyr period found in the grass fractions (Fig. 4 lower panel) is not an artifact of the spectral analysis. This 10 kyr period is really present in the data and is visible by eye in the time series (Fig. 3, middle panel). Of course, as already explained, the grass fraction is determined by the tree and desert fractions, so this might not be realistic for completely different reasons. The phrasing (clipping and artifact) is now explained in more detail in section 3.

(4) The referee is right that if the trees and desert are in anti-phase, this will not automatically lead to a 10 kyr period of the grass fraction. However, to our opinion in this case the term "anti-phase" is not correct. The fractions of trees and desert are not in anti-phase because they are both positive. It is simply an alternation of coverage of tree and desert and these vegetation types do also exist at the same time. This alternation results in a 10 kyr period of the grass fraction, being the residual. This is now explained in more detail in section 3.1.

(5) We now explain the 5 kyr signal in the runoff of the Asian monsoon in more detail in the text. We already showed a zoomed-in plot over half a cycle for the Asian monsoon (Fig. 6, right panels). Maybe the referee missed that because of the poor quality of the figure (see also comment on figures 7). This 5 kyr cycle is not a result of the clipping itself, but it is (again) caused by the coupling of grass to trees and desert.

(6) We now add a figure showing the June-August insolation for different latitudes together with the precession parameter. Because of the clarity of this figure and because we almost solely focus on boreal summer we only show the insolation for June-August.

(7) We have improved and enlarged most figures.

(8) We also improved the quality of Fig. 1. To exclude an "artificial impression of higher-resolution" we now explain in the caption that a black block only indicates the fraction of land in an atmospheric cell and that a block is placed arbitrarily within that cell.

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(9) We now label the figures.

(10) We will place Brostrom before Brovkin.

(11) We changed "The" into "the".

(12) We will use "CLIMBER-2" throughout the text.

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