

Interactive comment on “Impact of climate variability and land use changes on global biogenic volatile organic compound emissions” by J. Lathière et al.

J. Lathière et al.

Received and published: 27 February 2006

We would like to thank sincerely the referee for the useful comments and suggestions, enabling to improve our manuscript. Here are presented the modifications made accordingly in our manuscript:

Specific comments:

1-p. 10615, 2nd paragraph: The 3rd sentence should be split into two as: “Wang and Shallcross (2000) used a global land-surface and chemistry-transport model to show that the inclusion of isoprene emissions has a significant impact on ozone and oxidation products, such as peroxyacetyl nitrate (PAN), in both hemispheres. Their analysis

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indicated that the response of ozone to isoprene emissions was predominantly governed by the spatial and temporal variations in terrestrial vegetation, with a simulated ozone increase of about 4 ppbv over the oceans and about 8-12 ppbv over mid-latitude continental areas". Similarly, the 4th sentence beginning with "Sanderson" should be modified. We have split or rephrased a few sentences that could be unclear, and modified them according to the referee suggestion.

2- Page 10616, 2nd paragraph: The sentence beginning with "On top of the" should be reworded to begin with "In addition to the" The proper correction has been made.

3- Page 10618: 1st sentence should be modified to "Global mean estimated for the 1983-1995 period are given in Sect. 3 and compared to the results of other studies. Analysis of the impact of climate and CO2 interannual variability from 1983 to 1995 on the simulated biogenic VOC emissions is presented in Sect. 4. The sentence has been changed.

4-Page 10619, Figure 1: It is not clear why Loveland et al. (2000) is cited in the figure caption. Has the maximum LAI been prescribed based on Loveland et al. (2000) data? In that case, the reference should be cited on Page 10619. In order to clarify, the citation "Loveland et al., 2000" has been removed from the figure caption, since this reference only concerns the vegetation distribution, and not the maximum leaf area index prescribed in the ORCHIDEE model.

5-Page 10620, 1st paragraph : The influence of leaf age on biogenic emissions is mentioned here without any evidence and is then finally described near the end of Sect 2.2. I think it would be useful to either cite the references (MacDonald and Fall, 1993; Guenther et al., 2000) here or say that more details are given in Sect 2.2. The corresponding references have been cited.

6-Page 10620, 2nd paragraph : 4th sentence should be modified as " The atmospheric CO2 levels and can thus indirectly affect VOC" The sentence has been corrected.

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7- Page 10620, Sect 2.2: 1st sentence may be written as “In addition to isoprene and monoterpenes, we also explicitly estimate the emissions of methanol, acetone which are usually considered as a family of compounds and estimated as bulk emissions”. This change has been made in the text.

8- Page 10624, Sect. 2.3: It is not clear to me whether all the climate/CO₂ simulations were performed in static or dynamic mode. If the simulations are performed in static mode then how do changes in CO₂ influence the prescribed LAI. For instance, if the LAI for a grid cell is calculated to be mode than the maximum prescribed, is it assigned the maximum value associated with the prescribed PFT of the grid cell? In that case, there is a possibility that the model may be underestimating or overestimating the CO₂ fertilization effect. It would be useful to clarify this aspect of the simulations. Since our study focus on short time scales, all the simulations presented here have been performed in static mode, which means that the vegetation distribution is prescribed. However, the leaf area index is calculated based on environmental conditions, which is the case in static as well as in dynamic mode, and will thus vary depending on climate conditions and atmospheric CO₂ increase. Nevertheless, in order to take into account that a leaf can probably not expand infinitely, the leaf area index can not exceed a maximum value which is given for each plant functional types (see Figure 1 and Section 2.1). In order to clarify this point, we modified a sentence in the Section 2.3 “The simulations are performed in static mode, which means that the vegetation distribution is prescribed using a global map. The variability of climate conditions and the atmospheric CO₂ increase will thus not affect the vegetation distribution, but will impact the vegetation growth, and especially photosynthesis activity and carbon allocation to leaves. For our study,É”. The evolution of biogenic emissions on long time scales is analysed in our paper LathiÈre et al., 2005 (Past and future changes in biogenic volatile organic compound emissions simulated with a global dynamic vegetation model, GRL) and the ORCHIDEE vegetation model is then run in dynamic mode.

9-Page 10624, 1st paragraph: A reference for the annually varying atmospheric CO₂

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mixing ratios would be appropriate. The corresponding reference has been included in the text.

10-Page 10624, Section 3.1: The authors compare their results with other model results. How do these results compare to available measurements (if there are any)? The validation of our biogenic emissions model is not described in this paper, but of course several comparisons with on-site measurements have been done so that we could check the consistency of our results. To illustrate this point, we included a new table in our paper (Table 4, Comparison of the ORCHIDEE 1983-1995 mean biogenic emissions with on-site measurements) showing comparisons of our model results with a compilation of measurements campaign as well as a new figure (Figure 3, Comparison of the ORCHIDEE results with measurements of the ECHO campaign) to analyse the representation of the diurnal cycle in our model. Modifications have also been made in the text, in the section 3.1: “Comparison of the ORCHIDEE monthly mean emissions fluxes over the 1983-1995 with a limited compilation of measurements is given in Table 4 and show that the results of our model are broadly within the range of selected measurements. In the Figure 3, the diurnal isoprene emissions cycle calculated by our model is compared to measurements of the ECHO campaign (Spirig et al., 2005), which took place in North-West Germany in July 2003, and we can see that in this case, the diurnal variation of isoprene fluxes is quite well captured by our model. It is of course difficult to evaluate a global model based only on a few comparisons with measurements, and a more detailed validation is required. Nevertheless, the examples shown in Table 4 and Figure 3 underline that our model is generally consistent with the measurements.” A more detailed validation is required to further evaluate our model, but is however beyond the scope of our study.

11-Page 10625, 2nd paragraph: Comparison with Naik et al. is not very clear and can be modified to read better. Here is a suggestion: “Naik et al. (2004) considered a potential vegetation map with no agricultural land, which should lead to higher emissions than ours. However, they assumed that grasses are not a major emitter of isoprene

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(emission factor of 0) while we use emission factors of 16 and 24 ugC/gdm/h for C3 and C4 grasses respectively (Guenther et al., 1995), that results in an additional emission of 90 TgC/yr into the atmosphere.” The sentence has been rephrased.

12- Page 10628, Sect. 3.3: Remove “variability” from the 1st sentence. It would be helpful to mention the key variables with references to Equation 1. The effect of increasing leaf temperature on biogenic emissions is described in sentence 4. Surface temperature is actually used to model the emissions, this may cause some confusion. I would suggest rewording the sentence as “Increasing the surface temperature (used here as a surrogate of leaf temperature) in the biogenicE”. Those suggestions have been taken into account.

13-Page 10629, Sect. 4: It is a good idea to perform simulations of constant CO2 and increasing CO2 to understand the driving factor for variability and isolate the impact of climate variability from the combined changes in climate and CO2. It would be helpful to clarify what the 1.3% increase in total VOC for “increasing CO2” compared to “constant CO2” simulation signify. Terrestrial vegetation models generally simulate an increase in foliar biomass with increasing CO2, which implies an increase in VOC emissions. Rosenstiel et al. 2003, however observe a reduction in isoprene emission despite increases in photosynthesis and biomass accumulation from CO2 increase. The discussion would benefit from a consideration of the findings of Rosenstiel et al. In order to clarify the results, we modified the corresponding sentence in Sect. 4: “In 1995, the emissions difference between the “constant CO2” simulation and the “increasing CO2” simulation reaches 4 TgC/yr for isoprene and 10 TgC/yr for the total VOC, which corresponds to 0.8% and 1.3% difference, respectively, linked to an increase in foliar biomass under increasing atmospheric CO2 conditions.” The change related to the Comment n° 8, made in the Sect. 2.3, should also help to a better understanding. The impact of atmospheric CO2 increase on the ratio between biomass and isoprene emission, observed by Rosenstiel et al. (2003), is not considered in our study. It is true that the impact could be highly important for biogenic emissions estimate in

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the case of long time-scales study, such as simulations for 2100. Nevertheless, we can consider that over the 1983-1995 period, over which the atmospheric CO₂ increase reaches 5%, this influence would be rather small. A discussion on this subject has been added in the conclusion, also in response to the second referee's comment n°1: "Rosenstiel et al. (2003) showed that under increased atmospheric CO₂ level from 430 ppmv to 800 and 1200 ppmv, the isoprene production was reduced by 21% and 41% while above-ground biomass accumulation was enhanced by 60% and 82%. We can reasonably consider that considering this influence in our study would not change significantly the estimates calculated over the 1983-1995 period, characterized by a 5% increase of the atmospheric CO₂ but could however be important on longer time scales study."

14-Page 10630, 2nd paragraph: I think the r² values shown in Fig. 5 are insignificant to have any meaning. I would recommend removing the figures as they do not add much to the discussion. The regional variability in biogenic emission is best described in Figure 6. It would be useful to explain the cause of the variability in emissions for different regions. According to the referee suggestion, the corresponding section has been strongly reduced and the Figures 5 and 6 have been modified. A sentence was also added in this section to underline the key parameters in biogenic emissions variability: "Biogenic emissions variability is strongly affected by the evolution of environmental conditions such as radiation, temperature or leaf area index."

15-The deforestation and afforestation results are interesting and show that BVOC emissions would depend considerably on the vegetation species being substituted (high or low emitters). It would be helpful to mention that these results are subject to assumptions made about the extent and type of change in vegetation. Precisions have been given at the end of Section 5: "The vegetation distribution change considered in our study is only intended to be a sensitivity experiment and probably overestimates the future changes. Nevertheless, the results obtained in the tropical deforestation and European reforestation simulations underline the strong impact of vegetation distribu-

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tion alteration on VOC biogenic emissions as well as the high dependency of emission levels to the evolution of land management.”

16-Page 10631, Sect. 5.1.: How do the results for deforestation in East Asia compare with the results of Steiner et al., 2002? A comparison with the results presented by Steiner et al. (2002) has been included in the section 5.1: “The isoprene emission decrease calculated for East Asia reaches 26%, which is closed to the 30% decrease calculated by Steiner et al. (2002)”.

17-Page 10634, 1st paragraph: On line 4, the units of global annual emissions should be TgC/yr instead of TgC/an. When citing published studies in the text of the paper it is conventional to list citations by publication date rather than in alphabetical order; this highlights the evolution of research and credits those who pioneered the respective field. The units have been corrected, and the list of references in the paper have been reorganized.

18-Figures: It would be helpful to increase the size of Figures 2, 3, 7, 8, and 9 as they are extremely small and hard to read. The legibility of these multi-panels plots would also be improved by moving the tickmarks inside the axes - this provide neater plots for publication purposes. Wherever appropriate, use only one colorbar for a panel plot. For example, Figure 2 can be described wit only one colorbar. Similarly Figure 3 needs only 4 colorbars. The figures have been modified according to the referee suggestions.

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 10613, 2005.

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