

## ***Interactive comment on “Process based inventory of isoprenoid emissions from European forests: model comparisons, current knowledge and uncertainties” by T. Keenan et al.***

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Many thanks to Referee #2 for their thorough review. Below we address the points raised and outline how we plan to incorporate suggested changes in a revised manuscript.

1) R: The ability of the Niinemets model to simulate the mid-day decline in isoprene fluxes at the canopy scale in France is interesting and impressive. More discussion on the mechanisms and limiting factors behind this effect would be helpful. Were similar diurnal comparisons made between the models and the data collected from the Michigan, USA site? This would test the robustness of model and the increase the level of

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interest in the paper.

Authors – Unfortunately, diurnal data was not available for the Michigan test site. New efforts in eddy-covariance techniques should provide more diurnal measurements in the future. The mid-day decline of the Niinemets et al. model is related to its stronger dependence on light through the electron transport activity (Arneeth et al., 2007). As numerous studies investigating diurnal variations in chlorophyll fluorescence in drought-stressed plants demonstrate, electron transport activity is also downregulated around mid-day, in line with the rates of photosynthesis. We will develop the description and analysis in the text.

2) R: The time trends of isoprenoid estimates are most interesting for the period 2000-2100, when model estimates diverge. For isoprene, and probably light-dependent Monoterpenes, the effect of isoprenoid “down-regulation” with increasing ambient CO<sub>2</sub> is not apparently incorporated into the models. Monson and colleagues have recently found that this effect can at least offset isoprene emission increases due to rising ambient temperatures over similar time scales and ambient CO<sub>2</sub> projections. Can this mechanism be incorporated into the Niinemets model? This could be investigated, or at least discussed, in more detail.

Authors - The effect of isoprenoid “down-regulation” with increasing ambient CO<sub>2</sub> has been previously reported, and its inclusion (using a simple empirical reduction function with increasing atmospheric CO<sub>2</sub>) in the Niinemets et al. model has been shown to potentially offset any climate change induced increases in emissions (Arneeth et al., 2007) (though this may not be true for the Guenther model given its stronger response to projected climate change in this manuscript). A proper understanding of this CO<sub>2</sub> response will be necessary to fully understand and predict future emissions, but at present the only available incorporation is the empirical function based on a limited number of data. The explanation on Page 6152, line 22/23, will be expanded.

3) R: The CT,L functions from the Guenther studies were conducted under, and in-

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tended for simulating, short-term changes in light and leaf temperature. How comfortable are the authors with the assumption that they work for long-term annual changes over the course of centuries? Do the authors assume that no long-term adaptation will occur in the emission capacities?

Authors - Although the CT,L functions from the Guenther studies were, as the reviewer points out, developed under conditions of short term changes in light and leaf temperature, so too were the Niinemets et al. and Martin et al. models (and both the Guenther et al. and Niinemets et al. models have been used widely for estimating long-term emissions see e.g. Guenther et al., 2006; Muller et al., 2008; Arneth et al., 2007). This is due to the lack of long term series of emissions measurements, though present efforts in eddy-covariance techniques hope to soon produce reliable long term series. Given the lack of long term measurements, it is difficult to comment on the reliability of long term emissions estimates, particularly under changing future climatic conditions. Little understood factors such as responses to changing atmospheric CO<sub>2</sub> concentrations (see previous reviewer comment), and species adaptation to changing climatic conditions, could affect future emissions. Until these effects become clearer, we have opted to assume that there is no long term adaptation, in order to test the response of the original models. In part, by showing the model dependent range of potential future emissions, this manuscript suggests how comfortable we can be with the assumption that these models work for long term annual changes over the course of centuries.

4) R: It is difficult to tell if changes in forest cover and composition were included over the model assessment study period. European forest cover has changed dramatically (and probably will continue to do so until 2100?). Can the authors comment on this possible effect?

Authors – Past forest cover was assumed to be equivalent to current day (the date of the compilation of the forest cover database). We did not explicitly consider potential future changes in species distributions, thus allowing us to concentrate on the future response of the models themselves. We shall add a clear explanation in the text of the

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manuscript.

5) R: Reduced stomatal aperture appears to be cited here as a factor in reducing leaf-level isoprenoid emission, although some previous studies suggest that this is a minor factor. Can the authors comment on this with respect to this effect in the models?

Authors - This reference to stomatal aperture in the text (Page 4 line 23) is potentially misleading and will be removed.

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Other comments:

a) R: Page 6156 line 3: “isopenoids” should be “isoprenoids”.

Authors – O.K.

b) R: Page 6160 line 11: How were the inappropriate values of MA identified?

Authors – Three sources of errors were identified in MA values. 1) the reciprocal of MA, SLA (in units  $\text{cm}^2 \text{g}^{-1}$ ), had been used, and instead of multiplication, area-based values were divided by SLA; 2) MA had been calculated on the basis of total area, but emission measurements were based on projected area (mainly a problem in needle-leaved species), 3) errors in units. These errors were identified on the basis of information provided in the Material and Methods about the methods of area determination and expression of the characteristics, and on the basis of tabulated values of MA and the area-based emission rates. In the case of studies using literature-based MA values, original MA values were looked up from the literature.

c) R: Page 6165 line 11: Can the authors better discuss why the mid-day emission decline occurs in more detail?,

Authors – In addition to what has been said above, the model of Niinemets et al. based on overall energy level predicts that the mid-day decline is associated in downregulation of DMADP pool size (that is linked to the rate of electron transport). Recent support to

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this hypothesis comes from the study of Mayrhofer et al. 2006, *Atm. Environm.*

d) R: Page 6167 line 14: Has the suppression of emissions during summer drought been observed in emission studies? Can the authors cite the previous work on this subject?

Authors – Yes this has been recently reported (e.g. Grote et al., in press)

e) R: Bottom of page 6168 and Top of 6170: Can the authors determine why many of these large differences in emission potentials exist? Sampling issues in time and space? Analytical differences?

Authors – On the basis of existing reports, it is not straightforward to infer why such differences have been found. It is most likely that this is associated with different phenological periods used for sampling. Emission factors have been commonly determined by screening many species during a limited amount of time. Recent studies demonstrate that even strong emitters like *Quercus ilex* emit monoterpenes in early season with low rate (Ciccioli et al.). Analogously, the emissions may not have been fully induced in early studies in the moderate emitters. Clearly more information of the emission potentials is needed.

f) R: Literature cited: Do you need a bibliography for both the main text and Table 1 as well? Perhaps these can be combined to save space.

Authors – O.k. We will combine the two tables.

g) R: Figure 2. The R2 criterion alone may not be the best for comparing the model fit to measured emissions, the authors should consider also giving the root mean square error (RMSE).?

Authors – O.K.

h) R: Figures 3 and 4. What do the error bars represent?

Authors – Error bars represent the spatial standard deviation from the mean for the

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model ensemble. This explanation will be added to the Figure footer.

i) R: Table 1. Is MA is projected?

Authors – Yes. Will be reported in the new version

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Interactive comment on Atmos. Chem. Phys. Discuss., 9, 6147, 2009.

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