Interactive comments on « Implementation of the biogenic emission model MEGAN(v2.1) into the ECHAM6-HAMMOZ chemistry climate model. Basic results and sensitivity tests » by Alexandra-Jane Henrot et al.

Alexandra-Jane Henrot et al.

REFEREE #1

We would like to thank Referee #1 for useful and constructive comments which have helped us to improve the manuscript. The suggested changes will be addressed in the revised version of the manuscript.

Referee #1's comments are quoted in blue. Authors' answers are in regular font and authors' changes in the manuscript are quoted in italic.

Major comment

My only major objection lies is the use of a hybrid MEGAN model algorithm which mixes elements of the version 2.1 (Guenther et al., 2012) with the PCEEA developed for isoprene as part of MEGAN v2 (Guenther et al., 2006) and with the earlier algorithm of Guenther et al. (1993). The reader might want to know whether this setup provides results similar to those of the full version 2.1. Besides problems with the temperature dependence of light-independent emissions (see Specific comments, below), I am especially worried that the dependence on LAI is not correct. In Equation 3, I assume that γ_{LAI} multiplies both ligh-dependent and light-independent terms. The expression of γ_{LAI} is obtained from PCEEA, which is fine for light-dependent emissions, but certainly not for light-independent emissions, which are essentially proportional to LAI (cf. Equation 2 in Guenther et al., 2012). It is possible, although I'm not certain, that the authors were misled by a recently published model study (Messina et al., ACPD 15, 33967-34033, 2015). Messina et al. made the very surprising claim that, according to MEGAN, monoterpenes emissions show very little sensitivity (less than isoprene emissions) to changes in LAI. This result cannot be correct, and is contradicted by their reported results obtained with the ORCHIDEE model. Basically, the emission is proportional to the amount of leaf biomass, which is proportional to LAI. For light-dependent emissions, light attenuation dampens this relation. For light-independent emissions, this effect does not exist. Could the authors also estimate the sensitivity of their estimated isoprene and monoterpenes emissions to a given change in LAI (say, a factor of 1.5)?

According to the comments of Referees #1 and #2 we have amended the description of the calculation of the activity factor GAMMA_CE, in order to clarify the parameterizations used in the biogenic module presented in this study. As pointed out by Referees, the calculation of the GAMMA_CE factor applied here is a combination of the parameterization used in MEGANv2.1 and of the PCEEA approach for the light-dependent compounds as described in Guenther et al. (2006). The description of GAMMA_CE calculation has been modified (see Author response to Referee #2, specific comment 1). A discussion about the use of this « hybrid » parameterization and its potential effects on the global BVOC emissions has been added in the revised manuscript in section 4.2.

« In the biogenic module applied here the light-dependent activity factor are calculated using the Parameterized Canopy Environment Emission Activity (PCEEA) approach. This bulk canopy temperature parameterization is similar to the leaf-level temperature parameterization of the explicit canopy model but is slightly less sensitive to temperature. Guenther et al. (2006) report estimates of annual global isoprene emissions with the PCEEA approach that are within 5 % of the value estimated using the standard MEGAN canopy environment model, but differences can be up to 25 % for estimates at specific times and locations. »

As noticed by Referee #1, the light-independent activity factor GAMMA_TLI is calculated here following the monoterpene exponential temperature response function of Guenther et al. (1993). This algorithm is similar to the algorithm used in the fortran code of MEGANv2.1 for calculating GAMMA_TLI for all compounds with a light-independent activity, and is explicitly described in Guenther et al. (2012), Section 2.2, Eq (11). The only difference introduced here is that we assume that leaf temperature is equal to ambient air temperature. This simplification is the subject of Referee #2 second specific comment. Following his/her suggestion, we add a brief description and discussion of this simplification and implications in the revised manuscript (see Author response to Referee #2, specific comment 2).

Equation 3 has been corrected (missing parenthesis added) as follows:

GAMMA_CE = GAMMA_LAI * ((1-LDF) * GAMMA_TLI + LDF * GAMMA_TLD).

Indeed GAMMA_LAI multiplies both the light-dependent and light-independent activity factors. The first term of Eq (3) is similar to the calculation of light-independent activity factors in the fortran code of MEGANv2.1 (GAMMA_LAI*(1-LDF)*GAMMA_TLI). We agree with Referee #1 that this equation does not correspond to the development of Eq (2) in Section 2.2 in Guenther et al. (2012) for the light-independent fraction. Here, we based our model development on the MEGANv2.1 fortran code, and thus used GAMMA_LAI in the calculation of the light-independent part. We have stated explicitly in the revised manuscript that Eq (3) is derived from the basic equation used in the fortran code of MEGANv2.1 and differs from Eq (2) in Section 2.2 in Guenther et al. (2012). Messina et al. (2015) already discussed the use of GAMMA_LAI for both light-dependent and light-independent emissions and its effect on emissions.

Following the suggestion of Referee #1 we did an additional sensitivity test over the modeled period (2000-2012) to estimate the effect on isoprene and monoterpene emissions of a change in LAI (LAI scaled by a factor 1.5). The multiplication of LAI by a factor 1.5 leads to an increase of isoprene and monoterpene global emissions by 18.5 % and 16.5%, respectively, in comparison to the reference simulation. This effect is much larger than the global annual increases of isoprene and monoterpene emissions for the same sensitivity test with MEGANv2.1 reported in Messina et al. (2015) as 6.6 % and 6 %, respectively. However, the impact of LAI change reported here is lower in comparison to the effect of changing LAI datasets in different versions of the MEGAN model, leading to about 30 % of global annual isoprene emission changes (Guenther et al., 2006, 2012). As the same parameterization for GAMMA_LAI was used in our experiment and in the simulations performed by Messina et al. (2015), the difference in the sensitivity to LAI obtained here must result from the LAI data that are used to calculate the activity factor. The LAI distributions in winter and summer we have used for the reference simulation with the biogenic emission module are shown in Figure A below. The LAI values reported here are globally lower in comparison to the LAI values used in the MEGCRULAI simulation in Messina et al. (2015), reference simulation for the 1.5*LAI sensitivity test (Figure (4), Messina et al., 2015). In Eurasia and North America, LAI reaches a maximum value of about 3 to 3.5 $m^2\ m^{-2}$. Messina et al. (2015) report maximum values of between 4.2 and 4.9 $m^2\ m^{-2}$ in the same regions (from Figure (4)). The lower LAI values could explain the larger effect of LAI increase obtained here. The GAMMA_LAI factor has indeed a larger increase rate for LAI lower than 5 $m^2\ m^{-2}$ (Messina et al. 2015). Furthermore, Messina et al. (2015) reported a possible weaker impact of high LAI in MEGANv2.1 in their simulations due to the leaf self-shading effect (an increase in LAI increases the proportion of shaded and cooler leaves thus leading to lower emission rates (Sindelarova et al., 2014). This effect is not taken into account here due to the use of the PCEEA approach. We can finally remark that as both light-dependent and light-independent emissions are calculated using the GAMMA_LAI factor, isoprene and monoterpene emissions do not show significant differences in their sensitivity to LAI.

A description of this additional sensitivity test and discussion of the results obtained, have been added in the revised manuscript in Section 4.3.

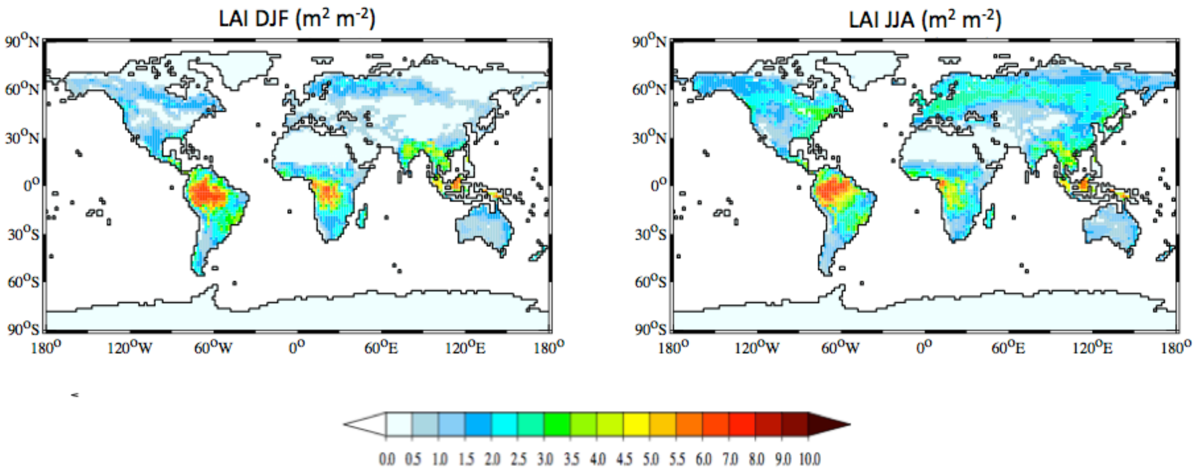

Figure A: Leaf Area index (LAI, $m^2\ m^{-2}$) geographical distribution for winter (DJF) and summer (JJA) in the reference simulation.

Specific comments

The title is long, I think that its second part (Basic results and sensitivity test) could be dropped.

We agree to shorten the title of the paper and to remove the second part of the title. The revised manuscript will be entitled *“Implementation of the biogenic emission model MEGAN(v2.1) into the ECHAM6-HAMMOZ chemistry climate model.”*

Page 3 line 30: please provide some more details on those global potential land cover maps. In what sense are those for potential land cover? Do they include realistic representation of human influence (e.g. crops, managed forests, etc.)?

The background of the land cover map used here is a map of potential vegetation derived from the reconstruction of Ramankutty and Foley (1999). Potential vegetation means here the vegetation that would exist in the climax state under today's conditions and in the absence of human activities. The potential vegetation map is then combined with land use maps (agricultural types considered are croplands, C3, and C4 pastures) of Ramankutty and Foley (1999) and Foley et al. (2003). The land cover map used here thus takes into account to some extent the human influence on the global vegetation distribution. We refer to Pongratz et al. (2008) for the details of the land cover map construction.

Page 4 line 25: the common MEGAN assumption that LDF is a species-specific constant is very unrealistic for monoterpenes (e.g. Rinne, Atmos. Chem. Phys. Discuss., 15, C11977–C11979, 2016). This should be (at least) mentioned somewhere in the manuscript.

As suggested by Referee #1, we have mentioned in the revised manuscript (in Section 4.2) the uncertainties linked to the use of species-specific light-dependent factors in the MEGAN model. The text has been amended as follows:

“The introduction of light-dependent factors for other compounds than isoprene in MEGANv2.1 has notably a significant effect on global emissions (Messina et al., 2015). Moreover, a large range of variation of light-dependent emissions, especially for monoterpenes, is observed across plant species (Rinne, 2016). Thus, the use of a single LDF value per compound in MEGANv2.1 can introduce further uncertainties in the model emission estimates and discrepancies between model versions using different values of LDF.”

Page 4 line 26: the temperature activity factor for light-dependent emissions is obtained from G06 (Guenther et al., 2006) but I find several differences between G06 and the expressions given in the supplement, e.g. the factor C_{eo} is equal to 1.75 for isoprene in G06. Please explain.

The temperature activity factor for light dependent emission GAMMA_T is calculated as described in Guenther et al. (2006). The factor Ceo has been updated to the value used in MEGANv2.1 in order to be consistent with the values of Ceo used for the other compound and taken from MEGANv2.1.

Page 4 line 28: this temperature dependence (Guenther et al. 1993) is considerably simpler than the temperature activity factor of Guenther et al. 2012. Please discuss the possible implications of this simplification.

See response to major comment

Page 7 line 14: the globemission website does not provide the box locations. The latitudes/longitudes of the regions should be specified in the figure legend.

As suggested by Referee #1, the latitudes/longitudes of the regions selected will be specified in the legend of Figure (1). This information is indeed not directly available from the website of the GlobEmission project.

Figures 3, 4, 6, 15: please enlarge the fonts, or enhance resolution for better readability

Figures have been enlarged to allow a better readability of the legends.

Page 8, lines 30-32: Messina et al. fail to provide good reasons for this supposed lower sensitivity of BVOC emissions to LAI in MEGANv2.1. The ORCHIDEE sensitivity to LAI makes much more sense.

This comment has been addressed in the response to the major comment.

Page 13 lines 2-3: here the soil water activity factor is said to depend on relative soil water amount. But the supplement reports a dependence on volumetric water content, as in G06. Are those two quantities the same thing?

The soil moisture content can be expressed as the amount of water (in m of water depth) present in the soil (depth of the soil water reservoir) or also in percent of volume (volume of water in volume of soil water reservoir). Both quantities are relatives and represent the same values if the surface of the soil water reservoir considered (here the surface of the grid-cell) is the same. We have modified Eqs (S10) to (S13) in the supplement to mention the relative water amount instead of the volumetric water amount in the calculation of GAMMA_SM.

Page 14 lines 21-24: Interannual variability is not well quantified by the ratio of maximum and minimum values. Since the periods covered by the different studies are all different, I'm afraid that the comparison amounts to a comparison of apples with oranges. It would make more sense to compare the standard deviation of annual totals in the different datasets.

Following the suggestion of Referee #1, we have based our comparison of interannual variability on the standard deviations of annual total isoprene emissions obtained here and calculated from the available information given in Sindelarova et al. (2014), Müller et al. (2008) and Lathière et al. (2006). The text of the revised manuscript in Section 4.3.4 has been amended as follows:

"The standard deviation of total annual isoprene emissions obtained here (+/- 9.1 Tg C/yr) is lower than the standard deviations of total annual isoprene emissions of +/- 30 Tg C/yr and +/- 20.2 Tg C/yr reported by respectively Müller et al. (2008) (1995-2006 MEGANv2 simulation forced with ECMWF reanalysis) and Sindelarova et al. (2014) (1980-2010 MEGANv2.1 simulation forced with MERRA reanalysis). However, the standard deviation of the reference simulation is closer to the +/- 10.8 Tg C/yr standard deviation obtained by Lathière et al. (2006) for a 1983-1995 simulation using the MEGANv2 model forced with satellite based climate archive."

Page 15 lines 8-9: I suppose that the process working on here is the influence of precipitation on soil moisture and hence on γ_{SM}. If so, this should be stated explicitly.

Indeed, the process described here is the decrease of isoprene emission in response to a reduction of soil moisture due to the decrease of precipitation obtained in the TEST_NUDG+SM simulation. The corresponding sentence has been amended as suggested to mention explicitly this process.

Technical comments

We have taken into account all technical corrections suggested by Referee #1.

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