Atmos. Chem. Phys. Discuss., 10, C14113–C14120, 2011
www.atmos-chem-phys-discuss.net/10/C14113/2011/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Evaluation of a photosynthesis-based biogenic isoprene emission scheme in JULES and simulation of isoprene emissions under modern climate conditions" *by* F. Pacifico et al.

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Received and published: 24 February 2011

Response to referee 2

General comments:

In the abstract, l.3: to underline the original aspects of this work we have added: 'We have incorporated a semi-mechanistic isoprene emission module into the JULES land-surface scheme, as a first step towards a modelling tool that can be applied for studies of vegetation - atmospheric chemistry interactions, including chemistry-climate feedbacks. Here, we evaluate . . .' See also comments on Introduction, last paragraph.

In the abstract, l.14: to comment on the contribution of vegetation on isoprene emissions, we have modified the sentence with: 'The model yields a global annual isoprene emission of 380±7 TgC/yr during the 1990s, 72% of which from forested areas'. See also comments on Section 2.1, description of JULES.

Introduction, last paragraph: to describe the strengths of this study we have added: 'A process-based approach to simulate isoprene emissions is the most appropriate for future projections since emission response is modelled consistently in the sense that the interactive effects of climate change, changes in air pollution and in atmospheric CO2 burdens on vegetation and its properties can be accounted for.'

Introduction, l.8-14: We have replaced the sentences with: 'A version of JULES including isoprene will be the land-surface component of the new Hadley Centre Global Environmental Model (HadGEM3). Inclusion of process-based isoprene emissions is necessary in order to quantify the feedbacks between biogenic emissions, atmospheric chemistry and climate within a global Earth System model under current and future climates (e.g., Arneth et al., 2010). The work described here provides a comprehensive evaluation of the performance of the land surface model in simulating isoprene emissions, a necessary step to enhance confidence in feedback estimates.'

Section 2.1, description of JULES, p.28316, l.13: to comment on the way crop is treated in the model, we have replaced 'JULES simulates vegetation dynamics using the TRIFFID DGVM (Cox et al., 2000; Cox, 2001)' with 'In agricultural areas grasses are assumed to represent crops, without any change in their parameterisation (following e.g. Arneth et al., 2008). JULES can simulate vegetation dynamics using the TRIFFID DGVM (Cox et al., 2000; Cox, 2001) or the fractional cover of each vegetation type can be prescribed, as in this study.'

Sections 2.2 and 2.3: we have not indicated units because they are not relevant for the variables in the equations.

p.28318, l.15: to clarify how CIst and IEF are calculated, we have added (p.28318, l.14): “To take advantage of published isoprene emission factors (IEFs), i.e. PFT-specific basal isoprene emission at the leaf level under standard conditions (i.e. temperature Tst of 30ïĆřC, photosynthetically active radiation of 1000μmol/m2/s and CO2 atmospheric concentration of 370ppm, see e.g. Guenther et al. (1995), Arneth et al. (2007b)) assigns PFT-specific values to ε such that II is equal to IEF.”

p.28319, l.13: see previous comment and p.28323 l.19-20 for present-day basal isoprene emissions values (IEFs) used in this study.

p.28319, l.19-21: to justify why the rate of photosynthesis is a reasonable approximation to the electron transport rate, we have modified the sentence into: ‘We assume that the rate of net photosynthesis (A) is a reasonable approximation to the electron transport dependent rate of net photosynthesis. The limiting rate of photosynthesis varies during the day and through the canopy (Sharkey, 1985). Electron transport limits photosynthesis under low light conditions, i.e. overcast/cloudy conditions, at the start and end of the day, for shaded leaves and understory vegetation. Under high light conditions ribulose-1,5-bisphosphate (RuBP), and not electron transport, limits photosynthesis, but under those conditions isoprene emission is mainly controlled by temperature. And simulate above-canopy isoprene emission (I) as:’

p.28321, l.14: to explain what was done with rainfall and snowfall missing data we have added: ‘The percentage of time step where data are missing is less than 1.5% for rainfall. Even if the number of missing snowfall data is larger for most of the sites (more than 82% for all sites but Harvard, where there are no snowfall missing data), the likely lack of leaves during snowfall times makes it irrelevant for isoprene emissions simulations. We assumed no precipitation when data are missing.’

Section 2.4, p.28320, l.28: we have added that: “LAI is simulated by JULES”.

p.28323: At line 21 we have added the sentence: ‘LAI phenological status was simulated.’ And we have modified the sentence at line 7 into: ‘and constant 360 ppm CO2

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atmospheric concentration'

Section 2.6: this section has been removed, and at the end of section 2.5 we have added 'We have also estimated global isoprene emissions from 1990 to 1999 based on the global simulation described above. These estimates are compared with previous model-derived estimates from the literature.'

p.28325, l.23-25: We have added observed LAI at UMBS in Fig. 5 in order to compare it against simulated LAI. We have changed the figure caption into 'Fig.5. Comparison of simulated and ground-based measured seasonal cycle of daily mean isoprene emissions (Pressley et al., 2005) and LAI (Pressley et al., 2006) at UMBS for 2000 and 2002.' In the text at p.28325, l.19 we have modified 'The onset of emissions is less well simulated in 2000 than in 2002, when simulated emissions start ca. 20 days earlier than observed, albeit at a very low rate. The model reproduces the observed decline in emissions during the autumn but simulated emissions continue for 20–30 days longer than shown by the observations. This reflects the fact that simulated LAI is still high during the autumn (Fig. 5), with simulated leaf fall beginning up 25 to 30 days later than observed (Pressley et al., 2005).' with 'Despite LAI being better simulated in 2000 compared with 2002, the onset of emissions is less well simulated in 2000 than in 2002, when simulated emissions start ca. 20 days earlier than observed, albeit at a very low rate (Fig. 5). The model reproduces the observed decline in emissions during the autumn but simulated emissions continue for 20–30 days longer than shown by the observations. Leaf fall beginning is well simulated in both years, but the intensity of the decline is less well simulated. During autumn 2000 simulated LAI is high for longer than observed, which could explain simulated isoprene emissions lasting for longer over autumn compared to observations. While the decline in simulated LAI is quicker than observed in autumn 2002, which does not explain simulated isoprene emissions continuing for longer over autumn compared to observations. The model overestimates LAI magnitude over the mid-summer period, with simulated emissions 43% higher than observed ones.'

At p.28328 l.24 we have modified 'Some of the mismatches between our simulations and observed isoprene emissions are most likely due to problems with the simulated vegetation phenology in JULES. Simulated emissions at the UMBS site, for example, continue for nearly one month longer than observed and this is because the trees retain their leaves for nearly one month longer than observed. Our ability to simulate the seasonal cycle of isoprene emissions, and hence the magnitude of the yearly emissions, is critically dependent on the phenology of individual PFTs as simulated by JULES. Improvements to, for example, the controls of leaf fall in JULES could produce a significant improvement in our estimates of isoprene emissions.' with 'Some of the mismatches between our simulations and observed isoprene emissions could be due to problems with the simulated vegetation phenology in JULES. Simulated emissions in autumn 2000 at the UMBS site, for example, continue for nearly one month longer than observed and this is because the trees retain their leaves for longer than observed. Our ability to simulate the seasonal cycle of isoprene emissions, and hence the magnitude of the yearly emissions, is critically dependent on the phenology of individual PFTs as simulated by JULES. Improvements to, for example, the controls of leaf fall in JULES could produce a significant improvement in our estimates of isoprene emissions. LAI is also a key variable when scaling isoprene emissions from the leaf level to the canopy-level and a more comprehensive evaluation of its magnitude would be useful for improving isoprene emission estimates'.

At p. 28329 l.9 we have modified 'We do not take leaf age into consideration in the isoprene emission scheme, although this would be possible. Our limited evaluation of the onset of emissions at the UMBS and the Harvard forest sites does not provide any guidance as to whether such a treatment is necessary: we simulate the onset of isoprene emission in 2002 and fail to simulate it in 2000.' with 'We do not take leaf age into consideration in the isoprene emission scheme, although this would be possible and could possibly explain the mismatch between well simulated isoprene onset and less well simulated LAI at the beginning of the season, and vice versa (Fig.5). Our limited evaluation of the onset of emissions at the UMBS and the Harvard forest sites does not provide enough guidance as to whether such a treatment is necessary.'

p.28327, l.13-20: we have added more details on the work by Arneth et al. (2007a) and Guenther et al. (2006). 'The results from Arneth et al. (2007a) and Guenther et al. (2006) are based on different time periods from that covered by our simulation but can be used to compare the first-order patterns of emissions.' has been turned into 'The results from Arneth et al. (2007a) and Guenther et al. (2006) are based on different time periods (1981-2000 and 2003 respectively) from that covered by our simulation , and they both obtain higher estimates for the global total (410 TgC/yr and 529 TcG/yr, respectively) but nevertheless these results can be used to compare the first-order spatial patterns of emissions (Fig. 1 in Arneth et al., 2007a and Fig. 10 in Guenther et al., 2006).'

p.28327, l.21-25: to explain how the IEFs needed to achive 600 TgC/yr were calculated we have replaced 'We have calculated the IEFs we would need to use to achieve 600 TgC/yr without further changes in the model (see Table 5). These emission factors are within the observed range of species-level IEFs measurements (Hewitt and Street, 1992; Wiedinmyer et al., 2004) for each of the model PFTs.' with 'We have calculated the IEFs we would need to use to achieve 600 TgC/yr, keeping the relative proportion of emissions between PFTs constant and without changes to the model (see Table 5). The emission factors required to achieve a global total emission of 600 TgC/yr are within the observed range of species-level IEFs measurements (Hewitt and Street, 1992; Wiedinmyer et al., 2004) for each of the model PFTs.'

Specific comments:

Throughout the paper: 'modern' has been replaced with 'present-day'.

p.28313, l.20: "are considered the main contributors" has been replaced with "are considered to be the main contributors".

p.28314, l.26: 'that seek to relate' has been replaced by 'to relate'.

p.28314, l.29: the phrase ‘Arneth et al. (2007b) scheme’ is considered correct and we have not modified it.

p.28320, l.16: ‘diurnal cycle and daily variability’ has been replaced by ‘diurnal cycle and day-to-day variability’.

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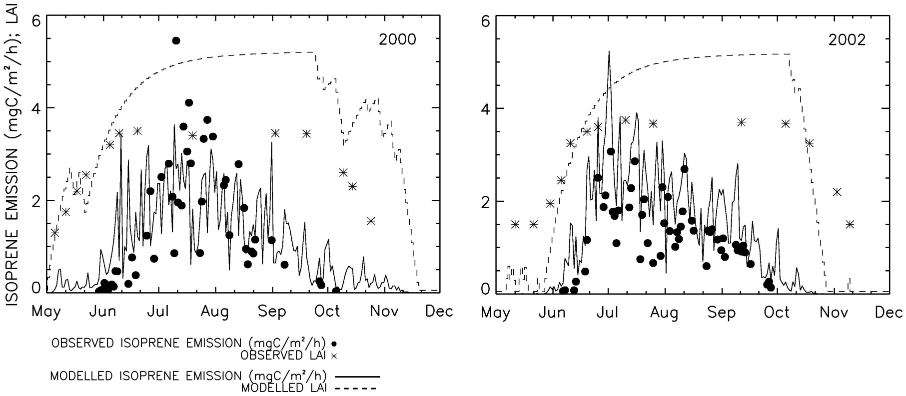

Fig. 1. Fig.5. Comparison of simulated and ground-based measured seasonal cycle of daily mean isoprene emissions (Pressley et al., 2005) and LAI (Pressley et al., 2006) at UMBS for 2000 and 2002.

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