Atmos. Chem. Phys. Discuss., 6, S74–S81, 2006
www.atmos-chem-phys.org/acpd/6/S74/
European Geosciences Union

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Estimates of global terrestrial isoprene emissions using MEGAN (Model of Emissions of Gases and Aerosols from Nature)" *by* A. Guenther et al.

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Received and published: 17 February 2006

The manuscript presents a new methodology of determining isoprene emissions from vegetation on a global scale and intends to replace former isoprene emission models from Guenther et al. 1995 and BEIS/BEIS2/BEIS3 regional models. The annual global isoprene emission estimated with the new model is about the same as previously proposed by Guenther et al., 1995, however strongly depending on the driving variables used. IPCC 2001 recommended using 56% lower global isoprene emissions compared to Guenther et al. 1995. The authors claim that the IPCC conclusion is based on insufficient performance of their model.

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The new model approach is termed MEGAN (Model of Emissions of Gases and Aerosols from Nature). This model is capable of handling the complex and manifold ecological, physiological and geographical factors that may influence emission of isoprene from vegetation. As such it extends the scope of biogenic emission modeling compared to previous efforts which were merely based on plant enclosure measurements and opens up the possibility to model future changes in emissions. Furthermore the presented method has the potential of including other factors (e.g. ozone stress and nitrogen fertilization) controlling biogenic emissions as soon as the underlying processes are better understood.

The given isoprene emission estimate is consistent with satellite observed columns of formaldehyde, a main product of isoprene oxidation. The authors give a comprehensive insight in the way how global distributed isoprene emissions will respond to changes in the Earth system.

However clearness of the given methodology description can be improved. There is some doubt about the availability of databases which are necessary for the correct implementation of the method. In spite the fact that the authors present a more simplified approach for including MEGAN in global models, called MEGAN-EZ, it is not made clear how much the computational load is reduced by this simplified approach.

On the whole MEGAN methodology is a large step forward in the description of biogenic emissions and facilitates the implementation of biogenic emissions in global models. Yet it has to be emphasized that further field campaigns are necessary to get a better coverage of the global isoprene emission distribution.

Specific Comments:

Page 112: While section 2 gives a detailed description of different measurement techniques and estimates of the isoprene fluxes and emission rates, nothing is said about the reasons why plants emit this compound in such large quantities. Also for a future prediction of emissions in a warming climate it would be of great interest to learn something about the ecological triggers for the isoprene release by plants.

Page 113: Global coverage of emission factors for isoprene is not complete as can be seen in Fig. 1. A large lack of data is visible for the boreal forests and tundra forests of Siberia. ACIA report predicts large climate changes for this region [ACIA (2004), and references therein]: 1) Most current global vegetation models and regional models project that a major part of the tundra (between 11 and 50% according to location) will be displaced by a northward shift of the boreal forest over the period in which atmospheric CO2 concentrations double. Forest is very likely to replace a significant proportion of the tundra and this will have a great effect on the composition of species. 2) Mean annual temperatures in western parts of North America and central Siberia have already increased by about 1 K (up to 2 K in winter) per decade between 1966 and 1995. 3) The tree line is projected to move north in all sectors of the Arctic, even in Greenland and Chukotka where only fragments of forest exist. Past tree migration rates were generally of the order of 0.2 to 0.4 km/yr but sometimes reached 4.0 km/yr. These rates suggest that in those areas of the Arctic that have warmed substantially in the last 30 years, tree line should already have advanced by about 6 to 120 km. However such an extension has not been recorded. 4)Rapid climate change that exceeds the ability of species to relocate is very likely to lead to increased incidence of fires, disease, and pest outbreaks.

Due to missing field observations in the region it is not clear how increasing temperatures in taiga and tundra forests will affect isoprene emissions. In addition tree composition and plant growth rates are expected to change and influence the rate of isoprene emission. It should be explained how the model copes with missing data coverage.

Page 114: On first sight it seems not necessary to define standard conditions for MEGAN. Previous definitions of standard conditions for isoprene emission factors (PPFD of 1000 mol mˆ-2 hˆ-1 and leaf temperature of 303.15 K) in Guenther et al. (1993) had physical-chemical reasons and were introduced to make different measurements of isoprene emission factors comparable. It should be emphasized already at the beginning of section 3 that the selected conditions are somewhat (or completely?) arbitrary and are eventually needed to harmonize different data sources like e.g. different canopy environment models and do not present a guideline for field measurements.

Page 114: It would be of great help to the reader, if a list of all the essential databases for the use of the complete MEGAN model and the simplified MEGAN-EZ model was provided already at the beginning of section 3. It should also be mentioned in section 3 that MEGAN-EZ is a simpler way of implementing isoprene emissions in regional and global chemistry and transport models (as already done by Abbot et al. (2003)).

On p. 116 the authors say:" Global PFT and epsilon databases are needed on time scales of 50 to 100 years for simulating global earth system changes. A considerably shorter time step for PFT and epsilon inputs is required for regional studies investigating the impacts of land cover change." This statement raises some questions. How should this goal be achieved, can it be done with justifiable effort? Are databases that use shorter time steps already available? How sensitive does the system react on the time step used?

On p.117 it is mentioned that tree isoprene emission factors were assigned to ecoregions using the Olson et al. (2001) ecoregions database. Again it would be useful to have this statement already in the beginning of section 3, because this database is now widely used and of great importance. Figure 1 depicts these ecoregions and should be larger to better recognize the ecoregions.

On p. 120 it is stated, that:" there is growing evidence that changes in the composition of the atmosphere, [...], may affect isoprene emission capacity." It should already be emphasized here that these factors are not yet accounted for by MEGAN, but may be included as soon as reliable algorithms become available (the authors mention this on p. 128).

Page 122: Exemplify the most important changes in the new algorithm for temperature and light dependence of the emission factor compared to former algorithms by

Guenther et al. (1993) and Guenther (1999a). The detailed description of the role of enzymes in isoprene production better fits into section 2.

On p.127 the authors conclude:" However, the emission rates estimated using variable t_i and t_m can be as much as 20% higher in tropical regions and 20% lower in boreal regions when foliage is rapidly changing." Can these deviations be tolerated or is the recommendation of the authors not to use constant values for t_i and t_m?

On the same page an emission factor accounting for soil moisture is derived and Equation 14 helps to estimate this emission activity factor. However, it is not mentioned at what depth the soil moisture should be determined. Could the authors better describe their utilized soil layer model?

Page 136: Please state more clearly the advantages of using MEGAN-EZ and differences compared to the full MEGAN approach. Is MEGAN-EZ the only way to use the given approach in a global climate model or are there ways to implement the complete MEGAN model? As already mentioned, it should be clearly mentioned which databases are necessary for MEGAN-EZ and there they are available (best way would be a list or a table).

The use of past (leaf) temperatures, T_24 and T_240, might be a problem for global climate models when temperatures are calculated during the run. Unfortunately, T_opt is used in MEGAN-EZ as given in Equation (8) and thus still depends on T_240. Is it possible to use for example the average monthly (air) temperature? Is it justified not to account for the influence of soil moisture on the emission? How large is the expected deviation from MEGAN if this factor is considered?

Page 161 (Table 2): an additional table should be provided to show deviations found for certain regions (boreal forest, tropics, temperate, etc.) when using different databases. Table 2 merely displays deviations for the total global emissions. This kind of table would be very useful for the reader. If the tropics (tropical broadleaf forests) dominate the global isoprene production by plants than it is especially interesting to see the

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deviations for this ecoregion.

Canopy loss and production, rho:

The effective emission of a tree canopy is lower compared to the emission from the leaf/needle surface. Loss of isoprene in the canopy is stated to be practicably negligible in the given concept. This is mainly based on the conclusions given by Stroud et al. (2005) and a sensitivity study using their model. When using standard conditions for friction velocity and canopy height (u_star=0.5 m sˆ-1 and H=30 m) and only varying isoprene lifetime from 1370 s to 6870 s Equation (15) gives rho values ranging from 0.982 to 1.004. Thus a change of isoprene lifetime in the given range does not influence rho significantly. Only if we introduce a value of 600 s for the lifetime of isoprene, delta becomes 0.95 and thus isoprene emissions are reduced by 5% due to chemical loss in the canopy. This behavior is in contrast to observations in different forest sites [e.g. Forkel et al. (1999), Makar et al. (1999)] where isoprene fluxes from the canopy were shown to be reduced by about 10 to 40% compared to the potential emission.

The canopy escape efficiency for isoprene calculated by Stroud et al. (2005) using the model from Makar et al. (1999) was 0.90, indicating that the transport time scale is considerably faster than the chemical loss time scale for isoprene. Results from Stroud et al. still suggest a 5 to 10% reduction of the isoprene emission rate due to chemical loss in the canopy. Applying Equation (15) to this forest site (u_star=0.2 m sˆ-1 and H=18 m) the isoprene lifetime has to be as short as 930 s to yield a rho value below 0.95. However, such a short lifetime cannot be explained using their simulated NO3 and OH concentrations. Altogether it seems that the simple approximation of the canopy loss term through Equation (15) underestimates the influence of chemical loss on isoprene emissions.

The possibility of canopy uptake of isoprene oxidation products is discussed at the end of this section. However, the authors do not give an approach to consider the loss of oxidation products. Is this intended for MEGAN in the future? Maybe the authors

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should also note that in a forest study at the Jülich forest site in Germany (Koppmann et al., 2005), no uptake of isoprene and its oxidation products methacrolein and methyl vinyl ketone in the canopy was observed. On the other hand accompanying plant chamber experiments revealed direct emission of methacrolein and methyl vinyl ketone from birch.

References used here:

ACIA, (2005): Chapter 7: Arctic Tundra and Polar Desert Ecosystems. In: Arctic Climate Impact Assessment, Cambridge University Press. http://www.acia.uaf.edu

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Koppmann, R., J. Kesselmeier, F. X. Meixner, M. Schatzmann, B. Leitl, T. Hoffmann, R. Dlugi, M. Zelger, J. Kleffmann, A. Neftel, J. Dommen, C. Thomas, T. Trautmann, and B. Neininger, (2005): Emission and chemical transformation of biogenic volatile organic compounds (ECHO) - Investigations in and above a mixed forest stand. In: Results of the German Atmospheric Research Programme - AFO 2000, ed. by R. Winkler, pp. 29-39, Federal Ministry of Education and Research, Publications Division, Bonn, Berlin. http://www.fz-juelich.de/icg/icg-ii/datapool/page/70/ECHO_Final_Report.pdf

Technical Corrections:

1.) p.122: "MEGAN canopy environment model is based on the method described by Guenther et al. (1999)..." > does this refer to Guenther et al., 1999a or 1999b or both?

2.) p.122: Equation (5), Exp should not start with a capital letter, replace with exp.

3.) p. 137: Equation (17), replace Sin (a) with sin (a).

4.) p.140: "Shim et al. conducted..." should be replaced by "Shim et al. (2005) con-

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ducted..."

5.) p.142: "Estimates of PTF changes generally indicate that isoprene emissions have increased in the past 50 to 300 years and will decrease over the next 50 to 100 years." $>$ predicted future change depends on the PFT distribution used. This should already be mentioned here but is discussed in section 7.1 on page 143: "MEGAN simulations using the IMAGE and MAPSS-P PFT databases predict isoprene emission responses to future (year ˜2100) PFT distributions that range from a 30% decrease with IMAGE to a 6% increase with MAPSS."

6.) Figure 1: the size of the three globes should be larger for a better visibility of the ecoregion distribution.

Interactive comment on Atmos. Chem. Phys. Discuss., 6, 107, 2006.