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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Evaluation of MEGAN-CLM parameter sensitivity to predictions of isoprene emissions from an Amazonian rainforest" *by* J. A. Holm et al.

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Response to Referee #1 – In review of MS acp-2014-684

We would like to sincerely thank the referee for taking the time and effort in reviewing our manuscript. The referee brought forward several issues that need clarification, most of which require changes in the manuscript with a focus on clarifying and revising the methodology, as well as revising some figures. We have incorporated these modifications and hope that the changes we are suggesting are sufficient. The changes listed below have been incorporated into a final version of the manuscript, which we

hope will be reviewed and accepted for publication.

Foremost, we agree with the comments by the anonymous referee.

1) We agree that the sensitivity analysis of the Monte Carlo simulations needs to be clarified. Below we have addressed each individual question, and we have updated the methodology section in the manuscript. First we would like to note that there are 19 model parameters used in MEGAN-CLM that determine isoprene emissions. Out of these 19 parameters, 5 are constants, and 14 are continuous. These can be found in Table 2 of our manuscript.

"Were the Monte Carlo simulations conducted varying 14 or 19 parameters?" The first simulation varied 14 parameters (i.e. the non-constant, continuous parameters. Results seen in Fig. 3a and row two of Table 3). In total we conducted 20 separate Monte Carlo simulations. The remaining 19 Monte Carlo simulations, were 'one-at-a-time' simulations, in which 1 parameter was varied and all other were held constant. These were conducted for all 19 parameters, thus 19 simulations (Table 3). We agree that this methodology is somewhat confusing. Therefore, we have re-ran the initial Monte Carlo simulation so that all 19 parameters are varied (as opposed to only 14), so including the constant values. This keeps a consistent number of evaluated parameters, such that (1) all 19 are varied, and (2) all 19 parameters are looked at individually.

"How did the authors decide to vary the parameters, and what is the range used?" We apologize that this methodology description was absent in the submitted manuscript, and should be included in the revised version. The parameters were varied between the minimum and maximum range as simulated by the CLM for the tropical study site over a time period of 20 years. Therefore accounting for model and annual variability. This model output range is now included in an updated Table 2 (see below). We found that the average range of continuous variables were around 10% of the mean. Therefore, with respect to varying the constant parameters, we created a minimum and maximum that was $\pm$ 10% of the constant value.

“In the one-at-a-time experiences, to what values were the other parameters held constant?” During the one-at-a-time Monte Carlo simulations, the non-varied parameters were held at the mean values determined from the 20-year CLM run for the tropical study site.

With respect to the comments referring to Fig. 3. Yes, we confirm that 3 of these top 10 variables are model constants. In accordance with methodology that was laid out above (which will be updated and clarified in the manuscript), we did also vary the constants by a 10% spread. Therefore in our sensitivity analysis the constant parameters did contribute to variability. Another study looking at parameter sensitivity in a forest carbon flux model (Verbeeck et al. 2006) has shown that constant variables in the model, once varied in a Monte Carlo approach, do account for output uncertainty. Therefore, we believe that varying the constant parameters in MEGAN could give us insight into isoprene uncertainty.

2) Evaluation of modeled isoprene emissions. We note that the referee is concerned with using observed isoprene emissions from four Brazilian sites, over different time periods, and using different measurement methods. We agree that this study cannot infer seasonal trends, or report seasonal variability due to site differences. We agree that we have created an artificial Brazilian data set in which spatial and inter-annual variability has been neutralized. This is because our goal was to find a regional average for isoprene emissions from the Brazilian rainforest to compare to ecosystem scale model predictions. MEGAN-CLM uses a 1 degree resolution gridcell, which is roughly ∼100km2, that reports canopy-level isoprene flux. To compare to this coarse, landscape scale, we found that it was beneficial to have estimates from multiple locations to incorporate high spatial variability in emissions. On page 24009 of the discussion paper we have tried to make this point that month-to-month variability should not be considered in this study because we are using estimates from four different sites. However, we can improve our language here to make this case stronger. On page 24009 we also reference Harley et al. (2004) who shows that there is high variance in

biogenic emissions taken from the same ecoregion. However in out methods section 2.5 (in situ Amazon isoprene emission measurements), we should state more clearly that in order to compare to a landscape level, 100km2 model gridcell over the annual time period, we wanted to use an average emission value that also takes into account spatial, site, and annual variability.

However, in addition to using the Brazilian artificial data set, we also think it is beneficial to compare the model results to one specific location and one measurement technique, thus retaining site characteristics and reducing variability. We believe this will show how the model cannot capture the fine-scale spatial and temporal variability that influences isoprene emissions. The site closest to the in situ leaf temperature measurements, and the single gridcell picked from MEGAN-CLM was the Reserva Biologica do Cuieiras, AM, Brazil site (02°36’S 60°12’W). Two different studies have conducted isoprene measurements at this site, but we picked the measurements conducted by Alves to reduce measurement biases. Isoprene flux from 2013 was found to be 1.7 mg m-2 h-1. These new site level results have been compared to MEGAN-CLM4.5 landscape level (2°35’S, 60°W) isoprene results for the same two-month period, finding that the model overestimates isoprene (4.0 vs. 1.7 mg m-2 h-1). These results will be included in the revised version of the manuscript.

3) Evaluation of modeled leaf temperature. We note that the referee is concerned with differences in inter-annual variability between meteorological data used by CLM and meteorology observed at the site. We agree that there are inherent differences in the meteorological forcing data used in CLM and the observed climate during the 2003 sampling period. In order to clearly define the modeling uncertainties and biases in predicting isoprene emissions, then the model should be forced with site level meteorological data from the field campaign. We conclude that is this a worthy revision, and CLM should be forced with site level meteorological data. However, a goal of this paper was to determine how MEGAN-CLM performed at modeling isoprene emissions, and which parameters contributed high levels of uncertainty. The atmospheric forcing

data sets and climate provided by CLM play a large role in isoprene uncertainty, and thus is worthy to be included in the over-all model evaluation. We agree with the referee that the observed leaf temperature measurements (which were recorded every minute) should be converted to the same scale as model outputs (i.e. hourly), for comparison purposes. Therefore the in situ data in minutes has been averaged to hourly intervals. Fig. 4 has been updated to include these changes.

Additional Comments: We hope that improving and clarifying the methodology section relating to the Monte Carlo simulations will improve the unclear sections of this manuscript. We also note that the audience might not be familiar with the CLM model and we have reduced the technical jargon related specifically to CLM. We also agree with the referee that there are too many values summarized from other modeling studies in the discussion section (specifically section 4.1). We believe that removing these values and including them in a short table can help streamline the discussion. We have included an example of this table below, which we have inserted into the revised manuscript. This has reduced the text in section 4.1 and made it straightforward, and easier to read.

We appreciate the thoughtful comments and reviews by the referee, and think the paper is stronger as a result.

Thank you for your consideration, J. A. Holm

Verbeeck, H., Samson, R., Verdonck, F., and Lemeur, R.: Parameter sensitivity and uncertainity of the forest carbon flux model FORUG: a Monte Carlo analysis, Tree Physio., 26, 807-817, 2006.

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 23995, 2014.

Table 2. Parameter name, sub-equation assignment, and mean ± SD estimated by CLM 4.0 and CLM 4.5 for a Central Amazon forest for all variables in the emission activity factor (γ, Ep. 1). NA = not a standard output in model version.

Parameter	Parameter Description	Sub-Equation	CLM4.0 (±SD)	CLM4.5 (±SD)	CLM4.0 Range	Units
T_{leaf}	Leaf temperature	γT	301.25 (0.78)	300.63 (0.74)	4.46	K
T_{leaf_24}	Leaf temperature in the last 24 hours	γT	301.25 (0.77)	300.49 (0.79)	4.43	K
T_{leaf_240}	Leaf temperature in the last 240 hours	γT	301.25 (0.72)	300.49 (0.69)	3.76	K
CT1	Empirical coefficient	γT	95	95	19	Constant
CT2	Empirical coefficient	γT	230	230	46	Constant
PAR_{SUN}	Sunlit PAR	γP	353.99 (34.24)	343.83 (34.84)	182.78	$\mu mol/m^2/s$
PAR_{24_SUN}	Sunlit PAR in last 24 hours	γP	341.47 (33.59)	327.02 (29.84)	173.86	$\mu mol/m^2/s$
PAR_{240_SUN}	Sunlit PAR in last 240 hours	γP	341.20 (32.29)	326.59 (23.66)	160.93	$\mu mol/m^2/s$
PAR_{SHADE}	Shade PAR	γP	131.85 (4.01)	118.55 (3.98)	20.28	$\mu mol/m^2/s$
PAR_{24_SHADE}	Shade PAR in last 24 hours	γP	144.37 (4.39)	135.26 (4.24)	21.48	$\mu mol/m^2/s$
PAR_{240_SHADE}	Shade PAR in last 240 hours	γP	144.67 (4.25)	135.64 (3.52)	20.97	$\mu mol/m^2/s$
$P0_{SUN}$	Standard condition for past 24 hours for sun leaves	γP	200	200	40	$\mu mol/m^2/s$ (Constant)
$P0_{SHADE}$	Standard condition for past 24 hours for shade leaves	γP	50	50	10	$\mu mol/m^2/s$ (Constant)
C_{CE}	Factor that sets emission activity to unity at standard conditions	γL	0.3	0.3	0.10	Empirical Constant
LAI	Leaf area index	γL	8.85 (0.13)	6.39 (0.08)	0.57	m^2/m^2
$forc_{pbot}$	Atmospheric pressure	γC	100,446.24 (105.73)	NA	556.00	Pa
Ci_{SUN}	Sunlit leaf intracellular CO_2	γC	-466.87 (19.31)	NA	41.46	Pa
Ci_{SHADE}	Shade leaf intracellular CO_2	γC	-466.11 (19.36)	NA	41.67	Pa
F_{SUN}	Sunlit fraction of canopy	γC	0.06 (0.002)	0.09 (0.002)	0.01	%

Fig. 1. Updates to Table 2

Table 5. Global isoprene flux (Tg C) predicted by various emission and ecosystem models, and estimated and direct measurements of local isoprene emission (mg m^{-2} hr^{-1}) from Amazonia sites.

Emissions Algorithm/Model	Model Name	Global Isoprene (TgC)	Reference
G95	57 ecosystems defined by Olson (1992)	503	Guenther et al. (1995)
CTM	LSM	530	Wang and Shallcross 2000
G95	NASA-CASA	559	Potter et al. (2001)
G95	CCSM	507	Levis et al. (2003)
G95	IBIS	454	Naik et al. (2004)
Niinemets et al. (1999), photosynthetic supply	LPJ-GUESS	412	Arneth et al. (2007)
G95	ISAM	601	Tao and Jain (2005)
Location	**Measurement Technique**	**Isoprene Flux (mg m^{-2} hr^{-1})**	**Reference**
Ducke Forest Reserve, Brazil	Chemistry model on vertical profiles within CBL	1.6	Jacob and Wofsy 1988
Ducke Forest Reserve, Brazil	Mixed layer gradient from vertical profiles within CBL	3.6	Davis et al. (1994)
Reserva Biologica do Cuieiras, Tower K34, Brazil	Relaxed eddy accumulation	2.1	Kuhn et al. (2007)
Reserva Biologica do Cuieiras, Tower Z14, Brazil	Relaxed eddy accumulation	7.8	Karl et al. (2007)
Iquitos, Peru	Mixed layer gradient from vertical profiles within CBL	8.2	Helmig et al. (1998)
Reserva Biologica do Jaru, Brazil	Tethered balloon-sampling	9.8	Greenberg et al. (2004)

Fig. 2. Table 5