Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2019-334-RC2, 2020

Geoscientific
Model Development
Discussions

Interactive comment on "Development of a Reduced Complexity Plant Canopy Physics Surrogate Model for use in Chemical Transport Models: A Case Study with GEOS-Chem v12.3.0" *by* Sam J. Silva et al.

Anonymous Referee #2

Received and published: 16 March 2020

This manuscript describes the development of a surrogate canopy model for implementation in Chemistry Transport Models (CTMs). The surrogate canopy model will allow canopy physics to be represented in CTMs without increasing computational costs with the futher aim of better representing atmosphere-biosphere exchange processes, which are necessarily highly parameterized in large scale CTMs.

The authors use a machine learning regression method to establish which variables are most important for determining leaf temperature and leaf-level PAR in the canopy physics model (MEGAN3). These were identified as air temperature, and PAR incident

on the canopy and local vegetation LAI, respectively. These variables were then used in simplified models of leaf temperature and leaf-level PAR.

The surrogate canopy model was tested against MEGAN3 for leaf temperature and PAR. The surrogate canopy model was then tested against MEGAN3 in the GEOS-Chem CTM for atmospheric composition. The authors found small changes at the global scale, but large changes in the regional distribution of isoprene emissions. Finally, the authors implemented the surrogate canopy model in to GEOS-Chem in conjunction with new MEGAN3 emissions.

General comments:

The development of the surrogate canopy model is useful advancement in modelling biosphere-atmosphere exchange in large scale CTMs. The authors demonstrate that the surrogate canopy model performs reasonably in comparison to the canopy physics model, MEGAN3, and can improve the performance of a CTM in simulating atmospheric composition. The manuscript is generally well written and clear, and I recommend it for publication. However, I have some comments that should be addressed.

1. I felt that there could be more analysis of why the surrogate canopy model performs differently from the full canopy model, or from MEGAN(PCEEA) when implemented in GEOS-Chem. For example: - Section 3.1.1, L245-255 -> Why is the surrogate canopy model biased cool over highly vegetated/tropical regions and biased warm over northern boreal forests and arid regions?

- Section 5, L570-585 -> What exactly drives the differences in isoprene emissions between MEGAN(PCEEA) and MEGAN(Canopy) in Figures 9b and 9c? Figure 10 suggests that the differences in isoprene emissions are due to differences in the way LAI and leaf level PAR are represented in MEGAN(PCEEA) and MEGAN(Canopy), but can the authors offer any more insight in to exactly how these differences in canopy physics might drive the differences in isoprene emissions?

- Section 5, L601-621 -> Again, can the authors suggest why monoterpene emissions are less in MEGAN(Canopy) compared with MEGAN(PCEEA)?

- Section 5, L629-640 -> What drives the differences in dry deposition between MEGAN(Canopy) and MEGAN(PCEEA)

2. While I am aware that there are limited observational data sets of surface isoprene concentration, there are a number available. For example, the OP3 campaign in SE Asia (Jones et al., ACP, 2011). I think the paragraph in section 5 (L593-600) could be expanded to include more observational data sets.

3. Please re-write the captions for Figures 3-6. For example, for Figure 3: "Surrogate model performance for the annual canopy average spatial temperature in 2012. Panels...."

Specific comments

Abstract: L26-28 -> The authors imply that surface ozone simulated in GEOS-Chem is closer to observationally constrained values when the surrogate canopy model is used - This should be quantified with e.g. a global total.

L26-28 -> The authors state that there is no noticeable impact on computational demand - would it be useful to provide an indicative metric to illustrate this? E.g. wall clock time for a years run?

Section 3: L200-205 -> The authors calculate 20 parameters with which to model all plant canopies across the globe, ignoring the role of vegetation classes, which if considered, would increase the number of parameters to 120. Although the surrogate canopy model performs reasonably well, did the authors test if using the 120 parameters improved the performance, or conversely , degraded the computational efficiency?

L223-225 -> For clarity, could the authors adjust the following sentence to something like this: "From this relatively simple three-function parameterization (Leaf Temperature, Leaf PAR, and Sunlit Leaf fraction), we are able to implement more physically re-

alistic parameterizations for biosphere-atmosphere interactions *in Geos-Chem/CTMs*."

Section 3.1.1 There are a couple of passages in this section that were unclear to me. Could the authors please re-word these sections so that their meaning is clearer.

L262 -> "The broad shape of the vertical distribution is consistent everywhere." By 'broad shape' do the authors refer to the canopy profile? And by 'everywhere' do the authors mean spatially, i.e. for different parts of the globe, or for different vegetation types?

L264-269 -> "The higher order variability (e.g. small differences within layers at the top and bottom of the canopy) stems from the more detailed representation of canopy energy balance in the full MEGAN3 model, which includes the influence of terms like PAR, relative humidity, LAI, and wind speed. However, the generally consistent behavior of this higher order variability allows for it to be reproduced in the simplified surrogate model."

Firstly, I do not quite understand where the 'higher order variability' occurs. In Figure 4 temperature is plotted at each canopy level so it is not possible to see any variability within canopy layers. Secondly, what is the higher order variability consistent with?

Section 3.1.2 L294-299 -> Please consider rewording the following sentences as suggested. "The low *leaf level PAR* values in the rain forest are coincident with the highest LAI values globally, leading to very strong shading effects below the first canopy layer. The northern boreal forests *have low leaf level PAR* in part due to relatively high LAI, but also due to reduced incoming PAR in the winter months when the solar angle is low."

L305-308 -> "The worst model R2 performance is over regions with the highest LAI, where the elevated importance of shading and resulting complexity in the PAR calculation is more challenging for the simplified representation of the surrogate model"

Is this really correct? Figure 5b shows the poorest surrogate model performance in central Asia, to the west of the Andes, eastern Australia and an area of the central Sahel - all areas with low LAI according to Figure 2. I do agree that there is relatively poor surrogate model performance in the western Amazon, central sub-Saharen Africa, and perhaps Borneo (although the surrogate model performance seems ok over the rest of the maritime continent), but the statement linking poor surrogate model performance to high LAI seems too broad brush - some further clarification is perhaps needed.

L351-354 -> Does the surrogate model struggle to simulate leaf level PAR in the lower canopy for high LAI regions due to the same reasons given in L305-309, i.e. that the shading and increased complexity of the PAR calculation is harder to do in the simplified model?

Technical comments:

Section 4.1 L453 L459 -> Should the Current Temperature of 298.5 K in L459 be the same as the current air temperature of 303 K in L453?

Section 6 L700-701 -> Should the units of umol m-2 h-1 be consistent with the units of ug m-2 hr-1 used in Figure 14?

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