

Interactive comment on “A study of the impact of land-use change in Borneo on atmospheric composition using a global model” by N. J. Warwick et al.

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Received and published: 27 June 2013

We thank the reviewers for their constructive and helpful suggestions which have improved the quality of this work. We have provided our responses to Reviewer #1 below.

1. The results from this study can be qualitatively arrived at from the several previous studies on isoprene emission changes and land use change. All that is new here is that the authors are applying a high(ish) resolution model over Borneo, as opposed to considering changes in the Amazon (e.g. Ganzeveld and Lelieveld, 2004), USA (e.g. Wiedinmyer et al., 2006) or globally (e.g. Ashworth et al., 2012). [I realize that Ashworth

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et al. (2012) specifically consider Borneo, albeit with a lower resolution model – is this study an extension of that? If so, this should be made clear in the Introduction.]

Response: Previous studies considering the impact of changing land use on atmospheric composition have included box/column model studies, looking at the impact of specific changes in emissions on local chemistry, and global studies using more general (and more uncertain) predictions of changes in biogenic VOC and anthropogenic emissions to diagnose changes in composition. Our study is original in that it uses actual flux measurements of oil palm isoprene emissions and detailed calculations of the associated oil palm NO_x emissions to assess the potential global extent of changes in atmospheric composition arising from the growth of oil palm industry in this region. It is also the only global 3D study to attempt to quantify the impact of current uncertainties in isoprene chemistry. In the revised paper, we emphasize the differences from previous work more clearly and expand the discussion on the global/regional aspect of our study, including additional figures showing the modelled changes in composition over a more extensive area.

2. Is there some way to apply the results? E.g. what is the maximum level for the associated NO_x emissions in order to satisfy AQ concerns? - Is there something unique about the maritime/terrestrial nature of Borneo that means it deserves particular focus? Could we have halogen-mediated oxidation of isoprene even? (E.g. Orlando et al., 2003) - Are there upper atmosphere/further afield impacts? Is Borneo a region where, pound-for-pound, these impacts are more strongly felt? - Are there bigger “Earth system” effects to consider? E.g. knock-on impacts to natural soil NO_x emissions, deposition impacts (was this changed?), links with biomass burning changes (e.g. changing from “natural” forest to palm oil might change emission composition, amount and frequency). As is hinted at by the last two suggestions, the manuscript would also benefit from a clearer identification of why Borneo is the focus of such a study. Is it building on previous work? Due to the availability of measurement data? Undergoing a particularly quick change?

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Response: We agree a clearer identification of why Borneo is the focus of this study would be helpful and is added to the revised version. We chose to focus on this region as it currently experiencing rapid changes in land use and there is also detailed flux and concentration measurement data available. As suggested, we have included discussion on further afield impacts in the revised manuscript and a Figure showing changes in composition in the upper troposphere to better reflect the global nature of this study. While interesting, we believe the other suggestions would require several further model simulations and would therefore contribute to a separate study.

3. Along these lines, is p-TOMCAT the right tool for this study? I.e., why use a global model to investigate a local region, when there are tools like WRF-Chem? Furthermore, in the cited Pike et al. study, those authors make use of a 0.56 resolution p-TOMCAT version. Why is that not used here? Are there issues with the orography for that version? Something else?

Response: We chose to use the global p-TOMCAT model as this would allow us to determine the spatial extent of the impact of changes in Borneo emissions on atmospheric composition and to calculate whether there could be a global scale impact. A ~1 degree rather than 0.56 degree resolution version of p-TOMCAT was used as it enabled us to run more model scenarios with the computer time available, assessing uncertainties in chemistry and other model parameters. We initially compared model output from model runs at 0.56 and 1 degree resolutions and found little difference in the results.

Title: Consider dropping "A study of"

Response: We have shortened the title to 'A global model study of the impact of land-use change in Borneo on atmospheric composition'

Abstract: Consider shortening this and making a little more "punchy"

Response: The abstract has been shortened.

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P7434, L1-2: Citation?

Response: Added.

P7434, L18: Citation?

Response: There are already three citations for this sentence.

P7434, L26: Define HCFCs

Response: Done.

P7438, L19-26: Not very clear for a non-specialist – please clarify

Response: The discussion on HO_x regeneration schemes has been expanded.

P7439, L3-4: "...taken from Stevenson et al. (2006)." (Sect. 3 and 4 could probably be considerably shortened, and combined to make a "Model set up" section, with two sub-sections)

Response: These sections have now been combined and shortened.

P7440, L4-123: There is a lot of text about possible palm oil scenarios here, only to finish with a sentence saying that none of that is taken into consideration and the whole of Borneo is going to be covered in palm oil. Perhaps this could be re-written with what was done, followed by a justification?

Response: This paragraph is now shortened in the revised manuscript.

P7440, L11: What is the "NCAR vegetation distribution"? Citation?

Response: The NCAR vegetation distribution is based on ground-based observations backed up by satellite retrievals. Full details of how it was compiled are in Guenther et al., (2006). This information is now provided in the revised manuscript.

P7440, L16: Why "< 60%" if "much is on Borneo"? What is the actual percentage?

Response: Although Figure 1D of Stickler et al., (2007) shows the distribution of areas

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suitable for oil palm, the actual percentage of the total Indonesian area situated on Borneo is not provided. However, it is clear from Figure 1D that a large fraction of the Indonesian total is situated on Borneo. This paragraph has now been shortened (see this Reviewer's previous comment for P7440, L4-23) and the percentage estimate quoted above has been removed.

P7441, L1-17: Why go into such detail with the NO_x emissions if the palm oil isoprene emissions are rather more general?

Response: Both the NO_x and isoprene emissions used in this study represent our best estimate for this region. In the case of isoprene, the best estimate is provided by isoprene flux measurements during OP3 as there are large uncertainties associated with isoprene emissions calculated by vegetation models. As NO_x fluxes were not measured during OP3, the best estimate of the NO_x fluxes is provided by N₂O measurements for the fertiliser application and estimates of palm oil yield and emission factors for the industrial emissions.

P7441, L7-8: Does the fertilizer application vary randomly for each model run?

Response: The fertiliser application varies randomly within the runs, but varies in the same way for each model run. This has been clarified in the text.

P7441, L14: what is meant by "believed to be"? Believed by who?

Response: The citation for this point is Reijnders and Huijbregts (2008) and was provided in the previous sentence. We have revised the text to make this clearer.

P7441, L24: Suggest that this last sentence is the first sentence of the section, in order to help those scanning the paper.

Response: The sentence has been moved.

P7442, L20: "...excluding a morning peak" – please clarify what is meant here.

Response: The model produces a morning peak in OH that is not seen in the mea-

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surement data. This sentence has been re-written.

P7443, L8: Express as lifetime perhaps?

Response: We have expressed the data as reactivities to allow easier comparison with data in the Whalley et al. (2011) paper which is expressed in units of s⁻¹.

P7443, L27-: Are the results robust to boundary layer height uncertainties?

Response: Further details on the boundary layer scheme used in p-TOMCAT are included in the revised manuscript. The discussion on boundary layer height uncertainties in the Pike et al. (2010) study focused on particular problems associated with the model representation in boundary layer height at the Bukit Atur measurement site in Danum Valley, a site located on a ridge, where it is particularly difficult for models to represent physical processes. As we are considering regional rather than local changes in composition, our results should be much less sensitive to the local uncertainties in boundary height.

P7444, L20-: This discussion in this paragraph would be strengthened with some ozone budget statistics. Also, "an increase in VOC concentration results in an increased NET chemical sink for ozone". Higher levels of reasonably complex VOCs can also impact ozone production terms, by impacting NO_y speciation.

Response: We have the ozone budget information for the model scenarios considered. However, as the surface NO_x emissions associated with fertilisation are introduced statistically, the budget varies significantly in time and space. This is now addressed in the revised manuscript. We have changed the text to read 'increased net chemical sink'.

P7445, L7-20: While it may be that moderate ozone concentrations can lead to adverse impacts on plants and humans, I feel that this connection is rather overplayed here. Why worry about 35 ppb in Borneo, where other regions of the world have far higher concentrations? In my view, highlighting potential health impacts needs much more

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justification than is there currently.

Response: In this paragraph our aim was to give a balanced review of the implications of an increase in ozone levels to 35 ppb. In addition to mentioning evidence for possible health/crop impacts, we do state that O₃ levels of 35 ppb are much less than seen elsewhere in the Northern Hemisphere and fall below WHO air quality thresholds. We also point out that if we apply the calculated 70% in O₃ to observed O₃ levels, then monthly mean O₃ mixing ratios only increase to 20 ppb. We will re-phrase this paragraph to further emphasize that our calculated O₃ mixing ratios in the PALMX scenario are much less than is currently seen elsewhere in polluted regions.

P7445, L22: "...decreases...up to 70%" (remove minus sign)

Response: Done.

P7445, L29: "Significant"? As per which statistical test, and against which measure of noise? (Also, P7447, L29)

Response: Sentence has been re-written.

P7446, L11-24. Much of the content of this paragraph is the same as that at the end of Sect. 5.1

Response: We acknowledge the repetition and it has been removed.

Figure 1: "Model fit to..." Clarify which model (i.e. not p-TOMCAT)

Response: The legend has been re-written. This is a sine curve fit to the data that is used to represent the emissions in the p-TOMCAT model.

Figure 2: Needs larger text. Legend in first panel only.

Response: Changed.

Figures 3-6: Titles above and to the side of the panels would make quick reference much easier than deciphering the caption.

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Response: Changed.

TYPOGRAPHICAL/TECHNICAL CORRECTIONS:

Throughout: "fertiliser" or "fertilizer"?

Response: Changed to fertiliser.

P7434, L1: "South East Asia"

Response: Done.

P7437, L9: "...tropical rainforests."

Response: Done.

P7437, Sect. 3: Should be past tense for what you "did" with the model

Response: Changed.

P7448, L10: "Paper XXX" Is there/will there be a number?

Response: We are still awaiting the number. It will be included in the revised version.

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 7431, 2013.

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