We thank the reviewers for their helpful comments, which have led us to a substantially improved version of the paper. Here, the reviewers' comments are shown in boldfaced black text, and our responses are shown in non-boldfaced blue text. The page and line numbers to which we refer in our responses correspond to the updated manuscript (the comments of all reviewers are taken into account in this updated manuscript).

First and foremost, we confirm that the tropospheric chemical mechanism in GISS ModelE2 is not CBM04. The original manuscript version contained an incorrect oversimplified description of the tropospheric chemistry scheme in GISS ModelE2 that has caused our Reviewers confusion and understandable concerns. We understand that using an old-fashioned chemical mechanism developed 25 years ago for urban polluted high-NOx environments would be an inappropriate tool to apply to a study of large-scale isoprene emission perturbation in the tropics. The chemical mechanism in GISS ModelE2 has been substantially updated and improved over the past 15 years, for example, to account for important reactions, pathways, and species under low-NOx conditions (e.g. Shindell et al., 2003; 2006; 2013; Schmidt et al., 2014).

We now include a more detailed description of the chemical mechanism in Section 2.1 (ModelE2-YIBs description) (Page 4, Line 32):

"The troposphere features NO_X-O_X-HO_X-CO-CH_4 chemistry; an explicit representation of isoprene; and a lumped hydrocarbon scheme involving terpenes, peroxyacyl nitrates (PANs), alkyl nitrates, aldehydes, alkenes, and alkanes. The representation of hydrocarbons generally follows Houweling et al. (1998), which is originally derived from the Carbon Bond Mechanism-4 (Gery et al., 1989) and the Regional Atmospheric Chemistry Model (RACM; Stockwell et al., 1997), but includes several modifications aimed at representing the wide range of chemical conditions found in Earth's atmosphere, such as the addition of reactions important in low-NO_X conditions including representation of organic peroxy radical chemistry under low-NO_X conditions and introduction of organic nitrate chemistry. Shindell et al. (2013) describe in detail the recent updates to the tropospheric chemistry scheme, including the incorporation of acetone chemistry (Houweling et al., 1998) and the addition of terpene oxidation (Tsigaridis and Kanakidou, 2007). SOA formation is driven by NO_X-dependent oxidation of emissions of isoprene, monoterpenes, and other reactive VOCs following a volatility-based two-product scheme (Tsigaridis and Kanakidou, 2007). The formation of secondary inorganic aerosols, including sulfate (Bell et al., 2005; Koch et al., 2006) and nitrate (Bauer et al., 2007a), depend on both modeled oxidant levels and the availability of source gases. Primary aerosol types include dust (which provides a surface for heterogeneous chemistry; Bauer and Koch, 2005; Bauer et al., 2007b), black carbon, organic carbon, and sea salt (Koch et al., 2006). Stratospheric chemistry, introduced to the chemical mechanism by Shindell et al. (2006), includes nitrous oxide (N_2O) and halogen (bromine and chlorine) chemistry. Recent updates to stratospheric chemistry are summarized by Shindell et al. (2013) and include changes in the representations of polar stratospheric cloud formation (Hanson and Mauersberger, 1988) and heterogeneous hydrolysis of N_2O_5 on sulfate (Hallquist et al., 2003; Kane et al., 2001)."

Interdisciplinary work is challenging. We would like to emphasize the novel aspects of this project. (1) The land cover dataset for maritime Southeast Asia that we use in our study is built from an existing classification based on Landsat images (Gunarso et al., 2013). This dataset represents a wall-to-wall mapping of land cover in this region, including explicit representation of plantations of oil palm (high isoprene emitter) and rubber (high monoterpene emitter). Gunarso et al. (2013) used a consistent classification methodology for each year of their analysis, which has provided an internally consistent set of land cover maps for this period for this region. Other studies have investigated the atmospheric composition impacts from land cover change in this region: Ashworth et al. (2012) considered a projection of forest to oil palm conversion based on meeting future demand for biofuels; Warwick et al. (2013) considered the total conversion of Borneo to oil palm from forest; and Silva et al. (2016) considered the impact of 2010 oil palm cover relative to an oil-palm-free landscape in addition to considering future projections of oil palm. We consider the impacts of actual historical land cover change, which is clearly different than Ashworth et al. (2012) and Warwick et al. (2013). The Silva et al. (2016) study imposes oil palm expansion by overlaying an oil palm map for 2010 on a separate 16-PFT land cover distribution; this is a different methodology than we apply here, where we apply an internally consistent set of maps developed using a wall-to-wall classification methodology. (2) We have developed the global climate model code to add four additional land cover type PFTs, focusing on land covers that are pervasive in maritime Southeast Asia, including oil palm and rubber plantations. Previous studies have focused only on the impacts of oil palm expansion. (3) We consider the impacts of land-cover-change-driven changes in emissions of both isoprene and monoterpenes. The study by Silva et al. (2016) presumably includes dynamic changes in monoterpene emissions for the land covers that are displaced by oil palm, but their one new land cover type – oil palm – only has the isoprene emission capacity altered relative to the forest land cover type. Ashworth et al. (2012) and Warwick et al. (2013) consider only isoprene emission changes. (4) We directly quantify the global radiative forcing induced by ozone and SOA changes driven by historical land cover change in this region using a coupled global land-chemistry-climate model framework with the embedded radiative transfer model developed by A. Lacis and J. Hansen in GISS ModelE2 (e.g. Schmidt et al., 2014). (5) We provide new climate policy metrics for global ozone radiative forcing per Mha land cover change in the tropics. (6) We quantitatively identify that important factors driving uncertainty in the forcing include (a) uncertainty in the magnitude of the isoprene BER for oil palm and (b) uncertainty in the areal extent of oil palm expansion. Using an analysis based on fixed SOA yields, we additionally show that the sign of the net forcing is sensitive to uncertainty in the SOA yield from BVOCs.

Responses to Reviewer #3

Overall comments:

This paper examines the impacts of land cover change in maritime Southeast Asia induced mostly by oil palm expansion and the associated changes in BVOC emissions on surface ozone concentrations and tropospheric ozone profiles, and the subsequent impacts on radiative forcing. This is a novel piece of work that highlights the importance of considering

atmospheric chemistry-mediated climate forcing in climate and land use change studies. The data integration and modeling approach are all scientifically sound, rigorous and valid. There are, however, insufficient or unclear exposition and explanation of the results at various places of the paper, as well as inadequate discussion of the results in relation to previous works. I recommend the publication of this paper, if the concerns raised below are addressed.

We thank the reviewer for their insightful comments and guidance.

Specific comments:

(1) P1 L21: The introduction section appears too short, and do not set up a context nuanced enough to motivate the work (the findings of which are exciting). I recommend the authors to expand the introduction (by 30-50%) by discussing at greater lengths the various references cited. More suggestions in relation to this are given below.

We have expanded the introduction to provide additional context and background for the study.

(1) A description of other environmental impacts associated with land cover changes in this region was added (Page 2, Line 1): "Land cover and land use changes in Southeast Asia perturb the Earth system in a variety of ways. Deforestation is a significant threat to Southeast Asian biodiversity (Sodhi et al., 2004), and the land-based carbon emissions associated with forest clearing have greatly contributed to Indonesia's status as one of the world's highest emitters of greenhouse gases (GHGs) (FAO, 2014; WRI, 2015). The magnitude of GHG emissions from deforestation is exacerbated by the pervasiveness of carbon-rich peat soils underlying Southeast Asian tropical forests (Carlson et al., 2012; Hooijer et al., 2010; Page et al., 2002; van der Werf et al., 2009). Peat soil drainage (i.e., drying) promotes oxidation of the sequestered carbon (Miettinen et al., 2017) and is often followed by fire clearing, despite the illegality of this practice in Indonesia (Indrarto et al., 2012). Indonesian forest and peat fires have fueled transnational air pollution episodes (Gaveau et al., 2014; Koplitz et al., 2016), potentially causing more than 100,000 premature mortalities in 2015 (Koplitz et al., 2016)."

(2) The bolded part of the following sentence was added to tie the air quality and climate impacts of isoprene and monoterpene emission changes back to the discussion of other environmental impacts of regional land cover change (Page 2, Line 19; our response to comment 5 of reviewer #3 also describes modifications to this sentence): "Both isoprene and monoterpenes are precursors to the short-lived climate pollutants tropospheric ozone (Atkinson and Arey, 2003) and secondary organic aerosols (SOA) (Carlton et al., 2009; Friedman and Farmer, 2018); **as such, perturbations in regional isoprene and monoterpene emissions serve as an additional mechanism by which regional land cover change can affect air quality and climate**."

(3) We replaced this sentence from our original introduction ("Previous investigations of atmospheric composition changes driven by land use change in MSEA have largely focused on the surface-level air quality impacts induced by BVOC emission changes from oil palm expansion (Ashworth et al., 2012; Silva et al., 2016; Warwick et al., 2013).") with an expanded description of the key findings of these cited studies. While no information was removed from the final introductory paragraph of the original version of the manuscript, the sentences in that final paragraph were rearranged and placed into the new expanded text to retain flow. The expanded text includes a description of how the land cover dataset used in the study by Silva et al. (2016) differs from that used in our study.

The expanded text (Page 2, Line 23):

"A few studies have used global modeling to investigate the atmospheric composition impacts of Southeast Asian oil palm expansion. Ashworth et al. (2012) analyzed the expected impacts from isoprene emission enhancements associated with the partial replacement of natural forest area with oil palm plantations under a land-use change scenario designed to meet a portion of the projected increase in demand for biofuels in coming years. Warwick et al. (2013) analyzed the impacts from isoprene emission enhancements associated with total conversion of Borneo from forest to oil palm. Both studies quantified the impacts of the isoprene emission changes first by applying a contemporary NO_X inventory and secondly by assuming increased NO_X emissions near the site of land-use change due to enhanced fertilizer application and increased on-site processing of the palm oil. Based on simulations that apply contemporary NO_X inventories, both studies predict reductions in surface ozone co-located with the isoprene enhancements because the increased VOC serves as a net sink for ozone in the low-NO_X atmosphere (Ashworth et al., 2012; Warwick et al., 2013). When NO_X emission enhancements occur in concert with the land-use-change-driven isoprene emission enhancements, both studies simulate a net increase in ozone production and a concomitant increase in local surface ozone pollution (Ashworth et al., 2012; Warwick et al., 2013). Ashworth et al. (2012) predict local enhancements in annual-mean surface concentrations as high as 11 % for ozone and 10 % for biogenic SOA (as the maximum change in any grid cell) in response to a 5 % increase in regional isoprene emissions and simultaneous enhancements in local NO_X emissions. Warwick et al. (2013) predict local changes in monthly-mean surface ozone as strong +70 % when simultaneously increasing NO_X and isoprene emissions. These studies highlight the potential for significant local surface-level pollution impacts from land use change.

A recent third study quantified the air quality impacts associated with year 2010 oil palm cover relative to an oil-palm-free scenario (Silva et al., 2016). Using the GEOS-Chem chemical transport model and contemporary inventories for NO_X emissions, Silva et al. (2016) simulate local enhancements in surface pollution as high as 26 % (3–4 ppbv) for ozone and 60 % (about 1 $\mu g\ m^{-3}$) for SOA. In Kuala Lumpur, Malaysia, the number of days that register ozone levels higher than the limits recommended by the World Health Organization more than doubled due to regional oil palm expansion (56 days based on 2010 oil palm coverage compared to 23 days in the absence of oil palm; Silva et al., 2016), again highlighting the strong impact of Southeast Asian land cover change on surface pollution.

The year 2000 16-PFT land cover distribution map that Silva et al. (2016) apply as the no-oil-palm case is designed for global modeling studies and, therefore, lacks information about the distribution of individual species of vegetation. For example, 7.2 Mha of oil palm existed in 2000 in Indonesia, Malaysia, and Papua New Guinea (Gunarso et al., 2013), yet many global vegetation distributions assign these plantations to one or more of a small number of PFTs. Silva et al. (2016) use a 250 m resolution satellite-based map of year 2010 oil palm plantations to define the contemporary oil palm distribution, and they overlay the oil palm on the palm-free base map, displacing the existing land covers in proportion to their fractional distributions. In reality, the prior land cover of oil palm plantations differs widely by region (Gunarso et al., 2013). Furthermore, the modified land cover distribution from Silva et al. (2016) lacks separate delineations for other pervasive land covers in Southeast Asia, including rubber plantations, which covered at least 6.4 Mha on the maritime continent in 2010 (Gunarso et al., 2013). Rubber trees (*Hevea brasiliensis*) are very weak emitters of isoprene (Geron et al., 2006; Klinger et al., 2002), but very strong emitters of monoterpenes (Baker et al., 2005; Klinger et al., 2002), which are important SOA precursors (Jokinen et al., 2015). Thus, while the study by Silva et al. (2016) provides evidence of significant surface pollution changes induced by oil palm expansion in Southeast Asia, it provides an incomplete picture of the impact of historical land cover change on atmospheric composition.

This small set of studies focuses on the atmospheric composition impacts induced by altered BVOC emissions from Southeast Asian oil palm expansion, all finding that the downwind impacts are smaller in magnitude than the local impacts near the site of land conversion and isoprene emission changes (Ashworth et al., 2012; Silva et al., 2016; Warwick et al., 2013). Ashworth et al. (2012) forecasted a small global climate impact from the increased isoprene emissions in their land-use change scenario, based on the very small simulated global changes in the tropospheric burdens of ozone and the hydroxyl radical (OH). However, no study has directly quantified the climate impacts associated with the induced changes in atmospheric composition.

Isoprene perturbations in the tropics may have a particularly powerful impact on longwave radiative forcing (Unger, 2014) because the strong vertical mixing prevalent in the tropics provides a mechanism for surface pollution perturbations to impact ozone concentrations in the upper troposphere (Thompson et al., 1997), where, on a per-molecule basis, ozone changes induce the strongest climate impact (Lacis et al., 1990). In response to isoprene emission enhancements associated with total conversion of vegetated land to oil palm on the island of Borneo, Warwick et al. (2013) simulate a 20 % increase in ozone at 500 hPa over Borneo and a 20 % increase in peroxyacetyl nitrate (PAN) at 500 hPa downwind of Borneo over the Pacific Ocean. PAN is an organic nitrate that can undergo long-range transport before releasing its reactive NO_X moiety (Moxim et al., 1996), providing a means for ozone formation in remote environments (Kotchenruther et al., 2001). The results of Warwick et al. (2013) suggest that regional isoprene emission changes have the capacity to alter ozone concentrations in the free troposphere and, therefore, induce a radiative forcing.

This study uses the ModelE2-Yale Interactive Terrestrial Biosphere (ModelE2-YIBs) global chemistry–climate model, in conjunction with multiple observational datasets, to quantify the global atmospheric composition changes and, for the first time, the concomitant radiative forcings associated with BVOC emission changes from 1990–2010 land cover change in MSEA. The calculations presented here consider changes in emissions of both isoprene and monoterpenes. The applied regional land cover changes are derived from a Landsat-based classification (Gunarso et al., 2013) and account for changes in eight land covers that are prevalent in MSEA, including high-monoterpene-emitting rubber trees and high-isoprene-emitting oil palm trees."

Added references:

Hooijer, A., Page, S., Canadell, J.G., Silvius, M., Kwadijk, J., Wösten, H., and Jauhiainen, J.: Current and future CO2 emissions from drained peatlands in Southeast Asia, Biogeosciences, 7, 1505–1514, doi: 10.5194/bg-7-1505-2010, 2010.

Indrarto, G.B., Murharjanti, P., Khatarina, J., Pulungan, I., Ivalerina, F., Rahman, J., Prana, M.N., Resosudarmo, I.A.P., and Muharrom, E.: The context of REDD+ in Indonesia: Drivers, agents and institutions (Working Paper 92), CIFOR, Bogor, Indonesia, 2012.

Kotchenruther, R.A., Jaffe, D.A., and Jaeglé, L.: Ozone photochemistry and the role of peroxyacetyl nitrate in the springtime northeastern Pacific troposphere: Results from the Photochemical Ozone Budget of the Eastern North Pacific Atmosphere (PHOBEA) campaign, J. Geophys. Res., 106, 28,731–28,742, doi: 10.1029/2000JD000060, 2001.

Miettinen, J., Hooijer, A., Vernimmen, R., Liew, S.C., and Page, S.E.: From carbon sink to carbon source: Extensive peat oxidation in insular Southeast Asia since 1990, Environ. Res. Lett., 12, 024014, doi: 10.1088/1748-9326/aa5b6f, 2017.

Moxim, W.J., Levy II, H., and Kasibhatla, P.S.: Simulated global tropospheric PAN: Its transport and impact on NOx, J. Geophys. Res., 101, 12,621–12,638, doi: 10.1029/96JD00338, 1996.

Page, S.E., Siegert, F., Rieley, J.O., Boehm, H.-D.V., Jaya, A., and Limin, S.: The amount of carbon released from peat and forest fires in Indonesia during 1997, Nature, 420, 61–65, doi: 10.1038/nature01131, 2002.

van der Werf, G.R., Morton, D.C., DeFries, R.S., Olivier, J.G., Kasibhatla, P.S., Jackson, R.B., Collatz, G.J., and Randerson, J.T.: CO2 emissions from forest loss, Nat. Geosci., 2, 737–738, doi: 10.1038/ngeo671, 2009.

(2) P1 L25: The "%" sign usually immediately follows the number without space.

Fixed.

(3) P1 L27: Can there be a sentence or two describing why we are concerned with oil palm planation from an environmental or ecological perspective (not just a climate perspective as included in the current second paragraph)?

Done. Our response to comment 1 describes this addition to the introduction.

(4) P2 L8-9: Please expand this paragraph by discussing briefly the key findings of these few papers (Ashworth et al., 2012; Silva et al., 2016; Warwick et al., 2013). How large or in what ranges are the concentration changes? Is the surface air quality changes significant relatively to, e.g., the impacts of anthropogenic emissions or warming?

Done. Our response to comment 1 describes this addition to the introduction.

(5) P2 L14: Why does upper tropospheric ozone have a larger climate impact than surface ozone?

Briefly, because it is colder at higher altitudes, which increases the longwave radiative forcing efficiency (outgoing energy at colder temperatures compared to surface). The stronger climate impact of upper tropospheric ozone relative to surface-level ozone, on a per-molecule basis, is related to the temperature contrast of the two environments in which ozone is absorbing and re-emitting the longwave radiation (e.g., Lacis et al., 1990). The forcing efficiency of the longwave-absorbing ozone molecule is stronger when the ozone exists in the colder upper troposphere than when it exists in the warmer temperatures at the surface.

We added the bolded portion to this sentence (Page 4, Line 4): "Isoprene perturbations in the tropics may have a particularly powerful impact on longwave radiative forcing (Unger, 2014) because the strong vertical mixing prevalent in the tropics provides a mechanism for surface pollution perturbations to impact ozone concentrations in the upper troposphere (Thompson et al., 1997), where, on a per-molecule basis, ozone changes induce the strongest climate impact **due to the thermal contrast with the surface** (Lacis et al., 1990)."

(6) P2 L19: How does the land cover change derived from this data source differ from or compare with that used by Silva et al. (2016)?

We added this information to the expanded introduction. Our response to comment 1 describes this addition.

(7) P3 L4: Please explain and justify whether the discontinuity created by using two different biomass burning datasets is acceptable, especially considering that biomass burning emissions are an important source of ozone there.

Identical surface maps and emission factors were applied in the creation of both the MACCity and interpolated ACCMIP-RCP8.5 biomass burning emissions datasets (Heil and Schultz, 2014).

We have added the bolded portion to the following sentence (Page 5, Line 23): "Prescribed monthly anthropogenic and biomass burning emissions of reactive gas and primary aerosol species follow the MACCity emissions pathway (Angiola et al., 2010; Granier et al., 2011) for all years, except for 2010, when the interpolated ACCMIP-RCP8.5 dataset (Heil and Schultz, 2014) is applied for biomass burning emissions **(as MACCity biomass burning emissions are available only through 2008).**"

We have then added the following explanation (Page 5, Line 27): "MACCity biomass burning emissions were built from the ACCMIP (Lamarque et al., 2010), REanalysis of the TROpospheric chemical composition (RETRO; Schultz et al., 2008), and Global Fire Emissions Database (GFED-v2; van der Werf et al., 2006) datasets (Granier et al., 2011). The interpolated ACCMIP-RCP8.5 emissions were created using simple temporal interpolation of the ACCMIP and RCP8.5 datasets (Heil and Schultz, 2014). Identical surface maps and emission factors were applied in the creation of both the MACCity and interpolated ACCMIP-RCP8.5 biomass burning emissions datasets (Heil and Schultz, 2014)."

Added references:

Lamarque, J.-F., Bond, T.C., Eyring, V., Granier, C., Heil, A., Klimont, Z., Lee, D., Liousse, C., Mieville, A., Owen, B., Schultz, M.G., Shindell, D., Smith, S.J., Stehfest, E., Van Aardenne, J., Cooper, O.R., Kainuma, M., Mahowald, N., McConnell, J.R., Naik, V., Riahi, K., and van Vuuren, D.P.: Historical (1850–2000) gridded anthropogenic and biomass burning emissions of reactive gases and aerosols: methodology and application, Atmos. Chem. Phys., 10, 7017–7039, doi: 10.5194/acp-10-7017-2010, 2010.

Schultz, M.G., Heil, A., Hoelzemann, J.J., Spessa, A., Thonicke, K., Goldammer, J.G., Held, A.C., Pereira, J.M.C., and van het Bolscher, M.: Global wildland fire emissions from 1960 to 2000, Global Biogeochem. Cy., 22, GB2002, doi: 10.1029/2007GB003031, 2008.

van der Werf, G.R., Randerson, J.T., Giglio, L., Collatz, G.J., Kasibhatla, P.S., and Arellano Jr., A.F.: Interannual variability in global biomass burning emissions from 1997 to 2004, Atmos. Chem. Phys., 6, 3423–3441, doi: 10.5194/acp-6-3423-2006, 2006.

(8) P3 L4-6: "Interactive" is a modeler's jargon, and even for modelers can mean different things for different purposes. I recommend avoiding it and state more clearly that these emission schemes are "semi-empirical", "mechanistic" or "dynamic functions of x, y, z, ...", especially for those that are not described more below.

(9) P3 L13: Avoid the use of "online".

(10) P3 L28: Avoid "online" and "model's".

Fixed for all instances where these terms were used in the manuscript.

(11) P3 L33: Please explain and justify the single chemical representation of monoterpene. Can all monoterpenes really be modeled as α-pinene?

The quantification of SOA yields for different monoterpene species is an exciting frontier for SOA modeling, but the uncertainties remaining in this field currently preclude expansion of this chemistry at the expense of the greater computational resources needed to run global model simulations. We have added a discussion on this matter (Page 7, Line 33): "Furthermore, the appropriateness of using α-pinene to represent monoterpenes as a single lumped species in global modeling is an active area of research. Friedman and Farmer (2018) find order-of-magnitude differences in SOA yields for OH-oxidation of different monoterpene species, but a clear explanation based on isomer structure remains largely elusive. While Friedman and Farmer (2018) find that the magnitude of the SOA yield from α-pinene is in the "mid-range" of the yields among the analyzed monoterpene species, other studies have shown that this may not be the case for other oxidation pathways (e.g., Draper et al., 2015)."

Added references:

Draper, D.C., Farmer, D.K., Desyaterik, Y., and Fry, J.L.: A qualitative comparison of secondary organic aerosol yields and composition from ozonolysis of monoterpenes at varying concentrations of NO2, Atmos. Chem. Phys., 15, 12267–12281, doi: 10.5194/acp-15-12267-2015, 2015.

Friedman, B. and Farmer, D.K.: SOA and gas phase organic acid yields from the sequential photooxidation of seven monoterpenes, Atmos. Env., 187, 335–345, 2018.

(12) P5 L30: What about the LAI values for the new PFTs used for this study for MSEA? They are not described above. Are dynamic but grid-level LAI observed from, e.g., MODIS, used, or

are PFT-level LAI values used for these new PFTs? If so, where are these values from? As LAI is so important for atmospheric chemistry, these need to be better stated and explained.

The PFT-level LAI values applied to each of the new PFTs are described in Table 1 and its footnotes in the main text (this table was previously known as Table S2 in the Supplement). We have updated the text to better draw attention to this information (Page 9, Line 20): "Table 1 shows, for the new land cover types, the assigned physical parameters (including LAI and vegetation height), photosynthetic parameters, and leaf-level basal emission rates of isoprene and monoterpenes.."

(13) P10 L1: In the methodology section above, the authors have only discussed about model validity and model-observation comparison for the vegetation aspects (e.g., GPP, biogenic emissions). What about an evaluation of the ozone simulations by the model? How does the model's simulated ozone globally compare with observations and with other models? Is the general high biases of simulated ozone in many climate-chemistry models also seen in this model? Since ozone concentration is crucial to this paper, I strongly recommend having a paragraph somewhere (preferably in the methodology section) discussing these.

We have inserted in the methodology section the following paragraph describing the extensive evaluation of ozone in ModelE2-YIBs (Page 7, Line 7): "ModelE2 has previously undergone extensive, rigorous validation of simulated present-day tropospheric and stratospheric chemical composition, circulation, and ozone forcing using multiple observational datasets (Shindell et al., 2006; Shindell et al., 2013). Shindell et al. (2013) compared simulated monthly zonal-mean total column ozone to that from observations (2000–2010 means) from the Total Ozone Mapping Spectrometer and the Ozone Monitoring Instrument (McPeters et al., 2008), finding: simulated zonal-mean total column ozone in the tropics shows little bias (< 5%) against measurements for each month, and, in the Northern Hemisphere middle and high latitudes, biases are smaller in the summer months (< 10%) than in the winter months (around 15–20%). Shindell et al. (2013) find only a small negative bias (-0.016 W m^{-2}) in the present-day global-average radiative impact of modeled tropospheric ozone relative to TES-derived tropospheric ozone. They note that the strongest biases in ozone concentrations in ModelE2 are generally located in regions where ozone exhibits little effect on radiation (Shindell et al., 2013). More recently, Harper et al. (2018) compared annual-mean ozone concentrations simulated by ModelE2 (representative of year 2005) with an ozonesonde climatology based on measurements taken over 1995–2011 (Tilmes et al., 2012), finding lower model biases at higher pressures (e.g., +2.6% at 200 hPa compared to +16.9% at 800 hPa)."

Added references:

Harper, K.L., Zheng, Y., and Unger, N.: Advances in representing interactive methane in ModelE2-YIBs (version 1.1), Geosci. Model Dev. Discuss., doi: 10.5194/gmd-2018-85 , 2018.

McPeters, R., Kroon, M., Labow, G., Brinksma, E., Balis, D., Petropavlovskikh, I., Veefkind, J., Bhartia, P., and Levelt, P.: Validation of the aura ozone monitoring instrument total column ozone product, J. Geophys. Res.-Atmos., 113, D15S14, doi:10.1029/2007JD008802, 2008.

Shindell, D.T., Pechony, O., Voulgarakis, A., Faluvegi, G., Nazarenko, L., Lamarque, J.-F., Bowman, K., Milly, G., Kovari, B., Ruedy, R., and Schmidt, G.A.: Interactive ozone and methane chemistry in GISS-E2 historical and future climate simulations, Atmos. Chem. Phys., 13, 2653–2689, doi: 10.5194/acp-13-2653-2013, 2013.

Tilmes, S., Lamarque, J.-F., Emmons, L.K., Conley, A., Schultz, M.G., Saunois, M., Thouret, V., Thompson, A.M., Oltmans, S.J., Johnson, B., and Tarasick, D.: Technical Note: Ozonesonde climatology between 1995 and 2011: Description, evaluation and applications, Atmos. Chem. Phys., 12, 7475–7497, doi: 10.5194/acp-12-7475-2012, 2012.

(14) P10 L14: Wong et al. (2018) also examined and quantified the factors behind the sensitivity of surface ozone to vegetation changes including isoprene emission and dry deposition. They also found a large impact of background NOx. See reference list below.

Please see response to point (15).

(15) P11 L1: Dry deposition definitely also plays a role, and have you quantified the relative importance of isoprene emission vs. dry deposition to surface ozone in your model simulations? This appears to be a major missing part of this analysis and should be better addressed or discussed, even if the authors have already found that dry deposition plays only a minor role. For instance, Wong et al. (2018) found it necessary and developed a method to formally disentangle the contributions from isoprene emission and dry deposition when leaf density changes.

The Wong et al. (2018) paper presents an exciting avenue for disentangling the various land cover change driven contributions to surface ozone changes; however, it is our understanding that their analysis does not take into account the effects of other biogeophysical changes, such as surface roughness and evapotranspiration. The land cover distribution changes in our model can alter such (and other) parameters, which might also be playing a role in the simulated surface ozone changes.

We have expanded our discussion on this matter (Page 16, Line 25): “The simulated changes in atmospheric composition might be a response not only to altered isoprene and monoterpene emissions, but also to changes in the deposition of atmospheric species induced by changes in leaf density (Wong et al., 2018) or related changes, such as surface roughness, stomatal conductance, and evapotranspiration, that are affected by the applied changes in land cover distribution. Here, the relative changes in regional ozone deposition rates (-19.7 to +4.3%) are similar to the relative changes in regional surface-level ozone concentrations (-18.3 to +4.3%) from 1990–2010 regional land cover change, in part because the ozone deposition rate

depends on the atmospheric concentration change. While increased isoprene emission leading to increased isoprene ozonolysis drives ozone losses near the surface, a formal quantitative attribution analysis disentangling the relative roles of emission and deposition changes requires further complex sensitivity simulations that are beyond the scope of this analysis. In their analysis of Southeast Asian oil palm expansion, Silva et al. (2016) used sensitivity studies to determine that the induced BVOC emission changes, rather than altered deposition rates from LAI changes, were almost exclusively responsible for the simulated surface ozone changes."

Added reference:

Wong, A.Y.H., Tai, A.P.K., and Ip, Y.-Y.: Attribution and statistical parameterization of the sensitivity of surface ozone to changes in leaf area index based on a chemical transport model, J. Geophys. Res.-Atmos., 123, 1883–1898, doi: 10.1002/2017JD027311, 2018.

(16) P12 L2: The physical reasons for the enhancements (as opposed to reductions) of ozone over the ocean have to be explained. Can these enhancements be explained by, e.g., the mechanisms suggested by Hollaway et al. (2017)? A discussion in relation to this paper is recommended. See reference list below.

Please see response to comment (18).

(17) P12 L16: In Fig. 2a) and 2c), why is there a second peak for isoprene and HCHO enhancement near the tropopause?

This is a signal of tropical deep convection (e.g., deep convective towers rapidly pulling up air into the upper troposphere).

(18) P14 L5: Now I see that the oceanic enhancements are explained. But this explanation, with reference to Hollaway et al. (2017), should be mentioned early (see comment to P12 L2).

We added reference to the Hollaway et al. (2017) paper and moved this explanation (now at Page 18, Line 1).

(19) P17 L8-9: "This sensitivity study demonstrates that the climate forcing associated with regional land cover change is rapidly increasing." I feel that this is too strong a statement. All the results are showing is that 2005-2010 as a 5-year period is responsible for a noticeably large fraction of the total RF compared to other possible 5-year periods, but without breaking down the other years into incremental 5-year periods (e.g., 1990-1995, 1996-2000, 2001-2005), we can't really say there is a rapidly rising trend in RF.

Agreed. We have removed this sentence.

(20) P18 L5-7: "increase in regional surface ozone concentrations is unlikely to have a significant impact on the induced ozone forcing since, as Lacis et al. (1990) find, changes in surface ozone have a much smaller effect on climate forcing relative to equivalent ozone changes in the upper troposphere." This is contingent upon the assumption that the formation and long-range transport of isoprene nitrate will respond in the same way even as the surface environment becomes more high-NOx. This needs to be justified.

We have removed this badly phrased sentence. Please see response to Reviewer (1) Point (66). We were originally trying to emphasize that increases in ozone near the Earth's surface do not exert appreciable longwave forcing, but we agree the original sentence does not read well and is not scientifically nuanced enough as is. Agreed regarding the assumption that the formation and long-range transport of isoprene nitrate would have to respond in the same way even as the surface environment becomes more high-NOx. To be clear, in this model, convective transport is moving isoprene, its oxidation products, and isoprene nitrate into the upper troposphere.

(21) P18 L24-31: I think one major missing discussion is to compare the ozone-mediated RF with the biogeophysical RF (e.g., changing albedo, latent heat, sensible heat, etc.) and biogeochemical (CO2 exchange) associated with oil palm expansion. Indeed, most climatologists are still just concerned with the biogeophysical or biogeochemical RF, and having a comparison between those and the ozone-mediated forcing would give much insight into the importance of considering atmospheric chemistry in climate/land use change studies.

Thank you for the brilliant idea, we agree with the reviewer, and these discussions did come up a few times in the project. Unfortunately, we are unable to access the albedo surface forcing diagnostics in the model output. We delved into LLGHG emission estimates for the recent land cover change in MSEA. Carlson et al. (2012b) estimated 11.4 MtC y^{-1} CO_2 emissions from 1989–2008 (mostly from deforestation fire). This amounts to a cumulative total of 216.6 MtC y^{-1} over the 19 years. Using IPCC AR5 GWPs, the CO_2 forcing is: 5.3 mW m^{-2} on 20-yr time scale and 19.9 mW m^{-2} on 100-yr time scale. However, the small region analysed by Carlson et al. (2012b) doesn't correspond to that applied here so is not a meaningful comparison. LLGHG land cover change emissions accounting is beyond the scope here, and would be a full paper in its own right. Interestingly, there is a substantial high impact published literature on future climate change impacts on the sustainability of oil palm plantations in MSEA (the opposite way around to that considered here).

Reference:

Carlson, K.M., Curran, L.M., Ratnasari, D., Pittman, A.M., Soares-Filho, B.S., Asner, G.P., Trigg, S.N., Gaveau, D.A., Lawrence, D., and Rodrigues, H.O.: Committed carbon emissions, deforestation, and community land conversion from oil palm plantations expansion in West Kalimantan, Indonesia, Proc. Natl. Acad. Sci.-USA, 109, 7559–7564, doi: 10.1073/pnas.1200452109, 2012b.

(22) P19 L18-19: "Inclusion of a temporally variable BVOC BER in the global model would allow for an improved estimation of radiative forcing induced by land cover changes in this region." I think the current debate is exactly that we are not sure about the circadian control or not, and thus this statement is not necessarily true.

We agree that this aspect of isoprene emissions is very uncertain and have removed this sentence to avoid confusion.

(23) P19 L33-34: "(2) its apparent inconsequence to the surface pollution impacts of regional land cover change" Is there really no OH titration problem in MSEA in ModelE2- YIBs? Is that because the BER is low to begin with, compared to, say, the Amazon?

In ModelE2-YIBs, OH is typically much lower than the global average in forested tropical regions in the model. We have removed this poorly phrased sentence and moved the entire discussion of chemistry uncertainties to the Methodology section (Sect. 2.1, Page 7, Line 21), where we have included a more balanced perspective on isoprene photooxidation uncertainties in global models (e.g., see introductory remarks to reviewer #2).

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