Response to reviewers' comments on manuscript "Impacts of Changes in Land Use and Land Cover on Atmospheric Chemistry and Air Quality over the 21st Century" (Manuscript Number: acp-2011-307).

We thank the reviewers for their valuable comments. We have added in the text more analysis and discussion, in particular those related to the uncertainty in this study.

We have made itemized responses to all the comments as described below. The reviewers' comments are repeated below in italics and our responses are in normal and bold font.

Point-to-point response:

1) The existing literature on this subject, which dates back several decades to Turner et al. Chemosphere (1991), is mostly missing from this manuscript.

Response:
We have added in 11 more references, including Turner et al. [1994; 1998].

2) What are the uncertainties associated with 1) the predicted changes in landcover and 2) the response of biogenic emissions and ozone deposition to these changes. Do we really even know the sign of the response?

Response:

We have added in the text:
p10 -"There are many sources of uncertainty in the projected responses of future atmospheric composition to the changes in land use and land cover. The future changes in anthropogenic land use is strongly affected by multiple factors (such as population and economic growth, development in renewable energy and new technology, policy regulations) which all show large spatial and temporal variability. The simulation of climate-driven changes in landcover only resolves PFTs but not specific vegetation species, introducing additional sources of uncertainty."

Biogenic VOC emissions in the model are calculated using the MEGAN scheme (Guenther et al., 2006) and the dry deposition follows Wesely [1989] using a resistance-in-series formulation with some updates [Wang et al., 1998]. Both the MEGAN model and the dry deposition scheme have been extensively evaluated in the literature. We have added in the clarification in the text -
p4 -"For the purpose of examining the future changes in biogenic emissions associated with land cover change, we assume that the vegetation composition (in terms of biogenic emission rates) for each PFT will remain unchanged since both the MEGAN scheme and the LPJ model resolves the PFTs but not detailed plant species".

p9 -"In addition, assigning emission factors to specific PFTs rather than plant species, as implemented in the MEGAN scheme, could introduce uncertainties in the projected isoprene emissions."

3) What is the impact of assigning emission rates to broad vegetation categories? For example, it is assumed that the replacement of a needleleaf forest with a broadleaf forest will increase isoprene emission but this is not necessarily the case: a maple forest has much lower isoprene emissions that a spruce forest in North America.

Response:
We have added in the text:
p4 -"For the purpose of examining the future changes in biogenic emissions associated with land cover change, we assume that the vegetation composition for each PFT will remain unchanged since both the MEGAN scheme and the LPJ model resolves the PFTs but not detailed plant species."

We do realize that resolving the detailed plant species instead of PFTs (plant function types) with the vegetation model and biogenic emission model would be ideal; however, these capabilities are not available for the current global models.

4) The results here are different than what is reported by others. Does this mean the other studies (or this study) are wrong or does it mean that our knowledge is not sufficient to make an accurate estimate?

Response:
Our study shows that climate-driven changes in vegetation could increase isoprene emissions, which is in contrast to Sanderson et al. [2003] who calculated a slight decrease of isoprene emissions using a different model. We have noted in the text:

p5-6 "Our calculated increase in isoprene emissions is in contrast to Sanderson et al. [2003] who reported a slight decrease of isoprene emissions resulting from climate-driven changes in vegetation cover. The model simulations of Sanderson et al. [2003] showed a dieback of large parts of the tropical forests of the Amazon basin between the 1990s and 2090s and ascribed this to be the major driver of the decreasing isoprene emission. We did not see this significant retreat of the Amazon forest in our simulations. Our GISS GCM simulations for 2050 and 2100, do not show substantial decreases in tropical terrestrial precipitation relative to the present-day, probably because they were forced by fixed late 20th century land cover as a boundary condition, and because our version of LPJ considers the deeply rooted vegetation in the tropics, allowing a maximum soil column of 2m [Kleidon and Heimann, 1999]."

p6-7 "The perturbations to surface ozone due to changes in land use and land cover calculated in this study are very different from those reported in Sanderson et al. [2003]. The factors that could contribute to this discrepancy are: (1) Our climate model simulations do not show the dieback of Amazon forests as found in Sanderson et al. [2003], and (2) there are large uncertainties associated with isoprene chemistry and in particular the treatment of isoprene nitrates, especially isoprene nitrate, could be different in different models [Giacopelli et al., 2005; Horowitz et al., 2007; Paulot

et al., 2009]. The response of ozone to isoprene emissions is highly sensitive to whether isoprene nitrates represent a terminal or temporary sink for NOx [Horowitz et al., 2007; Wu et al., 2007]. In our model, isoprene nitrate represents a terminal sink, as shown in Giacopelli et al. [2005]. Therefore, except for areas with abundant NOx available such as northeastern United States, the increases in isoprene emissions tend to reduce ozone levels because of (1) sequestration of NOx as isoprene nitrates [Wu et al., 2007], and (2) direct ozonolysis of isoprene [Fiore et al., 2005]."

5) The paper would benefit from some effort to use observations to confirm the modeling results. For example, the study concludes that the conversion of needleleaf to broadleaf forests will result in decreased SOA. Is there any evidence of this from field studies? Forests have compounds, such as sesquiterpenes, that are not considered in the study and could influence the results. It would also be useful to provide a few more details on what controls the model results. For example, what is the relative contribution of isoprene vs monoterpenes to SOA? What are the SOA yields used in the model?

Response:
The MEGAN biogenic emission scheme [Guenther et al., 2006] used in the study is primarily based on enclosure measurements of isoprene emission rates and has been shown to provide a good representation of the canopy-scale isoprene emissions.

We have added in the text:

p4 -"For the purpose of examining the future changes in biogenic emissions associated with land cover change, we assume that the vegetation composition for each PFT will remain unchanged since both the MEGAN scheme and the LPJ model resolves the PFTs but not detailed plant species."

p9 -"In addition, assigning emission factors to specific PFTs rather than plant species, as implemented in the MEGAN scheme, could introduce additional uncertainties in the projected isoprene emissions."

p5 -"Formation of SOA in the GEOS-Chem model follows the algorithm developed by [Chung and Seinfeld, 2002] for gas-particle equilibrium partitioning between SOA and semivolatile VOC oxidation products. SOA formation from terpenes, alcohols, sesquiterpenes, and isoprene are considered in this study. SOA production from isoprene oxidation photooxidation follows the work of Henze and Seinfeld [2006], which is based on chamber experiments of reaction of isoprene with OH at low NOx condition [Kroll et al., 2006]."

p7-"Our model simulations show that oxidation products from isoprene and monoterpene are dominant contributors to SOA production, accounting for about 70% and 20% of the total atmospheric SOA burden respectively."