Responses to reviews of the manuscript acp-2010-736

A regional chemical transport modeling to identify the influences of biomass burning during 2006 BASE-ASIA

Anonymous Referee #1:

1) General comments:

This paper describes a modeling study to identify the impacts of biomass burning in Southeast Asia on air quality in 2006. Two 2-day biomass burning episodes were analyzed using a regional chemical transport model and two fire emission databases. Influence of biomass burning on CO, O_3 and $PM_{2.5}$ was discussed. In general, description of modeling method and evaluation of model performance is very poor. The main problem however, is that a regional offline model system (WRF: meteorology, CMAQ: chemistry) was used to investigate the influence of biomass burning in this study (i.e. meteorological output is given as input to chemical model). Although the effects of biomass burning on atmospheric properties such as temperature and solar irradiation are mentioned in the introduction, there is no indication that the authors took them into account. The offline model system used in this study cannot consider the radiative effects of biomass burning aerosols. Changes in the atmospheric properties due to biomass burning aerosols might have a significant effect on chemistry. Such studies normally use coupled models to include two-way impacts. There is no discussion about it in this manuscript.

Response:

We thank the review's thorough comments on the manuscript. We totally agree that two-way aerosol feedbacks are important in regional climate/chemistry modeling. However, to accurately simulating feedbacks requires fully-coupled meteorology, climate and chemistry models, and the coupled models are not mature yet (Zhang, 2008).

Based on Zhang 2008:

(1) Accurately representing climate-aerosol-chemistry-cloud-radiation feedbacks in 3-D air quality/climate models will remain a major scientific challenge in developing a future generation of online-coupled models for the years to come, as many online-coupled models are currently not significantly-or fully-coupled, in particular, such feedbacks are not fully represented in many online-coupled models. There are several key issues associated with such needs. For example, performing an online calculation of all meteorologically-dependent emissions is necessary in all online-coupled models. There is a critical need for further improvement of model treatments of key processes such as the size-/composition-resolved aerosol/cloud microphysics for multiple size distributions (e.g., new particle formation, SOA, and aerosol/cloud interactions) and aerosol-cloud interactions, as well as subgrid variability associated with these processes.

(2) Representing scientific complexity within the computational constraint will continue to be a technical challenge. Key issues include (1) the development of benchmark

model and simulation and the use of available measurements to characterize model biases, uncertainties, and sensitivity and to develop bias-correction techniques (e.g., chemical data assimilation); (2) the optimization/parameterization of model algorithms with an acceptable accuracy.

(3) Integrated model evaluation and improvement, laboratory/field studies for an improved understanding of major properties/processes will also post significant challenges, as they involve researchers from multiple disciplinaries and require a multidisciplinary and or interdisciplinary approach.

WRF-CMAQ 2-way online coupling is also under development. Currently, there are still some unresolved issues based on Yu et al., 2010.

(1) WRF-CMAQ 2-way model currently underestimates SWCF (clouds) and it causes overestimation of radiation and subgrid convective clouds do not include aerosol effects

(2)

Evaluation of aerosol indirect effects is a challenge and more simulations are needed to perform at cloud resolving scales (4-km resolution)

Zhang, Y.: Online-coupled meteorology and chemistry models: history, current status, and outlook, Atmos. Chem. Phys., 8, 2895-2932, doi:10.5194/acp-8-2895-2008, 2008.

Shaocai Yu, Rohit Mathur, Jonathan Pleim, David Wong, Annmarie Carlton, Shawn Roselle, S. Trivikrama Rao and Yang Shao. Simulation of the indirect radiative forcing of climate due to aerosols by the two-way coupled WRF-CMAQ model over the continental United States: Preliminary results. 9th Annual CMAS Conference
October 11-13, 2010 Chapel Hill, NC.

We add some descriptions of two-way feedback models and illustrate the reasons why we use the offline model.

Besides the air quality impact resulting from biomass burning, the biomass burning aerosols could also affect radiative forcing. However, large uncertainty exists in coupled climate/air quality models, especially aerosol feedback may not be fully implemented (Zhang 2008), this study identifies the influences of biomass burning on East Asia during intense burning episodes by employing a regional “one atmosphere” offline model, the Community Multiscale Air Quality Modeling System (CMAQ) (Byun and Schere, 2006; Byun and Ching, 1999).

2). Specific comments:

a) Emission inventories: It is not easy to understand why authors used GFED inventory at all when the drawbacks were already known at the beginning (very coarse temporal resolution (8-day), limitation in spatial coverage of MODIS) while FLAMBE has a much better resolution (hourly).

Response:

The reason we want to compare FLAMBE with GFED is both FLAMBE and GFED are widely used biomass burning emission inventory (Reid et al., 2009; Chang and Song, 2010; van der Werf et al., 2006). We feel it is necessary to compare the magnitude of these two emission datasets. In the manuscript, we have already showed the emission magnitude of FLAMBE is larger than GFED. We further evaluated the model output with these two emission datasets (shown in Figure 2). If the evaluations show GFED is better, then we would keep the temporal and spatial distribution in FLAMBE, while change the magnitude from FLAMBE to GFED emissions. Our evaluations show the model output with FLAMBE emissions performs better. In this way, we keep the FLAMBE emissions. Thus, there is potential usefulness of GFED even though the temporal resolution of GFED is too coarse for the model simulation.

Reid, J. S., E. J. Hyer, E. M. Prins, D. L. Westphal, Z. Jianglong, W. Jun, S. A. Christopher, C. A. Curtis, C. C. Schmidt, D. P. Eleuterio, K. A. Richardson, and J. P. Hoffman (2009), Global Monitoring and Forecasting of Biomass-Burning Smoke: Description of and Lessons From the Fire Locating and Modeling of Burning Emissions (FLAMBE) Program, Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Journal of, 2, 3, 144-162.

Chang, D. and Song, Y.: Estimates of biomass burning emissions in tropical Asia based on satellite-derived data, Atmos. Chem. Phys., 10, 2335-2351, doi:10.5194/acp-10-2335-2010, 2010

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, 2006, http://www.atmos-chem-phys.net/6/3423/2006/.

b) Model evaluation: This section is very confusing. The parameters used for model performance analysis should be defined clearly. Authors used MFB and MFE for both O3 (15 and 35%, respectively) and PM2.5 (50 and 75%, respectively). It seems they were applied to CO as well (Figures 2 and S1) but this is not given in the text. In literature, MFB _ 60% and MFE _ 75% are recommended for particles (Boylan and Russell, 2006). For O3, USEPA recommends MNB _ 15% and MNG _ 35%. The definition, justification and correct references for the statistical parameters used for O3, CO and PM2.5 should be given. The names of the parameters in the text and in figures are not the same.

Response:

In the manuscript, we calculated the MFB and MFE for CO. In fact, there is no benchmark for CO. Thus, we did not compare with any benchmark for CO, but these two parameters (MFB and MFE) at least can give us some basic information how model performed.

We added the definitions and formula of MNB, MNE, MFB, and MFE in the manuscript. Also, the Mean Fractional Bias can be referred as Fraction Bias or MFB, and Mean Fractional Gross Error can be referred as Fractional Gross Error and MFE. It is now consistent between the descriptions and figures. We deleted the cutoff values and rewrite the explanations of MFB and MFE. We also incorporated the relationship between MNB/MNE and MFB/MFE.

Mean Normalized Bias (Normalized Bias; MNB) and Mean Normalized Gross Error (Normalized Gross Error; MNE) are shown in Equations (Eqs.) (1) and (2) below, where Cm is the simulated model grid value which correspondences to observational site i, Co is the observed value at site i, and N is the total number of observational sites. However, as is shown from the Eqs. (1) and (2), normalized bias and gross error can become extremly large when the observation data is quite low. On the contrary, Mean Fractional Bias (Fraction Bias; MFB) and Mean Fractional Gross Error (Fractional Gross Error; MFE) have the advantage of limiting the maximum model/observation bias and error. The formula of Fraction Bias and Fractional Gross Error are shown in Eqs (3) and (4). The reason is fractional bias and fractional gross error take the average of normalizing the bias and error by the average of model and observational data.

$$\mathrm{MNB} = \frac{1}{N}\sum_{i=1}^{N}\frac{C_m - C_o}{C_o} * 100\% \qquad (1)$$

$$\mathrm{MNE} = \frac{1}{N}\sum_{i=1}^{N}\frac{|C_m - C_o|}{C_o} * 100\% \qquad (2)$$

$$\mathrm{MFB} = \frac{1}{N}\sum_{i=1}^{N}\frac{C_m - C_o}{(C_m + C_o)/2} * 100\% \qquad (3)$$

$$\mathrm{MFE} = \frac{1}{N}\sum_{i=1}^{N}\frac{|C_m - C_o|}{(C_m + C_o)/2} * 100\% \qquad (4)$$

We add the reference (Boylan and Russell, 2006) the reviewer mentioned in the comments into the manuscript. We also deleted the reference of Morris 2005, which is not easy to find.

Boylan, J. W. and Russell, A. G., 2006. PM and light extinction model performance metrics, goals, and criteria for three-dimensional air quality models. Atmos. Environ. 40: 4946-4959.

c) Model seems to underestimate ozone in the afternoon significantly (up to 35 ppb difference) and overestimate it at night (Figure S1). Some discussion about it is needed. Modelled PM2.5 is too low -about 5-10 times lower than measurements. There must be some information what species are included in the model PM2.5 (primary, secondary).

Are biogenic SOA precursors included in the emissions? Without any chemical composition it is not possible to explain such a big difference.

Response:
Overall, the modeled PM2.5 is low in Phimai compared with observational data. However, from the trends between model output and observational data, we still can see the model outputs reflects the variations of observational data while systematic underestimation exists. We did include biogenic SOA precursors in the emissions. The modeled PM2.5 includes primary aerosol, secondary organic aerosol, sulfate, nitrate and ammonia. The systematic underestimation seems highly related to the emission inventory in Phimai, While in Hong Kong (four sites) where INTEX-B emissions could be more accurate, the particulate matters and ozone performs better. We believe if better emission dataset is available in Phimai and would improve the PM2.5 and ozone simulations in future.

3) Technical comments:

a) Figure 1: caption : Five (not Fiver)

Response:
We changed Fiver to Five

b) Figure 2: Although nowhere mentioned, modeling period seems to be between 1 April and 31 May (Figure 2, Figure S1). However discussion is about 27-28 March. Is something wrong with time axis? Julian date (91-151) doesn't seem to match the episodes. The x-axis should be given in calendar date.

Response:
The x-axis is right in the Julian date period. In fact, the simulation period is 60-151(March 1st to May 31st). In the Figure 2 and Figure S2, we only showed the period from March 1st to May 1st because the observational data is available starting from April. In those two figures, we aimed to evaluate the model output with observational output. We also changed the title of Figure 2 and added "(April 1 to May 31, 2006)" for easier recognizing the simulation period.

c) Figure 3: What is the height of CMAQ column? (top of 19 layers)

Response:
The height of CMAQ column is about 14 km on domain average.

d) Line 3084: in text as AOT, in figure 4 as AOD.

Response:
We changed all the AOT in the text to AOD to make consistent.

e) Reference for model evaluation Morris 2005 cannot be found easily. More appropriate reference should be chosen.

Response:
We delete the reference of Morris 2005. Instead, we cited USEPA (2007) and Boylan and Russell (2006), which are easily found and also contain the evaluation benchmarks.

Morris, R., et al., "Application of Multiple Models to Simulation Fine Particulate in the Southeastern US", National RPO Modeling Meeting, Denver, CO, 2005a.

Boylan, J. W. and Russell, A. G., 2006. PM and light extinction model performance metrics, goals, and criteria for three-dimensional air quality models. Atmos. Environ. 40: 4946-4959.

USEPA (2007), Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze, EPA-454/B-07e002. USEPA.