

Interactive comment on “Relative effects of open biomass and crop straw burning on haze formation over central and eastern China: modelling study driven by constrained emissions” by Khalid Mehmood et al.

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Anonymous Referee #2

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General comments:

- 10 The paper by Mehmood et al. investigates the relative effects of open biomass burning (OBB) and open crop straw burning (OCSB) on haze formation, specifically surface $PM_{2.5}$ mass concentrations, in central and eastern China. The authors used a fully coupled meteorological and chemical transport model (WRF-CMAQ), constrained by $PM_{2.5}$ measurements made in a wide area, to derive the optional OBB emission rates based on the FINNv1.5 inventory. They show that the model simulation of $PM_{2.5}$ improved significantly with the corrected FINNv1.5 inventory. The study is interesting and should be a welcome
- 15 addition to the literature. The paper is well written in general and can be accepted for publication before the following issues be addressed.

Response: We thank the reviewer #2 for the constructive comments and address them as below.

Specific comments:

- 20 1. While OBB activities took place in rural areas, mass concentrations of surface $PM_{2.5}$ and other chemical species were measured in the cities for this study. Is the grid resolution of the WRF-CMAQ model fine enough to capture the emissions and chemistry in the urban areas?

- Response:** For both urban and rural areas, we adopted 12km as the horizontal grid resolution to resolve all relevant emission and chemical processes in the WRF-CMAQ model. To some extent, this resolution (i.e., 12km) is the typical setup, since
- 25 previous studies have accumulated a wealth of similar experiences (Wu et al., 2018; Xing et al., 2018; Yu et al., 2018; Chen et al., 2019; Qiao et al., 2019). They have demonstrated that such configuration, together with reasonable settings for other numerical processes, could enable the model to derive reliable simulations for urban haze. Thus, this indirectly indicates that the horizontal grid resolution of 12km in the WRF-CMAQ model is virtually applicable to capturing the emissions and chemistry in the urban areas. On the other hand, several studies have directly explored the effects of horizontal grid resolution
- 30 on urban haze using the WRF-CMAQ model (Gan et al., 2016). Also, the horizontal grid resolution of 12km has been found to be fine enough for characterizing local gradients for limited regions (e.g., urban areas). Yet, certain biases and uncertainties

still exist because it is the challenge for this resolution to resolve the numerical processes in urban microenvironment, such as the turbulent diffusion with chemical reactions under the convective boundary layer (Han et al., 2019).

35 2. The MODIS AOD dataset is used to show the haze distribution pattern in comparison with that of the model-simulated surface PM_{2.5} concentrations. How about the AOD distribution from the model? A comparison between the AODs from the model and MODIS would be interesting. The analysis of OMI AOD data might be skipped over due to so many default values.

Response: We add the comparisons of simulated AOD for EP2 with the corresponding MODIS AOD datasets in Sec.3.4. Their respective spatial distributions are shown in the updated Figure 5. We find that the model could reproduce the
40 approximately spatial patterns of the observed AODs, in particular, the relatively high values spreading over Henan, Anhui, Hubei, and Hunan. In advance, we need to identify the calculation processes of the WRF-CMAQ-derived AODs, which would be supplemented in Sec.2.1.

Due to the excessive lack of the OMI AOD data, as the reviewer has pointed out, we rewrite all relevant descriptions and presentations that originally existed in Sec.2.4, Sect.3.2, Figure 5, and the statement of “Data availability”. As abovementioned,
45 we further replenish the model-derived AODs to enhance observational evidence, as well as to validate the model performance in Sec.3.4.

Added/rewritten part in Sect. 2.1: To comprehensively validate the model performance, we would evaluate the spatial distributions of model-derived AODs, besides primary chemical and meteorological factors. Theoretically, not only particles but also gases have the ability to attenuate the intensity of light. AODs, generally severing as the feature of extinctions, should
50 be the combined function of their scattering and absorption. However, owing to the insignificant magnitude of gases, we focused only on particles to estimate the model-derived AODs as the following equations (Malm et al., 1994; Binkowski and Roselle, 2003; Song et al., 2008; Park et al., 2011; Jeon et al., 2016):

$$\text{AOD}_{\text{MODEL}} = \sum_{i=1}^N (\sigma_{\text{sp}} + \sigma_{\text{ap}}) \Delta Z_i \quad (1)$$

$$\sigma_{\text{sp}} = 0.003f(\text{RH})(\text{NH}_4^+ + \text{SO}_4^{2-} + \text{NO}_3^-) + 0.004\text{OM} + 0.001\text{FS} + 0.0006\text{CM} \quad (2)$$

$$55 \quad \sigma_{\text{ap}} = 0.01\text{LAC} \quad (3)$$

where i denoted to the vertical layer number and Z_i referred to the corresponding layer thickness. The OM, FS, CM, and LAC were the mass concentrations of organic species, fine soil, coarse particles, and black carbon, respectively and uniformly configured with the units of mg/m³. Their respective scattering and absorbing coefficients (i.e., 0.003, 0.004, 0.001, 0.0006, and 0.001) were recorded in m²/mg. The $f(\text{RH})$ represented the aerosol growth factor that was estimated based on the relative
60 humidity. All relevant parameters were extracted from the model results.

Added/rewritten part in Sect. 2.4: Daily mean values of AOD at 550 nm retrieved from the satellite platform were examined during the target period to highlight significant spatial and temporal variabilities of regional haze in CEC. Here the episode-averaged AOD product from MODIS (MOD08_D3) at 550 nm was utilized (<https://giovanni.sci.gsfc.nasa.gov/giovanni/>, last access: 5 August 2019).

65 **Added/rewritten part in Sect. 3.2:** Figure 5 shows spatial distributions of episode-averaged AOD observed by MODIS (MOD08_D3) at 550 nm during EP2. It is in good agreement with spatial distributions of surface average PM_{2.5} concentrations. For instance, much higher AOD values were mostly detected in Henan, Anhui, Hubei, and Hunan, associated with relatively high surface observed PM_{2.5} concentrations and substantial OCSB emissions, as shown in Figs. 3 and 4. In addition, the satellite-based product detected that spatial distributions of high AOD values covered wider areas than the surface measurements, such as in Jiangxi, Zhejiang and Fujian. This was possibly due to the fact that PM suspended in the upper troposphere was more easily transported than that on the ground. This phenomenon further illustrates that OCSB dominated by OCSB is not only a significant local source but also an important regional source.

70 **Added/rewritten part in Sect. 3.4:** Besides, compared with the satellite retrievals, the model-derived AODs in the OPT case during EP2 presented the extremely similar spatial patterns over CEC (Fig. 5). Especially, they could reproduce the relatively high measurements over Henan, Anhui, Hubei, and Hunan. Nevertheless, we recognized the general underestimations of model-derived AODs, in particular over the areas with the extremely PM_{2.5} concentrations, which might be due to the uncertainties in the numerical predictions of the plume rise of OBB (Tai et al., 2008; Fu et al., 2012a). Another explanation may be contamination of the observed AODs due to opaque clouds as described by several studies (Huang et al., 2012; Aouizerats et al., 2015). These results establish reliable model performance.

80 **The updated Fig.5:**

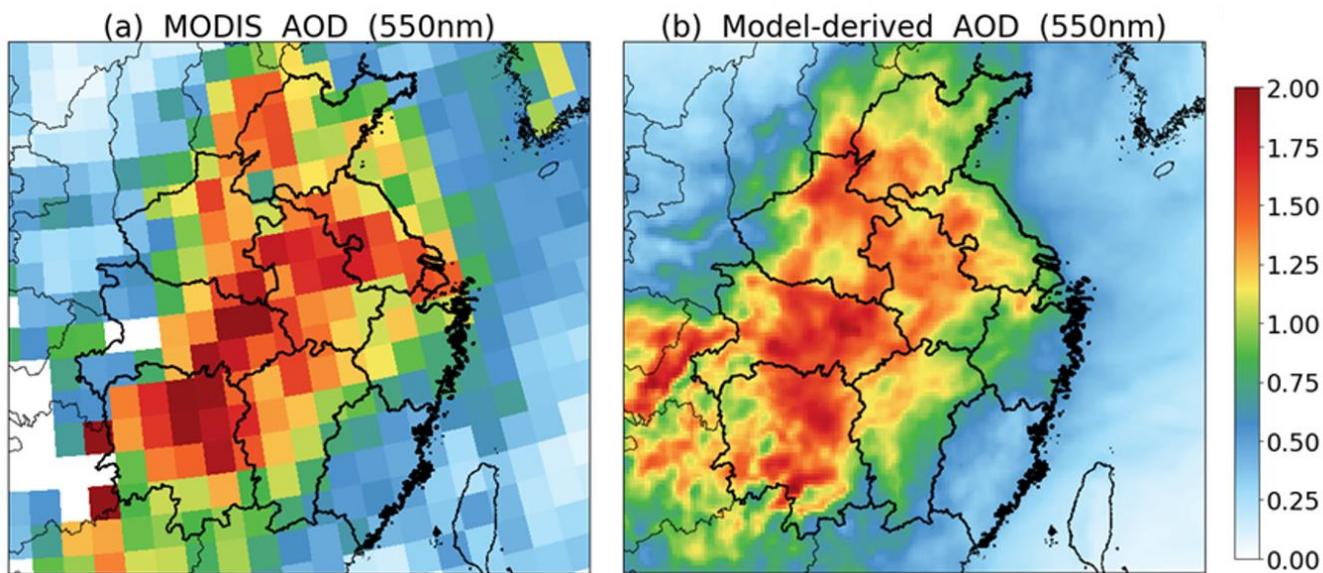


Figure 5. Spatial distributions of (a) satellite-based and (b) model-derived AODs in the OPT case over CEC for EP2.

Added/rewritten part in “Data availability”: The MODIS data can be freely accessed at <https://earthdata.nasa.gov/> (last access: 5 August 2019). GFASv1.0 data are available from <http://apps.ecmwf.int/datasets/data/cams-gfas/> (last access: 5

August 2019). GFED4s data can be downloaded from https://daac.ornl.gov/VEGETATION/guides/fire_emissions_v4.html (last access: 5 August 2019). FINNv1.5 data can be found at <http://bai.acom.ucar.edu/Data/fire/> (last access: 5 August 2019).

Technical issues:

1. Abstract: It may be difficult for the readers who are not familiar with the Chinese geography to follow the descriptions using
90 the province names.

Response: To further interpret the basic geographical profile of the focal region (i.e., CEC), we supplement two sentences to briefly introduce its inclusive provinces.

Added/rewritten part in Abstract: This region includes nine provinces, i.e., Hubei, Anhui, Hunan, Jiangxi, Shandong, Jiangsu, Shanghai, and Fujian. The former four ones are located inland, while the others are on the eastern coasts.

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