Review of "Influence of anthropogenic aerosols on the Asian monsoon: a case study using the WRF-Chem model" by Jiang et al.

General Comments

This study used the WRF-Chem model to investigate the direct and indirect effects of anthropogenic aerosols on the Asian monsoon system during the period of March-August 2008. The simulation is evaluated by comparing the simulated aerosol optical depth and meteorological fields with the satellite and reanalysis data. The sensitivity experiment was designed to examine the direct and indirect effects of anthropogenic aerosols on the precipitation, surface temperature, radiation, and circulations in pre-monsoon and monsoon period. The authors also want to answer what are the aerosols-cloud-precipitation interactions during Asian monsoon season. In general, they found anthropogenic aerosols tend to reduce precipitation in the source regions while slightly increase precipitation outside the aerosol source regions.

Anthropogenic aerosols also induced a reduction in pre-monsoon and monsoon precipitation over East Asia. Aerosol can play an important role in the climate system and interact with cloud and precipitation. It will be interesting and important to investigate aerosol impact on Asian monsoon precipitation and circulation. However, I cannot trust the results that the authors showed based their experiment design. Without ensembles or multi-year simulations, the aerosol impact "signal" is just too weak (e.g., Fig. 10). Most of the difference between two experiments may be just the noisy due to the chaotic behavior of weather or climate. The ensemble-mean of the impact could be significant different from what they had now.

➔Response: Thanks for the comment. We have carefully considered the reviewer's suggestions, and two more ensemble simulations have been carried out. Results presented in the revision are all updated to use ensemble means.

Most of their explanation of the modeling results is very subjective or just based on previous studies. In their version of WRF-Chem (v3.3.2), the aerosol indirect effect cannot be fully investigated. It missed aerosol impact on cloud ice nucleation and convective cloud microphysics. Most of the cloud and precipitation changes may be mainly due to aerosol direct and semi-direct effect. I have some specific comments below.

➔Response: We have acknowledged this in the revision, and some discussion about the limitation of this work from this perspective is included. Please see below for more details.

Major Comments

In v3.3 of WRF-Chem, the aerosol impact on the convective cloud microphysics is not included in the cumulus parameterization. Therefore, the simulation at a horizontal resolution of 42 km that cannot resolve convective clouds shouldn't be used to investigate aerosol indirect effect, particularly for the monsoon season when convective events are active.

➔Response: There is some previous work that used the similar version of WRF-Chem to study the aerosol effects on monsoon precipitation (i.e. Zhao et al., 2012). We acknowledged the limitation of this work as the model cannot resolve convective clouds that could have effects on the monsoon precipitation in the "Discussion and Conclusions" section.

Zhao C, X Liu, and LYR Leung. 2012. "Impact of the Desert Dust on the Summer Monsoon System over Southwestern North America." Atmospheric Chemistry and Physics 12(8):3717-3731. doi:10.5194/acp-12-3717-2012

The statistical analysis must be done for the signal of aerosol impact on cloud and precipitation.

➔Response: We have done comparisons between different ensemble simulations. There are no significant differences among different simulations, so that the statistical analysis is not necessary.

This work also tended to investigate the influence of dust aerosol on cloud and precipitation over West India and North China. The authors said, "The impacts due to dust aerosols are much smaller as compared to the effects from anthropogenic aerosols. There is a small increase in precipitation in the Indian region, and the changes in East Asia are different in different seasons". However, I cannot find any evaluation of the dust simulation (It is blank over the dust source regions, such as the Taklimakan Desert and Gobi desert in Figure 2). It may be because authors argued the default dust emission scheme is too poor. Please add the evaluation of dust simulation; otherwise the discussion about the dust effect should be removed.

➔Response: As the focus of this work is not dust, we removed the discussion about the dust effect as suggested here. Another paper by Kumar et al. (2013) has evaluated the dust aerosol simulations in Asia.

Kumar, R., Barth, M. C., Pfister, G. G., Naja, M., and Brasseur, G. P.: WRF-Chem simulations of a typical pre-monsoon dust storm in northern India: influences on aerosol optical properties and radiation budget, Atmos. Chem. Phys. Discuss., 13, 21837-21881, doi:10.5194/acpd-13-21837-2013, 2013.

There is already a new emission scheme based on GOCART dust emission scheme coupled with the MOSAIC aerosol module in v3.3. There is some evaluation of its performance over Asia (e.g., Chen et al., 2013). You can use that scheme to investigate the dust climate impact if you want. In addition, could you please explain why the dust-induced precipitation changes have the opposite patterns in pre-monsoon and monsoon periods (Figure 9)?

➔Response: As mentioned above, the discussion about dust effect has been removed.

There is another similar study, Wu et al. (2013), also using WRF-Chem to investigate aerosol impact on East Asian monsoon. What is the difference between this study and theirs? Authors, at least, need discuss the results from Wu et al. (2013). Need more discussion about the results from previous studies and this study. Why is this study unique if a regional modeling study has been done by Wu et al. (2013)?

➔Response: Thanks for pointing us to Wu et al's paper. We have carefully read the paper, and included some discussion about the difference between this study and their work. Also, more discussion about previous work has been included.

The presentation of the results includes an evaluation of the aerosol optical depth and meteorological fields. I would suggest adding an observation section that describes the satellite, AERONET, and reanalysis data.

➔Response: Section 3 is the comparison between model simulations and observations. The description of the observation data is included as well. To make the paper much more concise, we did not include a separate section for the data.

The comparison between the WRF-Chem and AERONET is too poor during your study period. I am worried about the conclusion about the aerosol impact found in your study. WRF-Chem can simulate much better results than what you presented (e.g., Gao et al. 2011). In addition, 2008 is a year of Beijing

Olympic Game. China government conducted emission control. It needs to be discussed about the uncertainty of emission inventory without counting this effect.

➔Response: We agree with the reviewer that the emission control around Beijing due to the Olympics could have some impact on the emission sources. However, some studies (i.e. Gao et al., 2011) found that the local emission control does not affect the regional scale emissions much as the control was more local scale. Also, our study domain and focused regions are away from Beijing. The small change in Beijing emissions would not have big impacts on our results. Besides, the control period was for a short period. There were no big differences in emissions in June or July. We also acknowledged that the emissions data used in this study have some limitations in the paper.

Gao, Y., Liu, X., Zhao, C., and Zhang, M.: Emission controls versus meteorological conditions in determining aerosol concentrations in Beijing during the 2008 Olympic Games, Atmos. Chem. Phys., 11, 12437-12451, doi:10.5194/acp-11-12437-2011, 2011.

In Figure 5, why not show precipitation over the ocean?

➔Response: Studies have shown that WRF has a low skill in simulating precipitation over oceans (i.e. Koo and Hong, 2009). We have included this information in the paper.

Koo, M.-S., and S.-Y. Hong: Diurnal variations of simulated precipitation over East Asia in two regional climate models, J. Geophys. Res., 115, D05105, doi:10.1029/2009JD012574. 2010.

Minor Comments

➔Response: Studies have shown that WRF has a low skill in simulating precipitation over oceans (i.e. Koo and Hong, 2009). We have included this information in the paper.

Koo, M.-S., *and* S.-Y. Hong *(*2010*),* Diurnal variations of simulated precipitation over East Asia in two regional climate models*,* J. Geophys. Res.*,* 115*, D05105, doi:*10.1029/2009JD012574.

Lines 4-7 of page 21402, the results from Chapman et al. (2009) may not be the case in this study, since they design relatively high resolution (up to 2 km) experiments that can properly resolve most clouds, which is not the case in this study.

➔ Response: This reference is removed here.

Lines 14-17 of page 21402, aerosol impact is important, however, it is hard to be proven by your analysis with inappropriate experiment design.

➔Response: We have considered reviewers' suggestions, and more ensemble simulations have been done. The results presented in this study have been updated and more discussion has been included.

Figure 2: please provide the seasonal-averaged AOD for pre-monsoon and monsoon seasons in 2008 from MISR/MODIS and WRF-Chem results.

➔ Response: It would be easier to see the model performance if we do month-by-month comparisons. However, there would be too many figures in Figure 2 if we show the comparison for each month. So we picked every other month.

The MODIS deep-blue products are preferred for the comparison with simulated AOD over land.

➔ Response: The product used in this study is the combined AOD from DB (deep blue) and traditional. As you could see from the AOD plot, the AOD values over the deserts are well retrieved.

Figure 3: It will be better to plot AERONET data in black dots to distinguish them with blue solid lines.

➔ Response: We changed blue dots to black dots.

Figure 4: "surface temperature" and "2-m temperature" are the different variables in the WRF model.

➔Response: Here "surface air temperature" and "2-m temperature" are exchangeable. We did not use "surface temperature". Surface temperature is different from surface air temperature.

Figure 6: Could you please explain the large increased surface air temperature in Mongolia during the monsoon season?

➔Response: This is caused by the changes in clouds. The indirect effect on clouds caused by aerosols could further affect the near surface temperature. We included the following statement in the revision.

"The slightly increase in surface air temperature in Mongolia is caused by changes in clouds from this fast and non-uniform responses."

Page 21395 line 2: please keep the temperature unit consistent with Figure 6.

➔Response: The temperature unit has been changed to " °C"

Figure 7: Please add a brief explanation of why select the highlighted regions, IN and

EA.

➔Response: We have considered the other reviewer's suggestion to change EA to East China (EC). A brief explanation is included "We selected India (IN) and East China as two representative regions to examine the aerosol impacts on clouds and precipitation as the two monsoon affected regions exhibit high concentrations of aerosols."

Figure 7: Please convert "sigma level" into "Pressure" or "Altitude" in the y-axis.

➔Response: Converted into "Pressure" level in the y-axis.

Figure 10: Lines 13-15 of page 21399 "Figure 10c and d shows that the changes in the precipitation evolution strongly correlate with the evolution of OLR changes in the two regions, with higher OLR corresponding to lower precipitation." It is hard to be seen from this Figure.

➔ Response: The patterns of changes in OLR are not the same as those in precipitation as the precipitation used here is accumulative. If we use daily precipitation, the patterns in precipitation would be less clear. So we used accumulative precipitation. However, we still can see from the two sets of figures that the location where when OLR starts to decreases/increases shows increases/decreases in precipitation.

References:

Wu, L. et al.: Regional simulation of aerosol impacts on precipitation during the East Asian summer monsoon, JGR, 2013.

Chen, S, et al.: Modeling the Transport and Radiative Forcing of Taklimakan Dust over the Tibetan Plateau: A case study in the summer of 2006, JGR, 2013.

Gao Y, et al.: Emission Controls Versus Meteorological Conditions in Determining Aerosol Concentrations in Beijing during the 2008 Olympic Games, ACP, 2011.