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Interactive comment on "Simulating aerosol–radiation–cloud feedbacks on meteorology and air quality over eastern China under severe haze conditions in winter" *by* B. Zhang et al.

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We thank the reviewer and the editor for their thoughtful and constructive comments to improve the analysis of the manuscript. The revisions/additions/edits are highlighted in BLUE in the revised manuscript. All the page/line/figure numbers in the response file refer to those in the revised manuscript with the changes noted.

Anonymous Referee #1 (Comments to Author): This study attempts to quantify the influences of the aerosol feedbacks on meteorology and air quality during a severe

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haze episode which occurred in January 2013 over eastern China. Three scenarios of WRF-Chem simulations were conducted to further differentiate the aerosol radiative and indirect effects. In general, it is a worthwhile analysis which should be published. Response: Thank you.

Major comments:

1. First, estimates of feedbacks were filtered in a statistical way, as shown in Figure 7-10. More discussion is needed to explain how the Student's t test was employed to distinguish the aerosol-induced changes from the system noises. To my understanding, aerosol indirect effects may not be that straightforward as direct effects which can be simply attributed to the aerosol loading.

Response: We've added more descriptions about how the Student's t test was used in the revised Section 4. The Student's t test is used to test the null hypothesis that the two sample means are the same. Rejection of the null hypothesis indicates that the two sample means are different; that is, the aerosol-induced changes are significant. For every meteorological and chemical variable in a given grid point, the sample size is 744 (24 hrs $\times$ 31 days). How the t statistic is calculated is shown in the revised Appendix. By employing the Student's t test, system noises are excluded and only significant changes are shown and discussed in the manuscript. We agree with the reviewer that aerosol indirect effect is not as straightforward as direct effect. Inevitably, some aerosol-induced changes, especially those caused by aerosol indirect effect, are excluded. However, the remaining changes after statistic filtering are strong enough for use to make reasonable judgments.

2. Second, as claimed in the manuscript, the PM2.5 was wrongly calculated by the model after the inclusion of aerosol indirect effects. Assuming that is true, I don't think the PM2.5 in BASE scenario is appropriate to be used for comparisons against observations, as presented in Figure 11 and 13. Considering large uncertainties in the estimation of aerosol indirect effects which are also less important than radiative

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effects during this particular episode, I would recommend the authors just focus on the discussion of radiative effects.

Response: The model results in this study showed that model performance was not improved when including aerosol indirect effects. The model performance was the best when only aerosol radiative effects were included. Our finding was consistent with previous studies (Kong et al., 2014; Makar et al., 2014a). As for the model setting, the scenario including both aerosol radiative and indirect effects represents the most realistic situation. Aerosol indirect effects might have non-negligible effects on simulating clouds, which is quite important for the wetter South China and for other seasons. We agree with the reviewer that our research should pay the most attention on radiative effects. However, considering aerosol indirect effects are very important and gain a lot of concerns (as shown in Reviewer #2's comments), we retained the discussion of the indirect effects.

Specific: P 26089, L29: "The model's meteorology is re-initialized every five days based on NCEP", why need to be re-initialized? Any nudging technologies was adopted?

Response: We found that the biases in meteorological variables would become larger when the model was run continuously for more days. So, re-initialization for every five days is a reasonable strategy given consideration to both efficiency and accuracy. We did not employ any nudging technologies, since aerosol effects were included.

P 26092, L13: any explanation about the high-bias? Such as land-use type? Lack of aerosol radiative effects?

Response: The overestimation of wind speeds possibly results from unresolved topographical features in surface drag parameterization and coarse resolutions of the domain (Cheng and Steenburgh, 2005; Yahya et al., 2014). This explanation has been added in the revised Section 3.1.

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P 26092, L17: the figures for "00:00" and "12:00" look quite similar, might consider to combine them as one.

Response: Agree. We've combined "00:00" and "12:00" as one profile in the figure. Please refer to the revised Figure 3.

P 26093, L20: it might be better to do the analysis on daily-averages instead of hour averages, because of the diurnal pattern. Response: Agree. We've obtained the enhancement ratio on the basis of daily average in the revised manuscript.

P 26094, L5: lack of the inclusion of aerosol feedback in traditional modeling might also contribute to such low-biases.

Response: Agree. We've added some discussion about this at the end of this paragraph.

P 26096, L7: "are less significant than solar radiation", how to qualify, in percentage?

Response: First, solar radiation is reduced by 21% over the regions where the change is determined as significant by the Student' t test. By comparison, wind speed and PBL height are reduced by 6% and 14%, respectively. Second, as shown in Figure 7, the regions with significantly reduced solar radiation are much larger than those with significantly reduced wind speed or PBL height. We've added the descriptions in the revised manuscript.

P 26096, L20: "aerosol indirect effects play a much more significant role in changing cloud proper ties", but mostly in the south, please clarify it.

Response: We've clarified this in the revised manuscript.

P 26096, L22-25: "The reduction over these relatively clean areas may be explained by the lower particle number concentrations in the BASE scenario than the default droplet number mixing ratio of 1.0×106 kg-1 in scenarios without aerosol indirect effect.", I don't understand the sentence, please clarify it.

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Response: In WRF-Chem, if aerosol indirect effect is turned off, the cloud droplet number concentration is prescribed as 1.0×10^6 kg^{-1} in the cloud microphysics scheme. If aerosol indirect effect is turned on, the cloud droplet number is calculated based on aerosol number concentration. We've modified this sentence as: "The reduction over these relatively clean areas may be explained by the smaller droplet number mixing ratio which is derived from lower particle number concentrations in the BASE scenario. The scenarios without aerosol indirect effects adopt the default value droplet number mixing ratio of 1.0×10^6 /kg which does not vary with aerosol number concentrations."

P 26097, L4: "the most parts of the domain", should be the north of the domain.

Response: Corrected.

P 26097, L10: "indicating similar sources of these pollutants", not true, suggest to delete it.

Response: Done.

P 26097, L12: "CO is enhanced by up to 446 ppb", is that domain-average? Please clarify it.

Response: It is the maximum enhancement over the domain. We've clarified it in the revised manuscript.

P 26098, L17: "The reduction of PM2.5 in WRF-Chem simulations with aerosol indirect effects mainly comes from two aspects". More intensive precipitations may also help reduce the particles, particularly in the south.

Response: Agree. We've added this explanation in the revised manuscript.

P 26111, Table 2: NMB for T2 is "-83.3%", the number does not make any sense. Using "K" unit would be better.

Response: We've re-calculated NMB for T2 using "K" unit in the revised manuscript.

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P 26114, Figure 2: lack of the label for x-axis.

Response: Figure 2 has been replaced with a revised one with x-axis included.

Editorial: P 26088, L18: "the model" should be "the model's performance"

Response: Corrected.

P 26089, L14: "such as" should be "including"

Response: Corrected.

P 26090, L8: "etc" should be deleted

Response: Corrected.

P 26090, L9: "(BASE-EMP)" should be "(i.e., BASE-EMP)"

Response: Done.

P 26093, L1: "evaluate" should be "evaluated"

Response: Done.

P 26096, L14: "is conductive for" should be "enhances"

Response: Done.

P 26097, L9: "the" should be "these"

Response: Corrected.

P 26097, L30: "Reduction" should be "Reductions"

Response: Corrected.

P 26098, L3: "respond" should be "responds"

Response: Corrected.

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 26085, 2014.

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