Reply to Anonymous Referee #2

We thank the reviewer for the careful reading of the manuscript and helpful comments. We have revised the manuscript following the suggestion, as described below.

The authors attempt to investigate the effect of aerosol-radiation feedback (ARF) on aerosol pollution at surface by using modeling simulations. The performance of WRF-CHEM simulations was fully evaluated, and the contribution of aerosol-radiation feedback to the near-surface $PM_{2.5}$ concentration was carefully quantified. However, I still have some minor issues about this work prior to its publication.

1 Comment: There are several problems about how the authors explain why ARF shows a negative effect on surface $PM_{2.5}$ concentration when $PM_{2.5}$ is less than 50 ug/m³. I understand that the suppressed updrafts result in less $PM_{2.5}$ at surface, but I don't think it is the case that the enhanced downward motion leads to reduction in $PM_{2.5}$ at surface (lines 476-578)? Also, what is the vertical velocity in Fig. 13 referring to, updrafts, downdrafts, or the net velocity by combining updrafts and downdrafts? Is panel (b) for the simulation of base case? The Y-axis label of (c) panel is different from the description in figure caption.

Response: We have clarified in Section 3.3: "*Figure 11b presents the average vertical velocity (the net velocity by combining updrafts and downdrafts) below about 400 m in f_{rad0} as a function of near-surface [PM$_{2.5}$]. Apparently, when ARF is not considered, the area with near-surface [PM$_{2.5}$] less than 100 µg m^{-3} is generally controlled by downward airflow, and vice versa for the area with near-surface [PM$_{2.5}$] more than 100 µg m^{-3}. The ARF induced cooling generally cause a downward motion in the PBL (Figure 11c), which suppresses the upward motion in the area with near-surface [PM$_{2.5}$] more than 100 µg m^{-3} to enhance near-surface [PM$_{2.5}$], but accelerates the downward motion in the area with near-surface [PM$_{2.5}$] less than 100 µg m^{-3} to strengthen the divergence intensity, further decreasing near-surface [PM$_{2.5}$].*". We have revised the figure caption "*Figure 13 Average (a) decrease of water vapor content and (c) increase of average vertical velocity below 400 m caused by ARF, and (b) average vertical velocity below 400 m as a function of the near-surface [PM$_{2.5}$] in NCP during daytime from 05 December 2015 to 04 January 2016.*" as "*Figure 11 Average decrease of (a) near-surface water vapor content and (c) vertical velocity below 400 m caused by ARF, and (b) average vertical velocity below 400 m in f_{rad0} as a function of the*

near-surface [PM$_{2.5}$] in the NCP during daytime from 05 December 2015 to 04 January 2016."

2 Comment: This work primarily quantifies to what extent the surface PM$_{2.5}$ could be enhanced because of the collapse of PBL when ARF is considered. How about the impacts of ARF on AOD, which can be used to denote the column-integrated aerosol abundance? The reason why I care about how the AOD changes under ARF effect is because the reduced incoming solar radiation might suppress the photochemical formation of PM, which could offset the effect of PBL collapse.

Response: We have clarified in Section 3.3 "*Figure 9 presents the temporal variation of AOD at 550nm averaged in the selected area during the episode in f_{base} and f_{rad0} to evaluate the impact of ARF on AOD. Apparently, except from 8 to 11 December, the ARF contribution to AOD is generally marginal, indicating that ARF does not play an important role in the column-integrated aerosol abundance. Additionally, the considerable AOD enhancement from 8 to 11 December is more likely caused by the substantial increase in RH due to ARF, which facilitates aerosol hygroscopic growth to augment particle size and further increases AOD. It is worth noting that the extinction of haze aerosols in the PBL also decreases the photolysis to suppress the photochemistry, further hindering the secondary aerosol formation to offset effects of ARF on near-surface [PM$_{2.5}$].*"

We have also clarified in Section 4: "*It is worth noting that modification of photolysis by aerosol scattering or absorbing solar radiation ultimately alters the atmospheric oxidizing capacity to influence the secondary aerosol formation, which potentially offsets ARF effect on the haze pollution. Hence, further studies need to be performed to evaluate the effect of aerosol photolysis interaction on the haze pollution.*".

3 Comment: Relative to the sensitivity study section, the evaluations of model performance appear as the major portion of the body text. The authors might want to shorten the model evaluation section a little bit, so that the entire manuscript looks more balance.

Response: We have moved the model validation of air pollutants and aerosol species to the supplement to shorten the part of model evaluations, and clarified in Section 3.1: "*Generally, the model simulates well the horizontal distributions and temporal variations of PM$_{2.5}$, O$_3$, NO$_2$, and SO$_2$ mass concentrations against measurements in the NCP. Additionally, the*

model also reasonably well reproduces the temporal profiles of the aerosol species compared to observations in Beijing. The detailed model validation of air pollutants in the NCP and the aerosol species in Beijing can be found in SI."