Anonymous Referee #2:

We sincerely appreciate for your time and attention on our paper. The comments and suggestions you gave are very helpful for us to improve our paper. We now present point-by-point replies (in black) to all your comments (in green) in this response and the corresponding changes in the revised manuscript have been highlighted in blue.

1. ***Introduction: This study focuses on the vertical distribution of the aerosol properties. However, it lacks of information about the importance of the vertical distribution of aerosols and the uncertainty in the observed aerosol vertical structure. The vertical distribution of aerosols is very important as it modifies the vertical profile of radiative heating in the atmosphere and affects the atmospheric stability and convection. It also influences the radiative effect at the top of the atmosphere (TOA), particularly when the aerosols have strong absorption of solar radiation. A number of field programs have also been carried out to measure the vertical distribution of aerosols. Please give a literature review about the research that have been conducted in association with aerosol vertical distribution, such as the following work:***

Reply: Thanks for your comment. We further optimize and make supplement for Section 1 in the revised manuscript.

"Such variable aerosol vertical distributions can alter the optical properties of aerosols such as AOD, thus affecting the regional radiation balance (Liu et al., 2012) and even the global radiative forcing estimation (Zhang et al., 2013). A number of field programs were carried out to measure the vertical distribution of dust or biomass burning aerosols by airborne and surface-based instruments(Johnson et al., 2008). Combine with a radiative transfer model, the radiative effects including aerosol optical properties (Gadhavi and Jayaraman, 2006) and absorption of solar radiation at the top of atmosphere (TOA) (Meloni et al., 2005)could be calculated accurately."

2. ***Page 3, line 27: What does NFS stand for?***

Reply: "NFS" should be "NSF", which stands for National Science Foundation. We have corrected it in the revised manuscript.

3. ***Section 2.1, Figure 1: It's hard to tell where the sites are with such a small map. It would be better to give a larger geographic map, at least for China and the coastal area, and then a zoom-in map for north China Plain and the sites.***

Reply: Thanks for your comment, we add a China Map (Fig. 1) to show the location of North China Plain, the coastal area and the Xingtai Supersite in the revised manuscript.

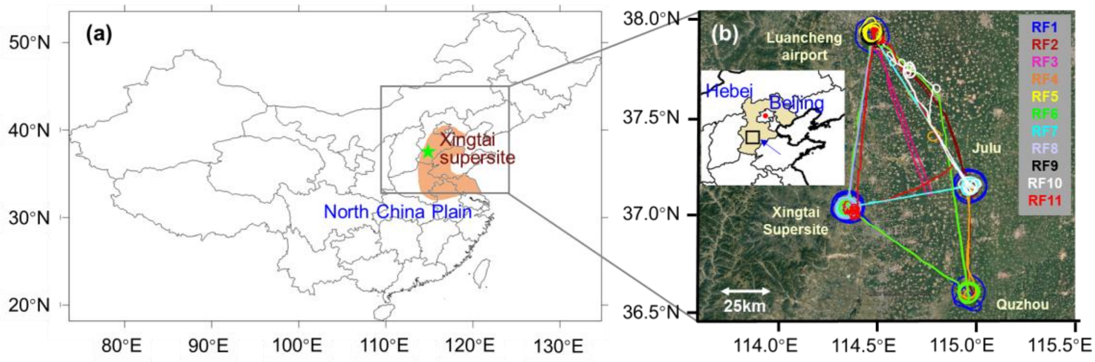

Fig.1 Map of the geographic location of North China Plain and the Xingtai supersite (a), and the flight tracks of the 11 research flights conducted over Hebei Province in May-June 2016 (b).

4. ***Section 2: Is this the first time that the ARIAs project is introduced (I didn't see any reference). If yes, I would suggest that a little more information should be given to describe the scientific objective of this project and justify how the super site in Xingtai was chosen.***

Reply: To better explain the background of this study and provide information about the jointed campaign, we added the following paragraph to the Introduction section.

"The overall goal of the ARIAs project is to integrate *in-situ* observations, satellite remote sensing, and chemical transport models to characterize and quantify tropospheric chemistry and composition over the NCP and to improve modeling tools that can be utilized routinely to eventually evaluate the effectiveness of air pollutant reduction policy scenarios. The trace gases and aerosols have major consequences for downwind areas such as Japan and South Korea, and even for North America."

We choose Xingtai as a surface supersite station for following reasons. First of all, it represents the typical geographical features and air pollution characteristics of the NCP regions, the most polluted area in China and Northeast Asia. Statistics shows that Xingtai and other southern Hebei cities were among the worst-ranked cities by seasonal or annual air quality index during 2013 and 2014 (Li et al., 2015). Secondly, as a national primary weather station, basic meteorological and sounding observations have been made at the Xingtai supersite. Lastly, it has existing infrastructure to support the field experiment.

5. ***Section 4: What is the definition for clean or polluted PBL, e.g., using a critical value of AOD within PBL? What is the scale height Hp in this study? Normally it represents the height when the aerosol is reduced to 1/e of its surface value. Is it a prescribed value or determined from the observation? And how is PBL height determined from scattering coefficient in this study?***

Reply: As the main focus of this section is aerosol scattering, we defined the clean or polluted PBL by σ_{sca} values and the shape of σ_{sca} vertical profiles. Weather phenomenon on flight days is another primary factor in our consideration. As clean PBL for example, the mean value of σ_{sca} at every 100 m should less than 100 Mm^{-1}

(except the surface layer) and decreases exponentially with altitude. Fig.6b shows the vertical profiles of σ_{sca} in the lower portion of the PBL. The profiles of this type show that the gradient of σ_{sca} are generally small from surface to a certain layer (H_{PBL}), then the value of σ_{sca} sharply decreased.

We use scale height (H_p) as one of parameters to describe a parameterized model of σ_{sca} distribution. H_p is determined from airborne observations.

The PBL height is determined by the shapes of σ_{sca} vertical profiles. When the pollution in the lower layer of the troposphere, the magnitude of σ_{sca} increased slightly with height until a layer where σ_{sca} sharply decreased. In this study, the mean decreasing rate is about 0.81 Mm^{-1} m^{-1}, We defined the bottom of this layer as the PBL height (H_{PBL}).

We have added the following description in Section 4.2 in the revised manuscript.

$$\sigma_{sca,\,H}=\begin{cases} \sigma_{sca,\,PBL}\cdot \exp(-(H-H_{PBL})/H_p), & (\text{if } H > H_{PBL}) \\ \sigma_{sca,\,0}+k\cdot H, & (\text{if } H \le H_{PBL}) \end{cases}, \quad (9)$$

where H_{PBL} is the normalized altitude of PBL height, H_p is the aerosol scale height in the free troposphere, k is the increasing rate of σ_{sca} in the PBL. In these cases, $\sigma_{sca,0}$=171 Mm^{-1}, H_p =216m, k= 0.03Mm^{-1} m^{-1} and r^2=0.9394. Fig. 6d shows the ambient RH profiles under dry and humid conditions. The shapes of dry and humid RH profiles were similar in the PBL, but at the top of the PBL, the RH_dry profiles dramatically decreased while the RH_humid profiles slightly changed. Linear fits were made to determine the correlation between RH and σ_{sca}. Under dry condition, there was a pronounced correlation (r^2=0.95) between RH_dry and σ_{sca} profiles. But under humid condition, the correlation coefficient was 0.12, which suggest a poor correlation between RH_humid and σ_{sca} profiles.

6. ***Section 4.1 & 4.2: What ambient RH is used to determine the cases as dry/humid conditions, e.g., the average RH within PBL or the RH at a certain level? What is the percentage of the dry and humid cases? Figs. 6b & 7b are interesting. Since Fig. 7b is done by separating dry and humid conditions, it would be interesting to see Fig. 6b in dry and humid conditions as well.***

Reply: We determined the dry/humid case by the mean values of RH vertically. In Section 4.1, the percentage of the dry and humid cases are 0.53 and 0.47, respectively; in Section 4.2, the percentage of the dry and humid cases are 0.67 and 0.33 respectively

We make a change for Fig. 6b by separating dry and humid conditions in the revised manuscript as the following:

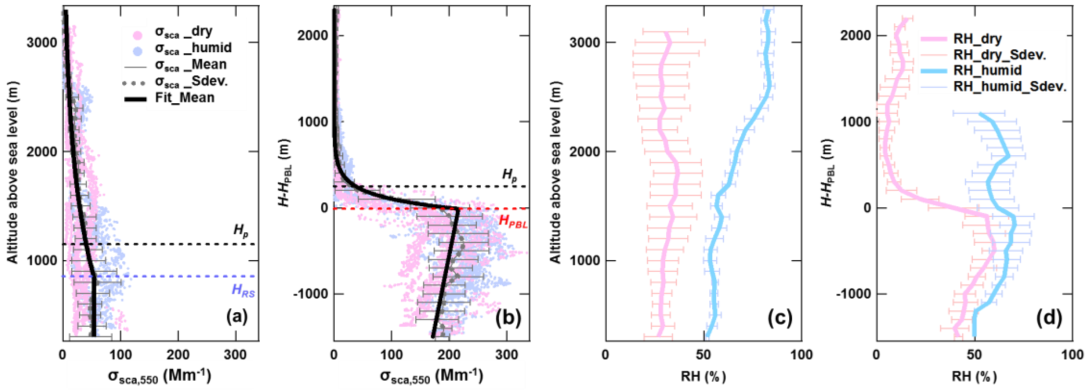

Fig. 6. Mean vertical distributions of σ_{sca} at 550 nm (in Mm^{-1}) and relative humidity (%) during the flight campaign for those cases of (a, c) clean PBL and (b, d) pollution in the lower layer of the PBL where PBL heights have been normalized to the same altitude. Grey dashed lines represent mean σ_{sca} vertical profiles, the light pink and blue dots represent 1 s Nephelometer-measured σ_{sca}, under dry of humid condition respectively. Thick lines show the calculated fitting curves of the σ_{sca} profiles (see Eq. 6 and 7). Magenta and blue lines represent RH data collected under dry or humid conditions (c, d). The horizontal error bars represent the standard deviations at every 100 m level.

References:

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