# Reply to RC1

This paper shows some VTDMA data from China, with the intent of investigating factors affecting the mixing state of refractory material in a polluted environment. The results are interesting and within the remit of ACP, and the manuscript is reasonably well written. Also, because measurements of this nature are particularly common, there is an element of novelty in its own right. However, this paper is slightly let down by the fact that the results are interpreted in a very self-contained manner, without really considering the wider body of knowledge. Addressing this should be fairly straightforward, however this could potentially change the character of the paper, therefore I recommend publication after 'major' corrections.

**RE:** The reviewer raised an important issue. In the revised manuscript, we further highlight the novelty of this study following a more comprehensive review of more previous studies. Our study is unique in the analysis of the volatility and mixing state of nucleation-mode soot-containing particles. The findings help understand the aging processes of soot particles and improving the accuracy of modeled aerosol absorption. Meanwhile, we add more results to validate our results against previous findings in the revised manuscript.

Major comments:

The authors give an interesting discussion investigating the potential reasons for the phenomena they observe, however they do not place this in the context of wider atmospheric implications. In particular, this paper would benefit from a comparison with equivalent measurements in other locations, or alternative methods of measuring BC mixing state (e.g. doi: 10.5194/acp-20-3645-2020). This will allow for a deeper insight into the processes and phenomena under investigation.

**RE:** The reviewer provides a good reference for us to compare the two studies. Yu et al. (2020) characterize mass-resolved mixing state of mass-resolved black carbon (BC) in Beijing based on the measurement of a coupled combination of a centrifugal particle mass analyzer (CPMA) and a single-particle soot photometer (SP2). A new inversion algorithm was used to characterize the mixing state of rBC-containing particles in Beijing. We characterize the size-resolved mixing state of soot particles based on the measurement of VTDMA in Xingtai using a different observation method but the measurement result is comparable. For example, Yu et al. (2020) finds that a more even distribution of rBC and non-rBC material mass fractions in summer, which may be caused by higher amount of secondary material. In our study, we find that the coating effect of volatile matter on soot particles was stronger in warm months (i.e, in summer) than in cold months. Another example is that Yu et al. (2020) finds that polluted air from the Southern Plateau dominated the aged rBC-containing particles in Beijing. In our study, the measurement site (Xingtai) is in the south of Beijing where highly aged soot particles (less NV particles) were observed.

In addition, more comparisons are made with reference to other studies in the discussion.

It would also better justify this as an ACP research article (as opposed to a measurement report) if either novel implications for wider atmospheric science could be specifically identified, or if newly-identified phenomena could be singled out.

**RE:** Most previous studies about mixing state of soot particles are based on the measurement of single-particle soot photometer (SP2) or soot particle aerosol mass spectrometer (SP-AMS). However, these measurements only denote the accumulation-mode soot particles. This is because the lower observation limit of particle size by SP2 and SP-AMS is larger than ~70 nm. VTDMA can make up this deficiency because its measurement is based on the aerosol number concentration, which is always high in the nucleation mode. This study firstly reports that the anthropogenic emissions and aging processes have different effects on the mixing state of nucleation- and accumulation-mode soot particles based on the five-month VTDMA measurement. Furthermore, factors influencing the coating depth of soot particles are found in this study. Some of the findings are new and important to improve the accuracy of modeled aerosol optical properties.

The discussion in the above has been added in the revised manuscript.

Minor comments:

Line 23: Taken in isolation, "weaken the volatility of soot particles" is a strange statement to make because many use the term "soot" synonymously with the refractory components like black carbon. I would rephrase.

**RE:** Agreed. It is revised as "weaken the mean volatility of soot-containing particles".

Page 69: Co-emitted organic carbon from biomass burning can be refractory (sometimes referred to as 'tar' or 'tarballs').

**RE:** Adachi et al. (2018, 2019) suggests that tarballs are mainly from biomass burning events (such as wildfires) and these particles are also refractory. The sentence is revised as "Aerosol volatility refers to the shrinking extent of particles at a certain temperature. The mixing state of soot particles or tarballs is closely related to aerosol volatility at high temperatures (Philippin et al., 2004; Wehner et al., 2009; Adachi et al., 2018, 2019).".

Line 157: This repeats a statement already made earlier.

**RE:** It is deleted.

Line 166: I presume the factory calibration was used to calculated MBC, but this should still be stated.

**RE:** Yes, it was. We have added the corresponding description in the revised manuscript.

Line 217: "better atmospheric diffusion conditions" needs to be better explained

**RE:** In August, there are more and stronger northerly winds, which is beneficial to the diffusion of air pollutants. The sentence is revised as "$PM_{10-400}$ was lower in August than in July, likely because of the better atmospheric diffusion conditions (more and stronger northerly winds) in August.".

Line 222: This paragraph doesn't really say anything substantial and can probably be removed.

**RE:** This paragraph has been removed.