Comment on acp-2022-840

General comments:

The present paper focuses on improving our understanding of the aerosol mixing state in a background site of the North China Plain in China. This is achieved by combining various techniques, including HTDMA, CCN counter, VTDMA, and SP2. The study provides a first-time intercomparison of the four aerosol mixing state parameters from the instruments above and offers insights into the interlink among these parameters and potential sources. I find this research to be important and interesting for aerosol mixing state studies. The manuscript is well-structured and scientifically engaging for the aerosol society. However, in terms of writing, it would be beneficial for non-expert readers if certain sentences were shortened and explanations were provided before reaching conclusions. Please see the detailed comments below. I suggest publishing the manuscript after a minor revision.

Specific comments:

1) Line 70. "..lead to substantial overestimation". Could you provide more details about the magnitude of the substantial overestimation?
2) Line 94. "highly correlated to those of a VTDMA at high temperature". Which temperature do you refer to and why?
3) Line 127-129. Please summarize the key messages of the meteorology influences on the aerosol mixing state.
4) Line 168 BBOA, line 173 FFOA.., please explain the full name when introducing a new term and check out the remaining of manuscript.
5) Line 177, what do you mean by "different chemical process" and could you give more details?
6) Line 187, why do you choose these three supersaturations for CCN measurements?
7) Line 211, the maximum temperature you chose is 200 degree Celsius, why do you choose this threshold?
8) Line 225-229, regarding the chosen size for SP2, which system was conducted for this study, with or without thermodenuder-bypass? Since you are expected to compare with HTDMA and VTDMA, why not choose the same sizes to measure for the three instruments?
9) Line 235, does the flow rate influence the measurements and by how much?
10) Section 2.3.1, the MAF is a fitting parameter from eq.7, what is the physical meaning of this parameter? Is it the maximum activation fraction?
11) Line 267, add sizes for the GF "The GFC for the four measured particle sizes were 1.1, 1.15, 1.175 and 1.2".
12) Section 2.3.3. Here you use the lag time between the peak of the scattering signal and the incandescence signal to classify the bare and coated BC. Is it related to the BC-coating mass ratio? The mass ratio is more commonly used and intuitive to understand.
13) Line 297-299, please give exact values of PM mass for the heavily polluted and clean period.
14) Line 315-316. "At lower SSs, the rapid increases in SPAR curves occur at larger particle sizes and the maximum AR of SPAR curves becomes smaller". Please briefly explain why.

15) Line 318, add SS for the “increases in SPAR curves, are approximately 90 nm, 120 nm and 180 nm”
16) Fig 2. Are bars representing the standard deviation of the campaign average?
17) Line 331-333, “In general, the size dependence of MAF, NFH, NFV and NFnoBC were similar to one another, suggesting they were dominated by the same particle group, namely BC-free particles”. I think this statement is not well supported, I would suggest weakening it or proving it with more evidence. For example, thickly coated BC particles can be very CCN-activate, hydrophilic and volatile, if mostly contain SIA.
18) Line 335, please provide exact values of the fraction of BC-containing particles and the applied diameter range, because the terms “higher” or “larger” are not accurate. Check out similar issues for the remaining manuscript too.
19) Line 342, what do you mean by “the more efficient secondary aerosol formation”, increase by secondary aerosol mass or particle size?
20) Line 356-357, what is the kappa value for hydrophobic mode aerosol?
21) Line 361, how do you get this statement with “lower than 0.07 but still CCN active”? please explain in detail.
22) Fig4, I would suggest simplifying the plot and keeping the sizes with most concurrent measurements, e.g. 150, 200 and 300 nm. Put other sizes to the supplement. Line 362-366, the diurnal variations should be described more explicitly as the pattern of RexBC is clearly different from the other three mixing state parameters and explain why.
23) Line 384, table S1 is quite interesting for readers thus I suggest putting it or making a correlation plot into the main context.
24) Line 385, why do you choose these three sizes? The critical size for the setting SS?
25) Line 386. A classification of the correlation should be clarified, such as the r range for the weak, moderate, and strong correlation.
26) Line 392, what do you mean by saying “..while the degree was the least for the correlation..”?
27) Fig. 5, what is the r in the plot? It would be more intuitive to use the same marker to represent different periods in the plot.
28) A summary table (or correlation matrix plot) of r in Fig5-7 will be helpful for readers to better understand the interlink between mixing state parameters and chemical composition.
29) Line 400, please give values to the sentence “correlation with MFFFOA was much weaker compared to MFBBOA”.
30) Fig.7. Which size of data do you use?
31) Line 428, please introduce what the difference (NF_{noBC}-NF_H *and* NF_V-NF_H) represents first before jumping to the results.
32) Line 438, why do you choose 200nm?
33) Line 459-462, out of curiosity, does the transport of ageing aerosols play a role in the increasing fraction of non-BC particles?