Responses to RC1

General Remarks

I would like to suggest this manuscript to be published as ACP Measurement report.

Response: Thank you very much for the reviewer's suggestion. From our perspective, this manuscript is still better suited as a research article for ACP rather than a measurement report. In Yin et al. (2021), we previously reported a consistent downward trend in AOD during 2010–2020. However, an open question remains as to whether this downward trend slowed or even halted after 2018, especially considering the slowed reduction in surface $PM_{2.5}$ since 2018 (Geng et al., 2024). The four additional years of lidar observations included in this study enable us to clearly identify a fluctuation period (of AOD) from 2018 to 2024. In addition, we also separate the contributions from dust (natural) and non-dust (anthropogenic) components and analyze their respective evolution during the study period. Importantly, the analyses presented here are based on first-hand, home-made lidar measurements collected consistently by our team over the past 15 years. These fixed-located, high-resolution, and height-resolved aerosol optical properties over central China provide an important basis for evaluating the effectiveness of emission control policies. Finally, this study includes extensive physical analyses for the contributions of meteorological and anthropogenic factors to variations in non-dust (anthropogenic) AOD.

Therefore, while we highly respect and appreciate the reviewer's suggestions, we believe that our manuscript meets the criteria for a research article. We respectfully leave the final decision to the editor.

References:

Geng, G., Liu, Y., Liu, Y., Liu, S., Cheng, J., Yan, L., Wu, N., Hu, H., Tong, D., Zheng, B., Yin, Z., He, K., and Zhang, Q.: Efficacy of China's clean air actions to tackle $PM_{2.5}$ pollution between 2013 and 2020, Nat. Geosci., 17, 987–994, https://doi.org/10.1038/s41561-024-01540-z, 2024.

Yin, Z., Yi, F., Liu, F., He, Y., Zhang, Y., Yu, C., and Zhang, Y.: Long-term variations of aerosol optical properties over Wuhan with polarization lidar, Atmos. Environ., 259, 118508, https://doi.org/10.1016/j.atmosenv.2021.118508, 2021.

Responses to RC2

General Remarks

The revised paper has been significantly improved. The authors responded to comments from two reviewers (RC1 and RC2) regarding the manuscript on the evolution of aerosols over Wuhan (2010-2024): To RC1, they clarified the basis for dividing AOD (Stage I: 2010-2017, declining; Stage II: 2018-2024, fluctuating) and DOD (downtrend extended to 2020) stages, improved the clarity of case studies by adjusting figure order, adding HYSPLIT backward trajectories, and supplementing comparative explanations of satellite and lidar data, while revising text wording, figure captions, and data processing descriptions. To RC2, they supplemented the calculation method and seasonal variations of DOD, justified that DOD is mainly from natural dust, emphasized the value of 4 additional years of observation data (2021-2024) to highlight innovation, added analysis of meteorological and anthropogenic contributions to AOD trends using the LMG method, and linked the two case studies (transboundary agricultural biomass burning smoke in June 2014, local haze in January 2019) to long-term trend analysis, ultimately improving the manuscript through text revisions and reference supplements. However, there are still some issues that require improvement.

Response: We appreciate the reviewer's thoughtful review of our first-round responses and revised manuscript. We have responded to the remaining two comments (in blue as below) and revised the manuscript accordingly (in red in the revised manuscript).

Specific comments

Comment: Page 10, line 250-254, and Page 21, line 472-475. The authors note that DOD declined until 2020 (-0.011 yr^{-1}) and rebounded after 2021, while AOD entered a fluctuating phase as early as 2018. However, the contribution of post-2020 DOD rebound to AOD fluctuations was not quantified. For example: What percentage of the monthly AOD increase in the extreme spring dust events of 2021 was attributed to DOD increments? What is the explanatory power of interannual DOD changes (2021–2024) for total AOD fluctuations? Without this analysis, the relative importance of natural (dust) and anthropogenic (non-dust) sources in driving Stage II AOD fluctuations cannot be clarified, leading to an underdeveloped conclusion on "differences in driving factors between stages."

Response: Thank you very much for the valuable comments. Regarding lines 472-475, we only discuss the evolution of non-dust AOD, which does not include the influence of dust (as stated in the first sentence of that paragraph). In this study, we first present the evolution of total AOD (Figure 2b), and then separate it into the respective evolutions of DOD (dust component; Figure 3) and non-dust AOD (non-dust component; Figure 4a). From our perspective, this storyline clearly illustrates the relative importance of natural (dust) and anthropogenic (non-dust) sources in driving Stage II AOD fluctuations.

In addition, we agree with the reviewer that, during 2021-2024 when DOD increased and non-dust AOD fluctuated, it is reasonable to discuss the potential contribution of the post-2020 DOD rebound to the total AOD fluctuations. Therefore, in the revised manuscript, we have added the ratio of DOD to total AOD in the new Figure 3b (Figure 1R b here), along with the following statements "**The ratio of DOD to total AOD is presented in Figure 3b. The monthly mean DOD fraction can reach up to 60% during dust-intrusion seasons in spring and winter (e.g., in 2012, 2018, and 2021). In contrast to the pronounced trend in DOD values, the annual mean fraction of DOD fluctuated only between approximately 20% to 30% over the entire period, indicating that the contribution of dust to total AOD remained relatively stable despite year-to-year variations.**" (please see lines 268-271).

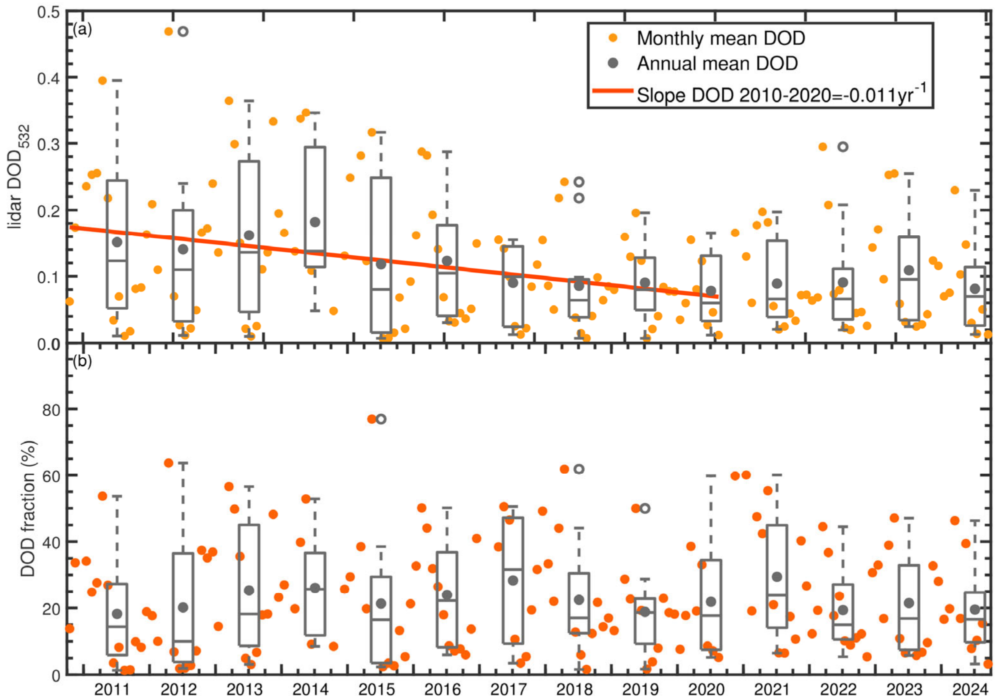

Figure 1R. Monthly mean (a) DOD and (b) the ratio of DOD to total AOD from 2010 to 2024. A box plot is presented for each year during 2011-2024, with the gray solid dots representing the annual mean values. The dark orange line represents the linear fit of the monthly mean DOD from 2010 to 2020.

Comment: Page 21, line 472-481. The authors generally conclude that "Stage II AOD fluctuations are driven by meteorological and anthropogenic factors" but did not disaggregate dominant factors by year. For example: Was the 2019 AOD increase mainly due to reduced precipitation (weakened wet scavenging)? Was the 2021 spring AOD rise dominated by dust increments? Did 2023 AOD fluctuations relate to regional transport (e.g., resurgent biomass burning)? Without year-specific driver analysis, conclusions are overly broad and fail to provide targeted support for "differentiated pollution control strategies".

Response: The statsments in lines 472-481 refer to the non-dust components; therefore, the dust intrusion during 2021 spring may not be included in the discussions here. To address the reviewer's concern, we have added the annual variations in the contributions of meteorological and anthropogenic factors to non-dust AOD throuth the LMG method (Figure 2R below and newly-added Figure 7 in the revised manuscript). Note than after 2022, RH has the dominant contribution. The meteorological influences in specific years are now discussed accordingly.

The following paragraph has been added in the revised manuscript "**In addition, the annual variation in the LMG method-derived relative contributions of daily mean meteorological and authropogenic factors are presented in Figure 7. The trends of the dominant factors, RH and $PM_{2.5}$, show increasing and decreasing patterns from Stage I to Stage II, respectively. Overall, the contribution of RH is larger than that of $PM_{2.5}$ except in 2015. In Stage II, the notable increase in non-dust AOD in 2018 is associated with the increased contribution of $PM_{2.5}$, which rises to 21% compared with 8% in 2017. In 2019, the contribution of vertical velocity is comparable to that of $PM_{2.5}$, which is inferred to be related to regional pollution transportation. From 2020 to 2021, the contribution of $PM_{2.5}$ decreases due to the COVID-19 lockdown. In 2021, wind speed contributes more than $PM_{2.5}$, likely due to enhanced air cleansing by cold air transported from high latitudes under the 'Warm Arctic-Cold Siberia' pattern (Zhang et al., 2021b). After 2022, the contribution of $PM_{2.5}$ increases to around 20%, coinciding with the resumption of industrial activities and production. It is worth noting that the contribution of RH is around 60% in Stage**

II, even exceeds 70% in 2023, which is higher than the value shown in Figure 6c. This difference arises because the contributions in Figure 7 are based on daily mean values rather than monthly means. Under these circumstances, the daily variability of RH is more pronounced than that of other meteorological variables, and the influence of hygroscopic growth on aerosol backscatter and thus AOD is more direct." (please see lines 343-354).

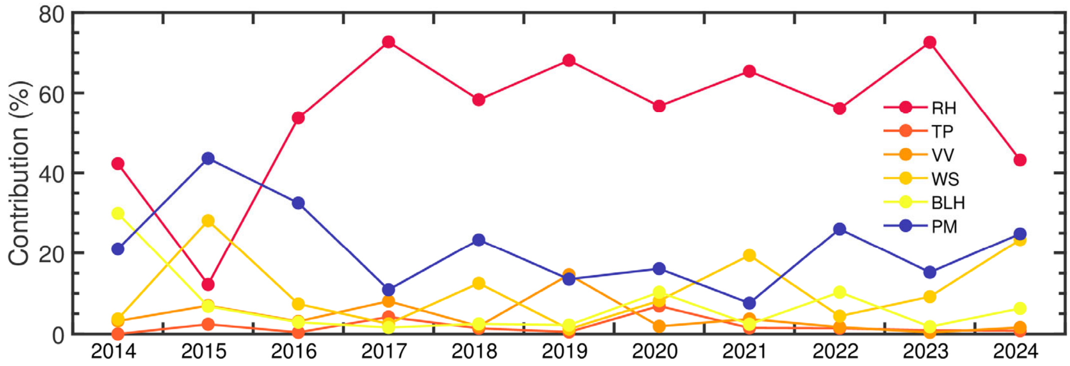

Figure 2R. Annual variations in the LMG method-estimated relative contributions (%) of daily mean meteorological variations and $PM_{2.5}$ concentration on daily mean non-dust AOD.