Review of "Aerosol reductions outweigh circulation changes for future improvements in Beijing haze (MS# ACP-2021-198)" by Liang Guo et al.

Based on the calculated PM2.5 concentration and two indices measuring the likelihood of haze in Beijing, this study evaluates the relative role of atmospheric circulation and aerosol emission in determining the future haze in Beijing in CMIP6 models. It suggests that the intensity of aerosol emission overweigh the changes in atmospheric circulation and dominates the future changes in haze days. The results are reasonable. I recommend the authors clarify the following two aspects before I give my next round of recommendations. Details are listed below.

1. At least for me, it is entirely within the expectation that the aerosol emission dominates the haze days when the emission reduces to a certain level. I do not think this conclusion alone is publishable. Nevertheless, it is meaningful to evaluate and explain when the effects of aerosol emission are comparable to those of circulation change in determining the haze days in Beijing.

We agree that our finding that the decrease in aerosol emissions under strong air pollution mitigation scenarios outweighs the continued increase in haze weather patterns and weakening of the winter monsoon for long-term haze changes feels intuitive, and thus not particularly surprising. However, recent observations have run counter to this expectation, and demonstrated a significant role for other drivers in long-term haze changes. Despite reductions in the emissions of anthropogenic aerosol, heavy pollution days over northern China have continued to increase since 2010 (Zhang, Yin et al. 2020). With a 90% reduction of key anthropogenic emissions during the 2019 city-lockdown, extreme pollution events simultaneously occurred over northern China (Le, Wang et al. 2020). These studies demonstrate that the connection between aerosol emissions and Beijing haze is less clear, with other factors such as meteorology and chemical processes also playing an important role.

2. Can the concentration of PM2.5 represent the haze? I think the answer is no. If my understanding is correct, the title and related expressions need changes in the manuscript. If there is no better way to represent haze in CMIP6 models, I suggest the authors adding some discussions to clarify the limitations of this approach.

Thank you for mentioning the difference between the $PM_{2.5}$ and the composition of haze. While PM2.5 does not account for all of the constituents of haze, long-term changes in haze are consistent with long-term changes in PM2.5 (Schichtel et al., 2001). These smaller particles also have a more significant impact on human health than PM10 (e.g. Samek, 2016), and target concentrations are specified for them in both the World Health Organization (WHO) air quality guidelines (WHO, 2005) and Chinese ambient air quality standards (GB 3095-2012). PM2.5 is one of six pollutants monitored by China's Ministry of Environmental Protection, and is used to calculate the Air Quality Index. As PM2.5 provides a clear link between haze and human health, we consider it a benefit, rather than a limitation, to include it in our analysis.

To make the motivation for a specific discussion of PM2.5 clear and confirm the link between PM2.5 and haze, the following has been added to the discussion section of the manuscript (Lines 107-113):

"The particle size distribution of haze varies within a wide range of particle diameters and the $PM_{2.5}$ fraction accounts for a part of this distribution (Wu 2011). While $PM_{2.5}$ does not encompass all the constituents of haze, it is the major factor for impacts on human health and reductions in visibility (An, Huang et al. 2019). As such, it is a key metric in the WHO air quality guidelines (WHO, 2005), and has been adopted as a major index for the air quality standard in many countries (e.g. GB 3-95-2012 in China, 2008/50/EC in Europe). Previous studies have shown that the long-term change in haziness is consistent with changes in $PM_{2.5}$ concentration (Schichtel, Husar et al. 2001). Besides, since haze is not a standard output from CMIP6 models, $PM_{2.5}$ is the best measurement of air quality impact that we have from all of the models."

The title has been modified to:

"Competing effects of aerosol reductions and circulation changes for future improvements in Beijing haze".

Reference:

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