Shen (referred hereafter as Shen2019-2) made four additional short comments on our earlier response in this discussion series. With the following short responses to the four comments, we hope the discussion series can converge to an agreement not-to-agree and let the audience draw their own conclusions.

1. We believe the audience would agree that Figure 1 of Shen2019-2 does not support their statement- "CMIP5 models can in general capture the wintertime RH trends during 1973-2016", contrary to the claim of Shen2019-2.

2. Shen2019-2 agrees with our earlier statement- "the correlation coefficient of PC1 with $PM_{2.5}$ changes with the of time scale of interest". So they should agree that the correlation coefficient "may not stay high for the time scale of climate change".

3. Shen2019-2 still had not addressed the fundamental issue raised by Liu et al. (2019)- "that a parameter such as PC1 should not be considered as a sole/exclusive/sufficient proxy of $PM_{2.5}$ just because PC1 has a good correlation with $PM_{2.5}$". In fact, it is well-known that even a perfect correlation coefficient (1.0) does not imply any causal relationship, let alone an exclusive/sufficient relationship. Therefore, the sweeping claim by Shen et al. (2018) that "insignificant effect of climate change on winter haze in Beijing" is invalid.

4. The extreme value (EV) model is irrelevant to the discussion series because EV statistics addresses different questions from general correlation statistics. Having said that, the fundamental assumption of a Poisson process is that the EV events are independent from one another, which is not the case for haze events. For example, the high $PM_{2.5}$ episode in January 2013 lasted weeks. The EV events were obviously autocorrelated in this episode. For that reason, haze (or heat wave for that matter) EV events cannot be directly modelled as a Poisson process. Removing the autocorrelations in EV events will greatly reduce the size of the dataset. As such, it calls into question the validity of the study results in which the autocorrelation of EV data was not properly treated.

References

Liu, R., Mao, L., Liu, S. C., Zhang, Y., Liao, H., Chen, H., and Wang, Y.: Comment on the paper Insignificant effect of climate change on winter haze pollution in Beijing by Shen et al. (2018), Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2019-193, in review, 2019.

Shen, L., Jacob, D. J., Mickely, L. J., Wang, Y., and Zhang, Q.: Insignificant effect of climate change on winter haze pollution in Beijing, Atmos. Chem. Phys., 18, 17489–17496, https://doi.org/10.5194/acp-18-17489-2018, 2018.