Reply to Referee 3's comments on egusphere-2023-2702

A. Zhao *et al.*

Correspondence: annizhao@pku.edu.cn

The climate in the mid-Pliocene Warm Period (mPWP) is usually viewed as an analog for future climate, but simulated mPWP climate change is largely different from the climate change in the 20th century. Also, there are large discrepancies between the simulation and proxies in the mPWP climate. To address the discrepancies, Zhao et al. suggested a different aerosol scenario from the pre-industrial aerosol setting should be used for simulating the mPWP climate. By removing pollutants of the industrial period in the mPWP climate simulation, the authors get more warming in the Northern Hemisphere and stronger ITCZ. The manuscript is well-written and I suggest a minor revision. My comments are below.

We would like to thank you for reviewing our manuscript and providing comments about our work. We are happy to adopt many of the comments and will revise the manuscript as requested.

1. How the results of this study can help resolve the underestimation of temperature increase in the climate models should be addressed. In the abstract and Introduction, the authors mentioned discrepancies between models and proxies in the mPWP. One important difference is that the models underestimate the high temperature in the mPWP, especially in the high latitudes. When simulating the mPWP climate, people often use pre-industrial aerosol forcing, and the results of this study tell us that using pre-industrial aerosol forcing leads to increased warming. Thus, if we use more aerosol forcing, as the authors suggest the mPWP may have more aerosols, the simulated mPWP climate should be even cooler, and the discrepancies between the simulation and proxies would be larger. This confuses me and I think it is important to let readers know how considering aerosols forcing scenario can help improve climate simulations in the mPWP.

Thanks for raising the question, but there might be a misunderstanding here. Our results show opposite finding actually. Results of this study do not mention that using pre-industrial aerosol forcing leads to increased warming. Sect. 3.1 describes the warming driven by prescribed mPWP boundary conditions (Plio_Pristine - PI) and compares the simulated mPWP change with the reconstructions, which points out the existence of data-model mismatch. The mPWP climate is expected to have less aerosols than pre-industrial. Sect. 3.2 and 3.3 analyse the effect of removing anthropogenic aerosol emissions (Plio_Pristine - Plio_Polluted), which actually show that less aerosols lead to further warming. It means that if we use less aerosols, the simulated mPWP climate should be furhter warm, and the discrepancies between the simulation and proxies would be smaller.

2. The title "Aerosol uncertainties in tropical precipitation changes for the mid-Pliocene Warm Period" confuses me. What does "aerosol uncertainties in tropical precipitation" mean? Does it mean the uncertainties of aerosol bring uncertainties in tropical precipitation in climate models?

"aerosol uncertainties in tropical precipitation" means the uncertainties induced by aerosol forcing in simulating (mPWP) climate.

L28: Repeated "e.g."s

We will delete the extra "e.g.".

L39: "emission induced": What emission? GHGs or aerosols?

It means aerosol emission. We will add "aerosol" in text.

L118 and L121: (Feng et al., 2022) -> Feng et al. (2022)

We will fix it.

Figure 1: What are the circles in Fig. 1b? Do the proxies in Fig. 1b represent precipitation minus evaporation? If so, why not compare them to the simulated P-E? Also, please increase the white space between Figure 1a and 1b.

Circles in Fig.1b are reconstructed annual mean precipitation change published in Salzmann et al. (2008). Triangles are signals of hydroclimate (precipitation minus evaporation) change published in Feng et al. (2022). The aim of panel b is to show precipitation change rather than hydroclimate change. It is difficult to have abundant quantitative evidence of mPWP precipitation anomaly. Therefore, we choose to plot this new qualitative wet-dry dataset to give an idea of the sign of precipitation change during the mPWP, though the compilation does not show precipitation anomaly directly. We will enlarge space between panels.

L169-171: If "removing aerosols causing more warming than the mPWP boundary conditions", then why do you say that "the changes in boundary conditions are more important than aerosols?" This seems to contradict each other.

We are trying to say that removing aerosols only causes more over Northeastern Pacific and high-latitude North Atlantic Ocean than the mPWP boundaries. We will rewrite the sentence to "However, the mPWP boundary conditions causes more warming than removing anthropogenic aerosols nearly global except Northeastern Pacific and high-latitude North Atlantic Ocean (Fig. 5a,c,e). More warming lead by the mPWP boundaries than removal of aerosols suggests ..." to emphasise that the mPWP boundaries lead to more warming than removal of aerosols.

L212: Figure 6 is about droplet concentration. This should be Figure 7.

There was extra panels about annual averaged change in droplet concentration and cloud liquid path in our old Fig.6. We feel Fig A3 would be sufficient, so we removed these panels before submission. We do apologise. We will rewrite this sentence to "Removal of pollutants decreases droplet concentration (especially over lands and high latitudes, Fig. A3a) and decrease cloud liquid path (except tropical Pacific between 5°S and 5°N and western Africa, Fig. A3b)."

L219: “general increase in sea level pressure”: But the left panel of Figure 9 shows an increase in sea level pressure.

Sorry we made a mistake here. We will rewrite the sentence to "Over tropical and subtropical regions, the overall uniform warming induce by mPWP boundaries (Plio_Pristine - PI) result in general decrease in sea level pressure and have relatively small effects on surface wind (Fig. 9a,c,e). Though removal of anthropogenic aerosols also show warming in tropical and subtropical regions, it rises the sea level pressure and have much stronger effects on surface wind that shows seasonal variances (Fig. 9b,d,f)."

L227-228: I cannot see the “overall aerosol effect is more important” from Figure 10b. The numbers of dots above and below the 1:1 line are nearly equal.

We will replot Fig.10.

L270: due to mPWP had warmer and wetter climate -> due to warmer and wetter climate in the mPWP

We will revise it.

References

Feng, R., Bhattacharya, T., Otto-Bliesner, B. L., Brady, E. C., Haywood, A. M., Tindall, J. C., Hunter, S. J., Abe-Ouchi, A., Chan, W.-L., Kageyama, M., Contoux, C., Guo, C., Li, X., Lohmann, G., Stepanek, C., Tan, N., Zhang, Q., Zhang, Z., Han, Z., Williams, C. J. R., Lunt, D. J., Dowsett, H. J., Chandan, D., and Peltier, W. R.: Past terrestrial hydroclimate sensitivity controlled by Earth system feedbacks, Nature Communications, 13, 1306, https://doi.org/10.1038/s41467-022-28814-7, 2022.

Salzmann, U., Haywood, A. M., Lunt, D. J., Valdes, P. J., and Hill, D. J.: A new global biome reconstruction and data-model comparison for the Middle Pliocene, Global Ecology and Biogeography, 17, 432–447, https://doi.org/10.1111/j.1466-8238.2008.00381.x, 2008.