Comments on "Aerosol uncertainties in tropical precipitation changes for the mid-Pliocene Warm Period"

In this study the authors analysed the climate uncertainties resulted from aerosol scenarios in the simulations of mid-Pliocene Warm Period. Three simulation experiments PI, Plio_Pristine, and Plio_Polluted were analysed, which represent pre-industrial, mid-Pliocene with pre-industrial emissions, and mid-Pliocene with pre-industrial emissions plus industrial pollutants. They found that the change of precipitation between Plio_Pristine and Plio_Polluted is generally larger than that between Plio_Pristine and PI. And they concluded that the aerosol forcing was the dominant driver in tropical precipitation change during mid-Pliocene.

This work seems to be a continuation of the work in Feng et al. (2019) with further analysis of the model results. In my opinion, there are some novel findings but not enough and explicit under current analysis. The details of some results and discussion are missing. And the conclusion is too strong. So I suggest the authors to make a major revision.

The general comments and specific comments are listed below:

General comments

1. Please reduce the number of colors used in the colorbars in the figures, it is difficult to relate the colors with the value ranges.

2. With the model experiments designed or shown in this study, it is reasonable to study the aerosol uncertainties with two idealised aerosol scenarios. However, the conclusion (aerosol forcing is the dominant driver in tropical precipitation change in mid-Pliocene) can not be derived following this work. First, in the PlioMIPs, the emissions of aerosols and their precursors were designed to be following the pre-industrial configuration (Haywood et al., 2011), so adding the industrial pollutants is an idealised experiment and not based on proxy data or derived mid-Pliocene conditions. Therefore, you can not say aerosol forcing was the dominant driver in mid-Pliocene, because the forcing was not real. Secondly, you may need more experiments to compare individual components. For example, an experiment with only aerosol change but keeping CO2 in a pre-industrial level, an experiment without aerosol-cloud interaction, etc. You can refer to the experiments in Feng et al. (2019) and Sagoo and Storelvmo (2017).

Specific comments

P1, L4: 'is' -> 'it'

P2, L51-53: "mPWP simulations now use modern-day or pre-industrial aerosol concentration that may differ from the conditions during the mPWP. It implies that aerosol effects may be one of the possible explanation for the mismatch between reconstructions and simulations."
The logic is not obvious here between two sentences. Please clarify it or add references.

P3, L62-63: "This increases the shortwave cloud radiative forcing, thus, cools surface temperature and amplifies polar warmth (Sagoo and Storelvmo, 2017)."
Please check the reference, I think if you have cooling effect on the surface, the polar amplification means the amplified polar cooling.

P3, L69-70: "potential analogue nature of Pliocene climate, not to the present-day polluted climate,

but to future climate scenarios which feature removal of anthropogenic pollutants"
Which future scenario do you refer to here? Please specify it.

P3, L77: Write the full name of CCSM4.

P3, L79-82: "which uses Aiken, accumulation and coarse modes to solve number and size concentration of internal condensation and coagulation of different species among modes."
What are "size concentration", "internal condensation"? This sentence is not clear and needs to be rephrased.

P3, L87: Please list key configurations or parameters in CCSM4-PlioMIP1 simulation related to this work.

P3, L87: Does 'direct effect' mean 'aerosol direct effect'? Please clarify it.

P3, Sec. 2.2: Are the experiments the same as the ones in Feng et al. (2019)? From the text in P3, L66-67, it seems that the simulations are the same. If they are the same, did you directly use the output data from their experiments or you rerun the experiments? Please specify it clearly in the text.

P4, L90-92: "The other prescribed pre-industrial emissions plus industrial pollutants of anthropogenic SO2 , sulfate and organic compounds estimated for the 2000s from an gridded (0.5° x 0.5°) emission dataset (hereafter referred as to Plio_Polluted) published in Lamarque et al. (2010)."
The description of the configurations of emissions are not clear. For example:
(1) Does "industrial pollutants of anthropogenic SO2" mean the SO2 emissions from industry sector, excluding all the emissions from other sources like vehicle emissions?
(2) Are other anthropogenic emissions included here, like NOx, black carbon?
(3) Here SO2 could be the precursor of aerosols, and sulfate and organic compounds can be directly emitted or formed from precursors, please provide more details of your emission configurations.

P4, L110: "PI" is used before defined. And please also specify what PI simulation represents, e.g., an average over a period from a specific CMIP5/6 simulation experiment?

P5, L122-123: "The combination regenerates the site sets 35, 72; 22, 77; 79,61; 58,61,79,101 and 65, 66 into new sites located at the center of sets."
Where do the numbers come from? Please clarify it.

P5, L131-133: "The underestimation in Northern Hemisphere warming may be explained by that Plio_Pristine was branched from an earlier CCSM4-PlioMIP1 simulation that had underestimated the warming in the Northern Hemisphere (Rosenbloom et al., 2013)."
What about the results from the latest simulations in PlioMIP2? It would be better to also compare your results with the newer experiment results.

P5, L134-135: "13 out of the 37 sites show a mismatch between simulated surface temperature anomaly and reconstructed SST anomaly smaller than 1.0°C."
Please also add the reference here besides in the figure caption.

P5, L138-139: "The reconstructed zonal temperature gradient along the tropical Pacific Ocean is around 0.5°C greater than simulations (Plio_Pristine - PI)"
How do you define the zonal gradient here, is it the temperature difference between two regions? How the regions are defined?

P5, L147-148: "Precipitation decreases over subtropical oceans, eastern parts of South America and monsoon areas over North America."
The proxy data in Fig. 1b show enhanced precipitation almost the whole globe, with only few sites showing reduced precipitation, which indicates a global scale of the precipitation increasing and a regional/local scale of the decreasing. However, the simulation results show reduced precipitation over a large area, especially the Atlantic Ocean. Could you explain the reason, or could you find any references which mentioned it or tried to explain it?

P6, L155: "Reducing atmospheric aerosols is expected to warm the climate."
It needs more details and references.

P6, L169-171: I do not understand the logic of these two sentences, please clarify it.

P6, L176: Why do you think ITCZ is narrower in your simulation Plio_Pristine compared to Plio_Polluted? Please clarify it.

P6, L183-184: "consistent with the positive correlation between tropical precipitation change and spatial deviations of SST warming from the tropical mean (Xie et al., 2010)"
Then what is the reason of decreasing precipitation over the warming SST areas in Fig. 5?

P7, Sec. 4.1: The discussion in this section about interaction of aerosol and cloud is not clear.
(1) It is better to first give the definitions of net shortwave/longwave flux, clear-sky/full-sky net shortwave/longwave flux, shortwave/longwave cloud forcing, and also how you estimate the aerosol direct effects from these variables. In Fig. 3, the aerosol direct effect is not shown, so you need to clarify it.
(2) "while clouds contribute to a net forcing greater than 2 W m-2 with more shortwave absorption and less longwave emission"
Which latitudes do you mean here? In this phrase "more shortwave absorption and less longwave emission", do you mean on the surface or in the cloud level?
(3) "is still less important than the change in shortwave cloud forcing."
How can you find this from Figs. 3 and 4?
(4) "Figure 6 shows decrease in droplet concentration (especially over lands and high latitudes, Fig. A3a) and decrease in cloud liquid path (except tropical Pacific between 5°S and 5°N and western Africa, Fig. A3b) after the removal of pollutants."
How could you conclude this from Fig. 6?
(5) The title of this section is "Key forcing driving tropical precipitation change", but there is no discussion about how the forcings are driving tropical precipitation change. Please add more discussion details.

P8, L225-228: "Figure 10 shows the relative importance of removing anthropogenic aerosols and mPWP boundary conditions on mPWP zonal mean precipitation change. The ratio (panel a) indicates that the relative importance of effects of aerosol forcing and mPWP boundary conditions (including high CO2) on precipitation is complicated, but overall aerosol effect is more important over the tropics (panel b), which could imply the importance of aerosol scenario in simulating Pliocene climate."
(1) Fig. 10a is difficult to see the features, please find a better way to plot the data, maybe increase the width-height ratio?
(2) Please add more detailed discussion about the relative importance instead of just one word "complicated".
(3) It is difficult to see "aerosol effect is more important over the tropics" from Fig. 10b, maybe a global map of the ratio is better to represent it?

(4) In Figs. 9 and 10 you mentioned the seasonal values and annual values, but you have never discussed any details related to seasonal change. Please add more discussion about it.

P8, L241-242: "SO2 increased by 11 Tg in Unger and Yue (2014) mPWP simulations, yet SO2 from anthropogic sources is estimated to be 120 Tg from 1980 to 2000s (Smith et al., 2011)."
Here 11 Tg should be 11 Tg/yr, which is the emission rate, the same for 120 Tg/yr.

P8, L42-43: "As such, despite that enhanced biogenic emissions may compensate some of the responses seen in the Plio_Pristine"
For "compensate", do you mean: "If the enhanced biogenic emissions, which will increase the secondary organic aerosol formation and growth, is included in the Plio_Pristine simulation, the difference between Plio_Pristine and PI will decrease."? The statement here is not clear, please clarify it.

P8, L246-247: "Sagoo and Storelvmo (2017) looked in to the effect of dust and demonstrated that increased dust emissions resulted in an enhanced dynamical response that lead to great changes in hydrological circulations."
The dust emission in mPWP is lower compared to pre-industrial, why you are talking about "increased dust emissions"?

P8, L247-249: "Their Pliocene simulation with idealised dust scenario shows greater change in precipitation than only consider CO2 forcing, yet only used idealized scenario (Sagoo and Storelvmo, 2017)."
Please add more details, e.g., which scenario, how large is the "greater change in precipitation", global or tropical precipitation.

P9, L251-252: Please add at least some simplified definition of the moisture budget component terms.

P9, L254-255: The statement from "high CO2 concentration" to "thermodynamic change plays an important role" is not explicitly clear here, please add more detailed discussion if you want to keep this statement.

P9, L255-257: Removal of anthropogenic emissions will also affect the thermodynamics itself in the atmosphere, and the anthropogenic emissions include both scattering (e.g., sulfate) and absorbing (e.g., black carbon) compositions, which are also related to shortwave and longwave radiation, so this process is complicated. Therefore, I do not think it "would logically increase the effects of thermodynamic and net energy input". Please add more discussion and references here.

Figs. 6 and 8: Change between which cases? Please specify it in the figure caption.

References

Feng, R., Otto-Bliesner, B. L., Xu, Y., Brady, E., Fletcher, T., & Ballantyne, A. (2019). Contributions of aerosol-cloud interactions to mid-Piacenzian seasonally sea ice-free Arctic Ocean. Geophysical Research Letters, 46, 9920–9929. https://doi.org/10.1029/2019GL083960.

Haywood, A. M., Dowsett, H. J., Robinson, M. M., Stoll, D. K., Dolan, A. M., Lunt, D. J., Otto-Bliesner, B., and Chandler, M. A.: Pliocene Model Intercomparison Project (PlioMIP): experimental design and boundary conditions (Experiment 2), Geosci. Model Dev., 4, 571–577, https://doi.org/10.5194/gmd-4-571-2011, 2011.

Sagoo, N., and T. Storelvmo (2017), Testing the sensitivity of past climates to the indirect effects of dust, Geophys. Res. Lett., 44, 5807–5817, doi:10.1002/2017GL072584.