

Responses to reviewer 1

The manuscript presents the results from several simulations with IPSL model regarding the effects of dust on mid-Holocene climate. The authors have used a suppressed dust by completely removing the dust forcing, and a reduced dust by considering what happened during mid-Holocene humid period when there were less dust emissions. The authors have provided the detailed analyses of the dust radiative forcing on mid-Holocene climate, with particular focus on western African monsoon and Indian monsoon region. They conclude that taking into reduced dust in mid-Holocene account has minor improvements for the simulated climate when comparing with the reconstructions. However, they emphasise that the dust pattern matters, which determine the changes in atmospheric thermodynamics and dynamics. The comprehensive test on dust forcing in this work is important to clarify the issues on neglecting the reduced dust in simulating mid-Holocene climate by using the same dust forcing as that in PI. The manuscript is well written and has provided clear message to the modelling community. For the final publication please consider the below minor comments.

1. For the dust forcing the authors only focus on the direct and semi-direct radiative forcing, but did not mention the indirect effects. The indirect effect is important for the monsoon region where the deep connection occurs. If the indirect effect can not be estimated in these experiments, some discussion would help the reader to understand why it has not been considered, and by neglecting the indirect effect, how much monsoon response could be underestimated.

In the current version of the IPSLCM6 model only the first aerosol indirect effect is parameterized, for soluble aerosol species; therefore dust, that is treated as insoluble, does not contribute to this effect in our simulations. As the reviewer suggests, this effect may be important, and future developments will take this into account. It is however difficult to quantify it.

2. In Fig2, Albani0k and Albani6k dust show increased dust in middle East, it would be helpful if the authors provide the information what cause this increase instead of refer to a reference. Reference for reconstruction in fig2 caption is missing.

Albani0k and Albani6k represent the interpolation into the IPSLCM6-LR model framework of the prescribed dust fields from the CESM simulations described in Otto-Bliesner et al. 2017 and Albani et al. 2015 and 2016. These prescribed dust fields were obtained using an “assimilation” process, so that the causes of Holocene variability cannot be inferred from the simulations themselves. For the middle East / central Asia region the observational constraints that were used are on two marine sediments records from the Arabian Sea (Pourmand et al. 2004, 2007), and the GISP2 ice core record from Greenland (Mayewski et al. 1997), based on information on dust provenance (Bory et al., 2003).. There is indeed scarcity of relevant data and significant uncertainty for this region, although newer work may improve our understanding of paleodust variability in this region. These precisions are included in the revised manuscript.

Bory, A. J.-M., Biscaye, P., and Grousset, F. E.: Two distinct seasonal Asian source regions for mineral dust deposited in Greenland (NorthGRIP), *Geophys. Res. Lett.*, 30, 1167, doi:10.1029/2002GL016446, 2003.

Mayewski, P. A., Meeker, L. D., Twickler, M. S., Whitlow, S., Yang, Q., Lyons, W. B., and Prentice, M.: Major features and forcing of high-latitude northern hemisphere atmospheric circulation using a 110,000-year-long glaciochemical series, *J. Geophys. Res.*, 102, 26345, doi:10.1029/96JC03365, 1997.

3. *On the model-data comparison presented in Fig14, the authors have mentioned that the dust forcing is not significant on regional climate change, given that the model results show large disagreement with the reconstructions (even opposite in sign), some explanation for the possible reasons would be helpful.*

Unfortunately, this would require interesting and extensive analyses, which is out of scope for this paper. The IPSL model has improved a lot over this sector concerning model developments and representation of midlatitude climate and Atlantic Ocean (I.E Boucher et al. 2020) The expectation would then be that it also helps to get better model-data agreement for this region for the mid-Holocene, which doesn't seem to be the case.

Boucher, O., J. Servonnat, A. L. Albright, O. Aumont, Y. Balkanski, V. Bastrikov, S. Bekki, R. Bonnet, S. Bony, L. Bopp, P. Braconnot, P. Brockmann, P. Cadule, A. Caubel, F. Cheruy, F. Codron, A. Cozic, D. Cugnet, F. D'Andrea, P. Davini, C. de Lavergne, S. Denvil, J. Deshayes, M. Devilliers, A. Ducharne, J.-L. Dufresne, E. Dupont, C. Ethé, L. Fairhead, L. Falletti, S. Flavoni, M.-A. Foujols, S. Gardoll, G. Gastineau, J. Ghattas, J.-Y. Grandpeix, B. Guenet, L. Guez, E. Guilyardi, M. Guimberteau, D. Hauglustaine, F. Hourdin, A. Idelkadi, S. Joussaume, M. Kageyama, A. Khadre-Traoré, M. Khodri, G. Krinner, N. Lebas, G. Levavasseur, C. Lévy, L. Li, F. Lott, T. Lurton, S. Luysaert, G. Madec, J.-B. Madeleine, F. Maignan, M. Marchand, O. Marti, L. Mellul, Y. Meurdesoif, J. Mignot, I. Musat, C. Ottlé, P. Peylin, Y. Planton, J. Polcher, C. Rio, N. Rochetin, C. Rousset, P. Sepulchre, A. Sima, D. Swingedouw, R. Thieblemont, A. Traoré, M. Vancoppenolle, J. Vial, J. Vialard, N. Viovy, and N. Vuichard, Presentation and evaluation of the IPSL-CM6A-LR climate model, *Journal of Advances in Modeling Earth System*, <https://doi.org/10.1029/2019MS002010>.

4. *The figure quality needs to be improved, for example, it is difficult to observe the moist static energy transport vectors in Fig8. And in Fig11 and Fig12, it is difficult to see the numbers labeled in contours.*

We will improve Figure 8 as it suffered from the conversion in pdf format. For both figure 11 and 12 we need to fix a pyferret bug, and have already spend time trying to overcome it. We fully agree that these Figures need improvement and will proceed to improve them.

5. *There are some typos throughout the manuscript, need to be carefully checked and corrected, some examples below (Line number is not shown complete, only show 2 numbers):*

Thank you for mentioning these typos. We corrected them.

P6, L52, MMD and SD, provide what do they stand for.

MMD is Mass Median Diameter. SD is Standard Deviation . We address these definitions in the text

P9, L21, "on ESG, should be ESGF

Done

P10, L62, "It extends further north over Northern India and Pakistan", should be further west?

The text now reads : "It extends further to the northwest of India and Pakistan"

P11, L76, "and over the Tibetan Plateau", actually the region is north of the Tibetan Plateau, should be Gobi desert region, it does make sense with reduced dust in Fig2.

This is right and we adjusted the text accordingly

P11, L82, Tibetan Plateau should be Gobi desert.

This has been corrected

P11, L83, Fig .6i should be Fig. 6j, in Fig6j should mention that large difference in precipitation also in Indian monsoon and East Asian monsoon region.

This will be adjusted in the revision, considering also only JF and JA averages instead of DJF and JJA, to have a consistent approach throughout the manuscript.

P12, L10, "...with interannual variability", should be centennial variability?

Corrected

P13, Section 3.3, talked about the meridional heat transport in PW in different latitude, which figures are these numbers referring to?

It refers to figure 8. Figure numbers have been added in the text

P17, L53, Tibetan Plateau should be Gobi desert.

Corrected

P20 L27, "associate with global warming", why global warming in this case?

Thank you we suppress gobal

P20 L27, "the reduces low level...", should be the weakening of low level...

Corrected

P20 L28, "EAJ", should be AEJ

Corrected

P22 L 66, "between in the ...", remove in

Corrected

P23 L 03, "colder coldest", remove colder

Done

Table 2, -0.-06, should be -0.06?

Corrected

Fig7, how to read the peak month? It is better to mark 1, 2, 3...12 with different colour.

We started with a map where the 12 months were represented with different colors, but such colored figure was too busy to convey the messages we were looking for. The point for this figure is to highlight if the major differences due to dust forcing occur in winter, summer or other inter-seasons, and if they are different or not in terms of annual timing compared to centennial variability. This is the best we managed to do with the software we are using and available color maps, with the request of having similar colors for month 11-12 and 1-2 that are part of the same season.