Reply to RC1

We thank the reviewer for the constructive and encouraging review which was very valuable for improving the manuscript. Below please find the point by point reply to the comments.

> The study described in the manuscript uses the atmospheric chemistry model EMAC to evaluate the direct and indirect radiative effects of dust-pollution interactions, i.e. as mineral dust particles are allowed to act as a surface for condensation of aerosol precursors, with the effect of changing the aerosol mix optical properties, hygroscopicity, number, and size. I found the manuscript and its results interesting, and generally well written and clear. I recommend that some aspects are clarified before publication.
> p. 3, 19 – Could you give a few more details on what are the actual dust-pollution interactions happening in the model? i.e. which are the other aerosol species interacting with dust? Can you specify what "pollution" is exactly here? Black carbon?

We have expanded section 2 to better present the coagulation of pollution and dust particles and the condensation of gaseous pollutants on mineral dust as the main dust-pollution interactions. "Pollution" is defined based on the emission sources as described in section 3, most of the black carbon is part of pollution but some fraction originates from natural biomass burning.

> p. 3, 24 - Please discuss dust optical properties in your model in light of the relevant literature (e.g. Kaufman et al. 2001, Müller et al., 2011, Di Biagio et al. 2019). It is elevant to assess this potential source of uncertainty.

We have added a discussion on the imaginary part of the refractive index of dust and included the references.

> p. 3, 34 - The indirect statement about the particle size distributions seems unjustified. AOD at a given wavelength is usually parameterized as the product of aerosol column loading for a given size mode/bin times the size-dependent mass extinction efficiency. At least, the statement should be supported by additional evidence that the optical properties that you use are "reliable".

We are aware that these observations are no proof but only an indication of a realistic size distribution. To give this better justification, we have rephrased the statement and now mention a reliable ratio of the extinction efficiency as a precondition for the argument. Still, we do not expect a big uncertainty in this ratio because of the consistent treatment of the optical properties throughout the spectrum.

> p. 5, 11 – Is there a spatial component in your procedure of reducing anthropogenic biomass burning emissions?

No, since we do not have more detailed estimates, a constant fraction is used globally.

> p. 5, 20 – Can you elaborate on the two different strategies for averaging?

From the SST results we use annual global mean values as "x" in Eq. (2) whereas for the nudged simulations we skip the global averaging and apply the equation for each grid cell separately to obtain the spatial distribution of the interaction term. We clarified the formulation.

> p. 5, 25 – Please clarify what your strategy is, in light of e.g. IPCC AR5 terminology: "The difference of the radiative fluxes from both calls yields the instantaneous forcing . . ." vs e.g. "Globally averaged, the net forcing in the solar spectrum shown in Fig. 2 (a) is (0.23 ± 0.01) Wm−2, the SST simulations yield an ERF of (0.3 ± 0.1) Wm−2" (p. 7, 8). Please clarify how each metric that you will discuss is calculated, and try to be consistent in the terminology you chose, in differentiating between instantaneous RF, ERF, and direct and indirect radiative effects.

We have expanded the paragraph to provide more a detailed presentation of the forcing definitions and calculations.

> p. 6, 6 – In light of your strategy (i.e. experimental design) is that because of a local aerosol effect or else?

Since the locations of regional maxima of this aerosol effect (other effects cancel in Eq. (2)) resemble the pollution hotspots over Asia, Europe and North America, the effect is clearly dominated by the local aerosol. Nevertheless, transport is involved as well, in particular in bringing desert dust to non-arid regions (e.g., Europe).

> p. 8, 17 – "Our SST simulations . . ." please rephrase, and resume briefly your experimental setup in the conclusions. Also, in this section you should discuss the limitations related to the experimental setup, as suggested by the editor.

We have rephrased the sentence and expanded the first paragraph of the conclusions by a brief summary of the experimental setup and a discussion of limitations.

> Figures 1, 2, 3 - It would be useful to see the individual (dust, pollution) effects alongside with their interactions. It would also be useful to see the average dust and pollution burden maps somewhere also within this manuscript.

We have added the new figures S2 to S9 to the supplement, showing the dust and particulate pollution burdens as well as the individual effects of dust and pollution on clouds and radiation.

> Figure captions – "Over stippled regions the results are consistent with zero at 2 σ significance level." What do you mean by "zero"? A null hypothesis of zero difference in the mean among the ensemble members? Please clarify the captions, and provide the details of your procedure.

The null hypothesis is no effect, sigma is estimated by the standard error of the mean of the annual values (page 5, line 4ff). We have rephrased to “Over stippled regions the results differ from zero by less than two times the SEM of the annual values.”

> Figure 4 – The bar chart is not very clear in its present form. Please make it explicit which simulation ensembles you are depicting in each of the top bars: only pollution and dust+pollution?

We now mention explicitly the terms represented by the bars.

> References

> Kaufman, Y. J., D. Tanré, O. Dubovik, A. Karnieli, and L. A. Remer, 2001: Absorption of sunlight by dust as inferred from satellite and ground-based remote sensing. Geophys. Res. Lett., 28, 1479–1482, https://doi.org/10.1029/2000GL012647.
> Müller, T., A. Schladitz, K. Kandler, and A. Wiedensohler, 2011: Spectral particle absorption coefficients, single scattering albedos and imaginary parts of refractive indices from ground based in situ measurements at Cape Verde Island during SAMUM-2. Tellus, 63B, 573–588, https://doi.org/10.1111/ j.1600-0889.2011.00572.x.
> Di Biagio, C., Formenti, P., Balkanski, Y., Caponi, L., Cazaunau, M., Pangui, E., et al. (2019). Complex refractive indices and single scattering albedo of global dust aerosols in the shortwave spectrum and relationship to iron content and size. Atmospheric Chemistry and Physics Discussions, 19(24), 15,503–15,531. https://doi.org/10.5194/acpâĂŘ2019âĂŘ145.