Responses to reviewers' comments
Comments in black and responses in blue

We thank the reviewers and Editor for their constructive and supportive comments, which we address below.

This work presents an inverse modelling framework that improves the representation of the global dust cycle by using global model simulations and observational constrains dust aerosol optical depth, extinction efficiency and dust size distribution. The authors compare the inverse model results against independent observations of surface concentration and dust deposition and show the large improvements obtained in the northern hemisphere and the modest improvements in the southern hemisphere.

Furthermore, the authors include interesting discussion on the limitations and implications of the results as well as the potential and future perspective of the developed methodology. The paper is well written and well structured. Although the paper is long, the effort to present the methodology is appreciated and the authors do a good job in explaining it. Considering the extensive work done and numerous results obtained, the authors manage to focus on the main results and not get lost in the details.

Thank you for these positive and helpful comments.

I only have some very minor comments after which I believe the paper can be published.

Line 98-104: I don't see the point of including results of the work at this point. This is not the place to present results, the methodology hasn't even been presented.

Since the end of the introduction is a point of emphasis, we think that summarizing our main results and conclusions here helps ensure that the reader will obtain the paper's main points.

Line 113: I would suggest to replace "inform"with "force". The information (observations) in inverse modelling is not provided (inform) to the model but used in the model to produce (force) a change.

Corrected as suggested.

Line 113-114: What are these substantial differences?

We've added "in that it integrates several different constraints on dust microphysical properties and uses a bootstrap to propagate and quantify uncertainties" to the end of this sentence to clarify the main differences here.

Figure 3e-f: I couldn't find any reference to figures 3e and 3f in the text. Either include a reference to the figures in the text or remove the figure.

Thank you for pointing this out. Somehow, the paragraph discussing this figures was accidentally deleted from the revised version. We have added it back in on lines 549-560.

Lines 973-974: Could absorption AOD be an additional independent dataset to which compare the inverse model results?

That's a good idea. Unfortunately, AAOD cannot be measured directly with current remote sensing assets – it's always retrieved – and existing retrievals by show large differences (e.g., Samset et al., 2018). In fact, our group is working on a paper that indicates substantial errors in AERONET retrievals of AAOD, apparently due to errors in retrievals of dust optical properties and size.