

This work presents an inverse modelling framework that improves the representation of the global dust cycle by using global model simulations and observational constraints 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. 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.

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.

Line 113-114: What are these substantial differences?

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.

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