

Comment on acp-2021-572

Anonymous Referee #2

Referee comment on "Quantification of the dust optical depth across spatiotemporal scales with the MIDAS global dataset (2003–2017)" by Antonis Gkikas et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2021-572-RC2>, 2021

Gkikas, A., Proestakis, E., Amiridis, V., Kazadzis, S., Di Tomaso, E., Marinou, E., Hatzianastassiou, N., Kok, J. F., and García-Pando, C. P.: Quantification of the dust optical depth across spatiotemporal scales with the MIDAS global dataset (2003–2017), Atmos. Chem. Phys. Discuss. [preprint], <https://doi.org/10.5194/acp-2021-572>, in review, 2021.

Summary and Recommendation

This paper presents a quantitative estimation of spatial and temporal variability of dust globally. It uses a data set that coalesces satellite (MODIS total aerosol optical depths) and aerosol model outputs (MERRA-2 reanalysis) to provide a +15-year global dust aerosol optical depth (DAOD) at 0.1×0.1 degree resolution. The dataset (called MIDAS) was introduced in a separate study (Gkikas et al, 2021a) and this paper is an application of the MIDAS dataset. This study consists in a statistical analysis of the average spatial distribution of DAOD over each continent and discusses how the results compare with previous studies. In addition, monthly time series and inter-annual variability plots are presented for representative major dust sources.

Overall, this is an impressive amount of very detailed work and provides an overall picture of dust distribution with excellent graphics. In addition, it is a good idea to create a gridded high spatial resolution dataset.

However, I have one critical point in this analysis and in my opinion, it is disqualifying for publication as it is. I think that this analysis provides a global picture from data sources that are not suitable for being merged in this way. I think the paper could eventually be published but significant modifications should be added, and concerns addressed.

More detailed Comments

As a matter of disclosure, I work in one of the satellite algorithm development teams used in this study.

I recognize the effort in trying to create a more complete global picture of dust distribution. While it is true that tremendous advances have been made in global aerosol detection and concentration observation (global AOD), there hasn't been significant progress in observational global aerosol type identification from satellites. The MODIS sensors are not sensitive enough to do aerosol type identification for aerosol loadings below the range AOD=0.15-0.2 (and this can be debatable too because it highly depends on the surface). The corresponding algorithms are designed to mitigate but not eliminate this problem. So, there is a clear observational under sampling of dust in medium to low concentrations. The advances in aerosol modeling in the last decade, particularly in transport of air masses that correctly place the location and arrival time of any air mass anywhere of the world to the point that it can be used in air pollution forecasting. However, aerosol transport modeling still has significant difficulties in the generation and characterization of aerosol sources and specifically, dust.

Therefore, my concern is the nature of the MIDAS dataset. It is a mixture of observational and model data. It offers a tremendously practical dataset. However, it casts a doubt on the reliability of the data. The satellite source data is still quite imperfect to be merged this way. Specifically, there are 3 MODIS aerosol algorithms used in this study: Dark

Target- Land, Dark-Target-Ocean and Deep Blue (only over land). All of them have mutual inconsistencies in aerosol detection which are particularly manifest in low-to-medium aerosol loadings. For example, in the Sahel region in Africa, both algorithms disagree depending on the surface assumed by each of them and on the aerosol loading in the scene.

The methodology relies on the assumption of using MERRA-2 DAOD/AOD ratios to provide the proportion of dust present in the pixel observed by the satellite. This assumes that the model is correct in not only placing dust in the selected pixel but also the proportion of dust is correct. However, it is well documented that global dust models are still having serious discrepancies not only in quantitative terms in aerosol loading but also in activating dust sources. Several studies have pointed this out. (Pu and Ginoux, 2015; Wu et al, 2018,2019,2020; Gliß et al, 2021). While these studies did not specifically address MERRA-2, they do highlight that global dust models still are struggling to consistently produce realistic dust simulations and it is an evolving topic. Certainly, there are encouraging advances such as those from Kok's group in UCLA but the modeling of quantitative dust generation is still a subject in progress. While MERRA-2 partially overcomes this weakness by assimilating total AODs from MODIS, it still has limitations regarding the generation of different aerosol types including dust. With all these mutual discrepancies in dust generation, how could a user trust that outputs provided by MERRA-2 is any better than the other models?

In the paper and in Gkikas et al, 2021a, I noted behaviors that are difficult to interpret, and it is not clear whether it is sourced to the satellite or model data because the data was mixed at its generation. For example, in Gkikas et al, 2021a the database puts dust in places where no dust has been observed (Arctic, upper right corner in figure 8a) and it includes pixels that only have less than 20-30 observations in 15 years of daily sampling. It does not include dust that is not visible from space nor modeled by MERRA-2 (such as high latitude dust such as Alaska, Iceland and Greenland that occur mostly in cloud conditions and their sources are not included in MERRA=2) . There are inconsistencies in the data that makes it look unphysical for example, in figure 1 the sharp discontinuity in aerosols along the coast of the Gulf of Guinea (along 5 degrees N) where AODs are high in the inland side but drop sharply in the immediate ocean. Aerosols do not behave like that (most likely this is an issue due the land and ocean satellite algorithms). These inconsistencies are present in the original data used, that is in the daily Level 2 satellite data. For example, this image (see <https://go.nasa.gov/2VaLKLv> and <https://go.nasa.gov/3ihzpxW>) displays markedly different AODs between ocean and land in an air mass (containing smoke and dust in each case) advecting from land to ocean. Perusing other days in the same webpage will show a similar pattern. Clearly aerosol concentrations cannot change so drastically in such short distance, and this is clearly an artifact. Also, figure 9 has a sharp straight line North-South in the center of Brazil: aerosols do not behave like that.

So, what casts a doubt to this study is how one can reliably trust what MIDAS is showing? Specifically, if it shows a specific feature or trend that do not agree with independent sources of data or observations, is this discrepancy sourced in the observational data or in the model? How a user would be able to understand and trace the source of discrepancy? Would the user be able to conclude that it is an actual geophysical feature?

As far as the scientific questions addressed by this paper, I think they are good ideas to address.

However, they can be (partially) addressed with similar satellite only databases. For example, this paper presents an analysis of the major dust producing basins, places we already know are the major dust sources and in general they are cloudless which means satellite coverage is very good. So, the addition of model data does not contribute meaningful additional information as far as understanding of these sources which were already addressed in other recent satellite studies (for example, see Voss and Evan, 2021 and Gupta et al, 2020).

Therefore, I think this analysis is not well conceived because the dataset in my opinion is not adequate for addressing the questions set out to answer in this study. My recommendation is to reject the paper in this form. Below I suggest on one possible to use the same dataset and salvage this submission (so perhaps it can be labeled as "Major corrections and resubmit")

Suggestion for improvement of the manuscript

This dataset contains a valuable aggregation of satellite data and I think is still of value,

particularly if merged with LIVAS. My advice to the author is to use this dataset to update some of the reference studies on dust activity using only satellite data. For example, the satellite data set can be used to update some of the Ginoux et al, (2012b) study regarding location of dust sources and activity. The database from this submission is more complete and is updated with respect what was used in the Ginoux paper. Such updated analysis will be very welcomed. For example, such analysis would include the observations of high latitude dust that are already available within the MODIS data base. These sources were not in the original Ginoux analysis nor in the Voss and Evan 2021 paper.

References

Gkikas, A., Proestakis, E., Amiridis, V., Kazadzis, S., Di Tomaso, E., Tsekeli, A., Marinou, E., Hatzianastassiou, N., and Pérez García-Pando, C.: ModIs Dust AeroSol (MIDAS): a global fine-resolution dust optical depth data set, *Atmos. Meas. Tech.*, 14, 309–334, <https://doi.org/10.5194/amt-14-309-2021>, 2021a

Gupta, P., L. A. Remer, F. Patadia, R. C. Levy, and S. A. Christopher. 2020. "High-Resolution Gridded Level 3 Aerosol Optical Depth Data from MODIS." *Remote Sensing* 12 (17): 2847 . doi: /10.3390/rs12172847.

Voss, K. K., & Evan, A. (2020). A new satellite-based global climatology of dust aerosol optical depth. *Journal of Applied Meteorology and Climatology*, 59(1), 83-102. doi: 10.1175/jamc-d-19-0194.1

Ginoux, P., Prospero, J. M., Gill, T. E., Hsu, N. C., and Zhao, M.: Global-Scale Attribution of Anthropogenic and Natural Dust Sources and Their Emission Rates Based on MODIS Deep Blue Aerosol Products, *Rev. Geophys.*, 50, RG3005, <https://doi.org/10.1029/2012rg000388>, 2012b.

Pu, B. and Ginoux, P.: How reliable are CMIP5 models in simulating dust optical depth?, *Atmos. Chem. Phys.*, 18, 12491–12510, <https://doi.org/10.5194/acp-18-12491-2018>, 2018.

Gliß, J., Mortier, A., Schulz, M., Andrews, E., Balkanski, Y., Bauer, S. E., Benedictow, A. M. K., Bian, H., Checa-Garcia, R., Chin, M., Ginoux, P., Griesfeller, J. J., Heckel, A., Kipling, Z., Kirkevåg, A., Kokkola, H., Laj, P., Le Sager, P., Lund, M. T., Lund Myhre, C., Matsui, H., Myhre, G., Neubauer, D., van Noije, T., North, P., Olivié, D. J. L., Rémy, S., Sogacheva, L., Takemura, T., Tsigaridis, K., and Tsyro, S. G.: AeroCom phase III multi-model evaluation of the aerosol life cycle and optical properties using ground- and space-based remote sensing as well as surface in situ observations, *Atmos. Chem. Phys.*, 21, 87–128, <https://doi.org/10.5194/acp-21-87-2021>, 2021.

Wu, C., Lin, Z., Liu, X., Li, Y., Lu, Z., & Wu, M. (2018). Can climate models reproduce the decadal change of dust aerosol in East Asia? *Geophysical Research Letters*, 45, 9953–9962. <https://doi.org/10.1029/2018GL079376>

Wu, M., Liu, X., Yang, K., Luo, T., Wang, Z., Wu, C., et al (2019). Modeling dust in East Asia by CESM and sources of biases. *Journal of Geophysical Research: Atmospheres*, 124, 8043– 8064. <https://doi.org/10.1029/2019JD030799>

Wu, C., Lin, Z., and Liu, X.: The global dust cycle and uncertainty in CMIP5 (Coupled Model Intercomparison Project phase 5) models, *Atmos. Chem. Phys.*, 20, 10401–10425, <https://doi.org/10.5194/acp-20-10401-2020>, 2020.