October 20, 2022

The Editor
Earth System Science Data

Dear David Carlson

On behalf of my co-authors, we thank you very much for giving us the opportunity to revise the manuscript titled "**Full-coverage 250 m monthly aerosol optical depth dataset (2000-2019) emended with environmental covariates by the ensemble machine learning model over the arid and semi-arid areas, NW China**" (**Manuscript ID: essd-2021-426).** Also, we are grateful to anonymous reviewers for their careful and constructive comments and feedback on our manuscript.

Based on the reviewers for their attentive and insightful reviews of the manuscript, we have made appropriate corrections and clarifications on the manuscript, especially with regard to the comparison among FEC AOD and other AOD products in the long-term trends. We have performed a more rigorous and methodological analysis and repeated the experiments with comprehensive validation. Revised portions are marked in red and highlighted in the manuscript. The responses to each of the points raised by the reviewers are also in red after each of their comments.

We hope that with these revisions the manuscript warrants full acceptance for publication.

Thank you for the opportunity and for further considering the publication of this manuscript.

Sincerely yours,

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Responses to RC2

Thanks authors for considering my comments but there are still some remained major concerns that need be addressed.

1. For AOD downscaling, although fine spatial resolutions, two main input DEM and LUC data have much low temporal resolutions, e.g., annual, or even many years. Thus, it is not clear what role these data play in the downscaling of daily AOD data.

Response: Thank you for your careful reading and valuable suggestions. Referring to previous research, we divide the environmental covariates into static and dynamic variables. Dynamic variables are commonly referred to as the fast change factors, and static variables are the slow change factors. The slow change factors are assumed to show no significant variation over time, and the LUCC and DEM are the typical slow change factors, especially for our study area (Arid areas and semi-arid areas are widely covered by bare land and deserts with little human disturbance, so the LUCC change is minor).

Usually, as delegates of surface properties, the LUCC is often likely to indicate the intensity of human activity and is closely related to aerosol emissions, transport, and dustfall (Fan et al., 2020; Li et al., 2022). DEM, as a delegate of terrain, with a strong correlation with surface pressure, was used to represent the dispersion condition of aerosols (Xue et al., 2021; Fan et al., 2020). In this paper, LUCC selects the median time (2010) over the study period to minimize uncertainty and DEM adopted Shuttle Radar Topography Mission 90 m Digital Elevation Model (SRTM). Through Space-for-time substitution (Padarian et al., 2022), we combine the advantages of both dynamic and static variables to realize AOD spatiotemporal reconstruction. Generally, static variables, similar to a baseline condition, play an initial constraint role in the downscaling of monthly AOD, while dynamic variables play a more dynamic evolution role (Yan et al., 2022). In revision, we have described static variables in more details and clarified the role played by LUCC and DEM in the process of AOD downscaling (Pages 9-10/Lines:213-214, 215-217, 239-241, 250-251).

[1] Fan, W., Qin, K., Cui, Y., Li, D., and Bilal, M.: Estimation of Hourly Ground-Level PM2.5 Concentration Based on Himawari-8 Apparent Reflectance, IEEE Transactions on Geoscience and Remote Sensing, 59, 76-85, https://doi.org/10.1109/TGRS.2020.2990791, 2020.

[2] Li, K., Bai, K., Ma, M., Guo, J., Li, Z., Wang, G., and Chang, N.-B.: Spatially gap free analysis of aerosol type grids in China: First retrieval via satellite remote sensing and big data analytics, ISPRS Journal of Photogrammetry and Remote Sensing, 193, 45-59, https://doi.org/10.1016/j.isprsjprs.2022.09.001, 2022.

[3] Padarian, J., Stockmann, U., Minasny, B., and McBratney, A. B.: Monitoring changes in global soil organic carbon stocks from space, Remote Sensing of Environment, 281, 113260, https://doi.org/10.1016/j.rse.2022.113260, 2022.

[4] Xue, W., Wei, J., Zhang, J., Sun, L., Che, Y., Yuan, M., and Hu, X.: Inferring Near-Surface PM2.5 Concentrations from the VIIRS Deep Blue Aerosol Product in China: A Spatiotemporally Weighted Random Forest Model, Remote Sensing, 13, 505, https://doi.org/10.3390/rs13030505, 2021.

[5] Yan, X., Zang, Z., Li, Z., Luo, N., Zuo, C., Jiang, Y., Li, D., Guo, Y., Zhao, W., Shi, W., and Cribb, M.: A global land aerosol fine-mode fraction dataset (2001–2020) retrieved from MODIS using hybrid physical and deep learning approaches, Earth System Science Data, 14, 1193–1213, https://doi.org/10.5194/essd-14-1193-2022, 2022.

2. Figures S2 and S3 highlights the advantage of the generated high-resolution (250 m) AOD dataset at the city level that should be placed in the main text. But question is, why is the spatial distribution of FEC AOD opposite to MAIAC AOD? For example, FEC is low while MAIAC is high in the northwest, and southeast is just reversed (Figures S2). In addition, MxD04 with a higher spatial resolution rather than MxD08 should be used here for comparison.

Response: Thank you for your careful reading and precise advice. According to your suggestion, we have added the figures in the main text (Pages 31/Lines:630-632).

About "But question is, why is the spatial distribution of FEC AOD opposite to MAIAC AOD? For example, FEC is low while MAIAC is high in the northwest, and southeast is just reversed (Figures S2)"

Generally, FEC AOD is highly consistent with MAIAC AOD on the whole, Specially, the monthly correlations are all above 0.78 in the study area, and most of these are higher than 0.9 (N = 240, Rmean = 0.928, $P < 0.001$, Figure S3). However, there are some differences in a few cases, i.e., in the case of what you have raised. Therefore, we have quantitatively analyzed the difference between FEC AOD and MAIAC AOD (Figure S9), and we found: (1) FEC AOD and MAIAC AOD are close in the northwest (±0.05, close to the magnitude of one standard deviation), which is also seen in the Shaybak District zoom legend in Figure 14 (the range of FEC AOD and MAIAC AOD both in 0.15-0.2). (2) FEC AOD and MAIAC AOD have shown evident differences in April 2010 over the southeast of Urumqi. Accordingly, we have carefully compared multiple AOD products in April 2010 over Urumqi, and found the reasons for the obvious difference and determined the rationality of the existence of the difference. From Figure 15, we have found significant heterogeneity in some areas, and the portrayal of local AOD features vary from product to product, for example, FEC, MERRA-2, MERIS, MOD04L2, and MOD08 AOD show high value in the southeast. Therefore, we think the main reasons for the difference between FEC AOD and MAIAC AOD in the southeast of Urumqi may be as follows: (1) Limitations of the algorithm.

The MAIAC algorithm assumes that the surface state is stable over a short period of time, resulting in a large number of high AOD records not being detected in MAIAC AOD (Lyapustin et al., 2018; Lyapustin et al., 2011). Certainly, our model and the selection of environmental covariates also introduce some uncertainty, which has been systematically discussed in Sections 4.1 and 4.2; (2) Scale effect and spatial heterogeneity. As we all know, scale effects are common phenomena in remote sensing, which are inevitable and hard to eliminate. The spatial heterogeneity, as the 2nd law of geography, is the scale effect source. As the result, the richness of feature information varies in accordance with spatial scales in remote sensing data, and in most cases certain patterns are only found on specific scales (Miller et al., 2015). The MAIAC AOD may have fuzzed and smoothed the details in the high AOD value area and have not well captured the local information. In addition, we compute the long-term trends of four AOD products over each district/county in Urumqi and single ecosystem by removing seasonal cycles, and found that FEC AOD still has a good ability to capture long-term trends in fine spatial resolution(Figure S10). In summary, there is good consistency between FEC AOD and MAIAC AOD on the whole and long-term trend capture in fine resolution, but on the local scale, especially complex surfaces, the differences are reasonable and unavoidable (Pages 19-20, 28-32/Lines:397-410, 579-636).

Finally, MxD04 are used here for comparison in Figure 14 (Pages 31/Lines:630-632).

[1] Lyapustin, A., Wang, Y., Korkin, S., and Huang, D.: MODIS Collection 6 MAIAC algorithm, Atmospheric Measurement Techniques, 11, 5741-5765, https://doi.org/10.5194/amt-11-5741-2018, 2018.

[2] Lyapustin, A., Wang, Y., Laszlo, I., Kahn, R., Korkin, S., Remer, L., Levy, R., and Reid, J. S.: Multiangle implementation of atmospheric correction (MAIAC): 2. Aerosol algorithm, Journal of Geophysical Research Atmospheres, 116, 0148-0227, https://doi.org/10.1029/2010JD014986, 2011.

[3] Miller, B.A., Koszinski, S., Wehrhan, M., and Sommer, M.: Impact of multi-scale predictor selection for modeling soil properties, Geoderma, 239-240, 97-106, https://doi.org/10.1016/j.geoderma.2014.09.018, 2015.

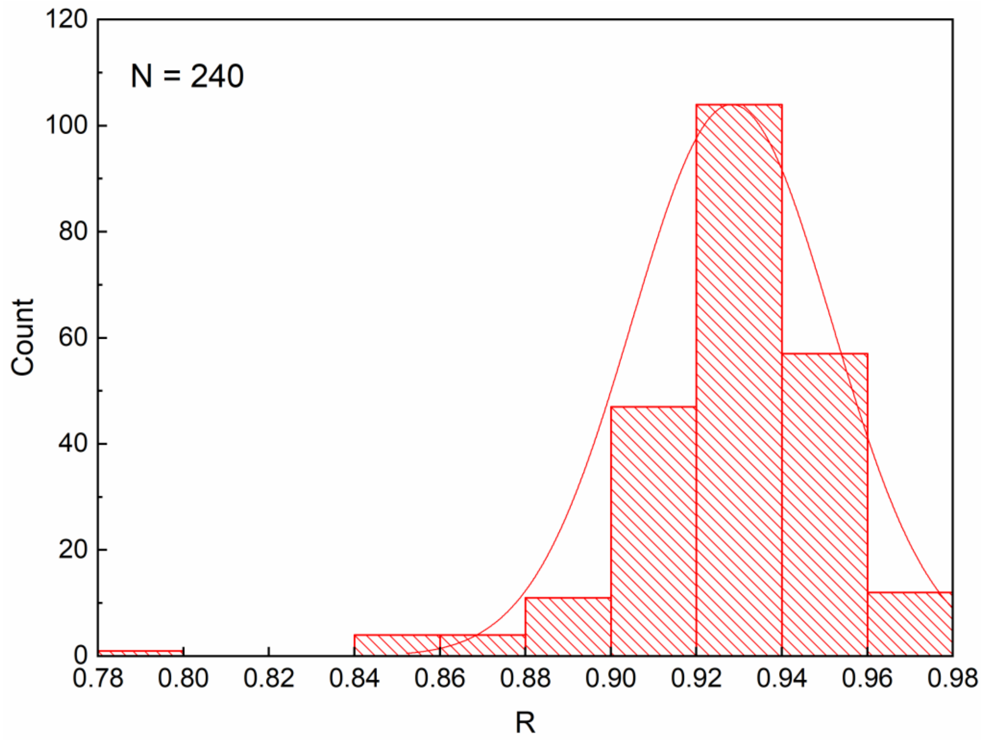

Figure S3. Monthly correlation between FEC AOD and MAIAC AOD in the study area (P < 0.001).

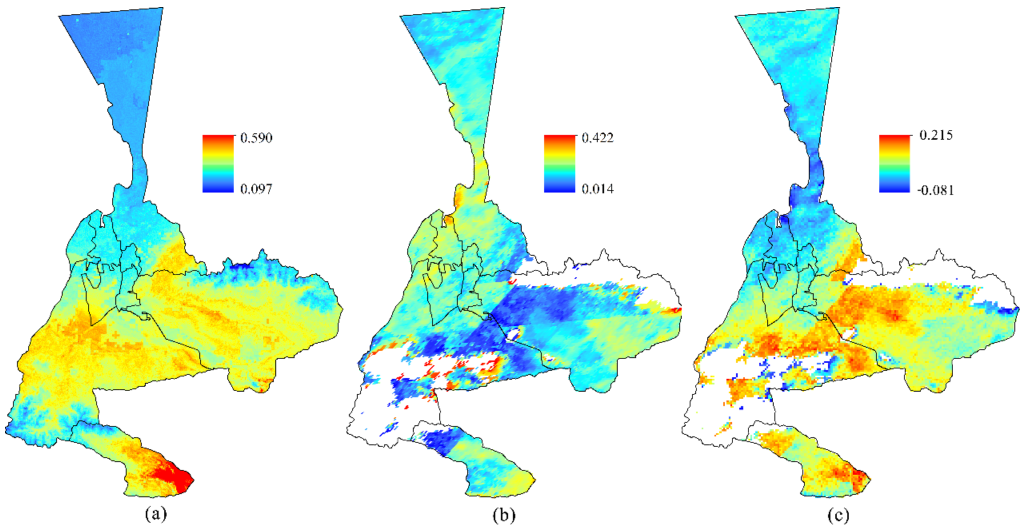

Figure S9. The spatial pattern and their difference between FEC and MAIAC AOD in April 2010 over Urumqi. (a) FEC AOD, (b) MAIAC AOD, (c) FEC minus MAIAC AOD.

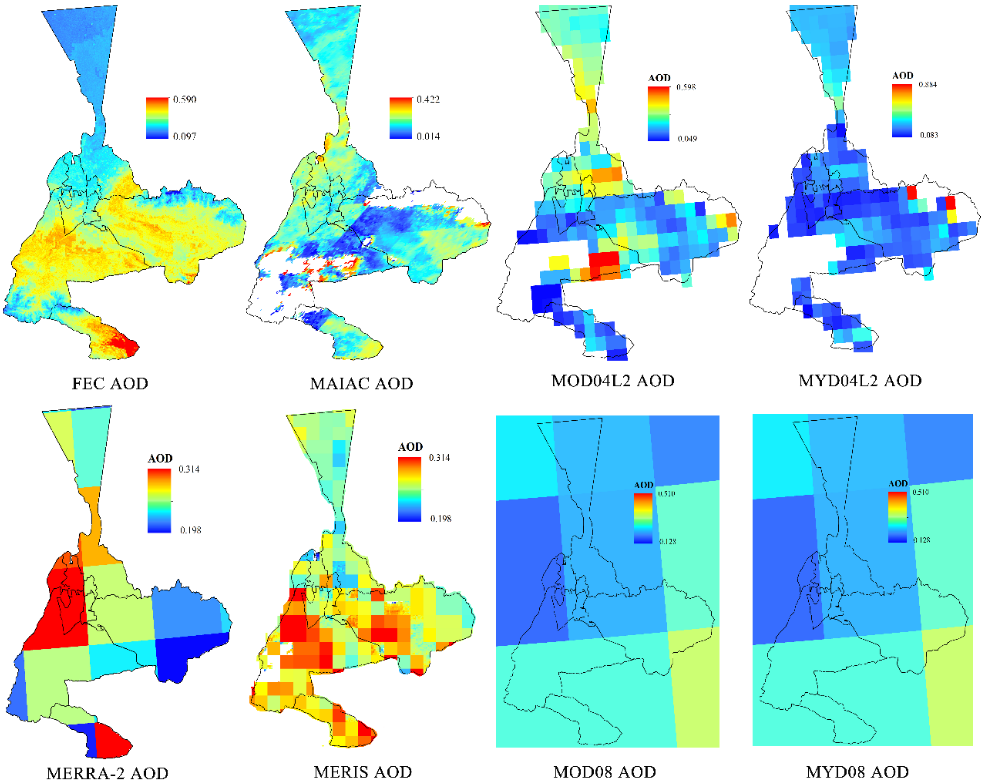

Figure 15. The spatial patterns between FEC and other AOD products in April 2010 over Urumqi.

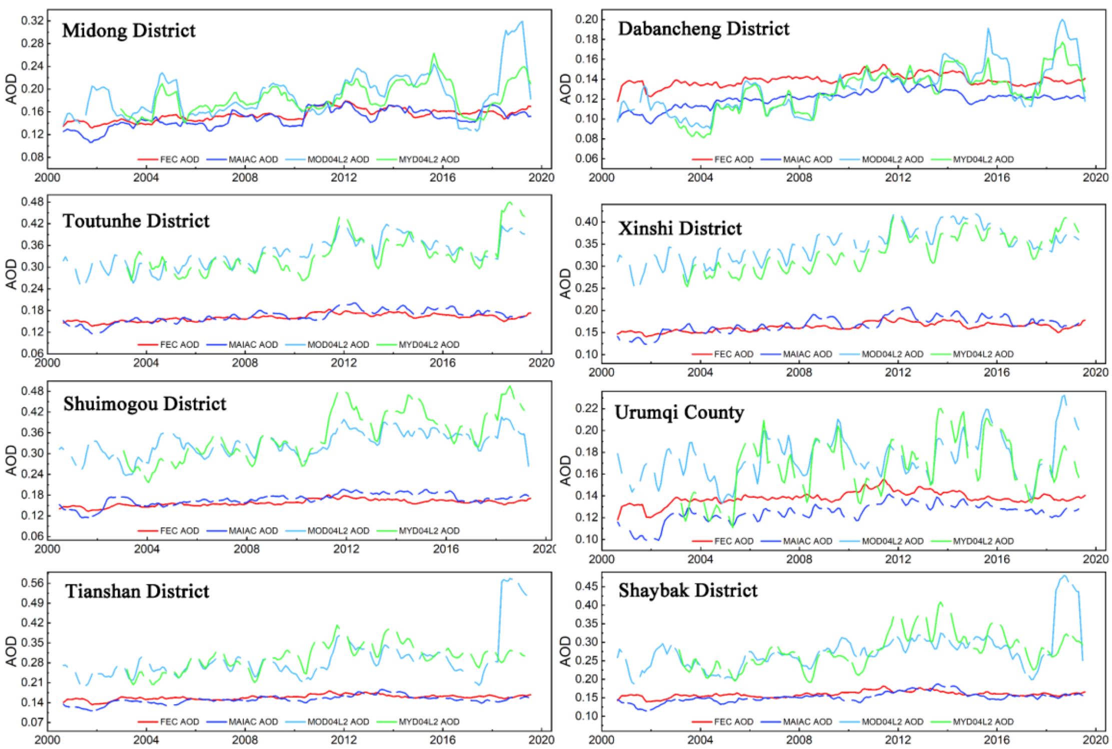

Figure S10. The long-term change trend of four AOD products over each district/county in Urumqi by removing seasonal cycles.

3. The author did not well address my last question. Data analysis is an important aspect of verifying the reliability of data sets. Since the authors have generated long-term AOD data, it is necessary to validate and compare the ability in capturing the long-term trends, to see whether it is consistent with other AOD products and ground observations?

Response: Thank you for your valuable advice. According to your suggestion, we have added the comparison of the ability in capturing the long-term trends based on deseasonalizing between FEC AOD and other AOD products to enrich the validation. In revision, we have divided original Section 3.1 Performance evaluation based on in-situ and satellite to Section 3.1 Performance evaluation based on in-situ observation and Section 3.2 Comparison with satellite AOD products. In current Section 3.1, we have collected all available AERONET sites in the study area to validate the FEC AOD performance, and also compared performance among FEC AOD and other AOD products. The result indicates the FEC AOD has a strong consistency with AERONET AOD and is superior to other products, with obvious improvements compared with MAIAC AOD (Pages 15-26/Lines:326-342). In addition, in current Section 3.2, we make a more detailed comparison of FEC AOD and other satellite AOD products. Firstly, we compare the spatial pattern among FEC AOD and other AOD products on monthly, seasonally, and yearly scales. Secondly, we discuss the ability in capturing the long-term trends of FEC AOD and other AOD products. Based on seasonal-trend decomposition, we acquire the long-term trends of four AOD products by removing seasonal cycle (Figure 5). In addition, to further explore the difference and consistency between FEC AOD and MAIAC AOD in the capture of the long-term change trend on the pixel scale, we calculate the monthly, seasonally, and yearly trends and significance test, and the result shows that FEC AOD has a strong consistency with MAIAC AOD in the ability of long term trend capture (Pages 16-20/Lines:343-410).

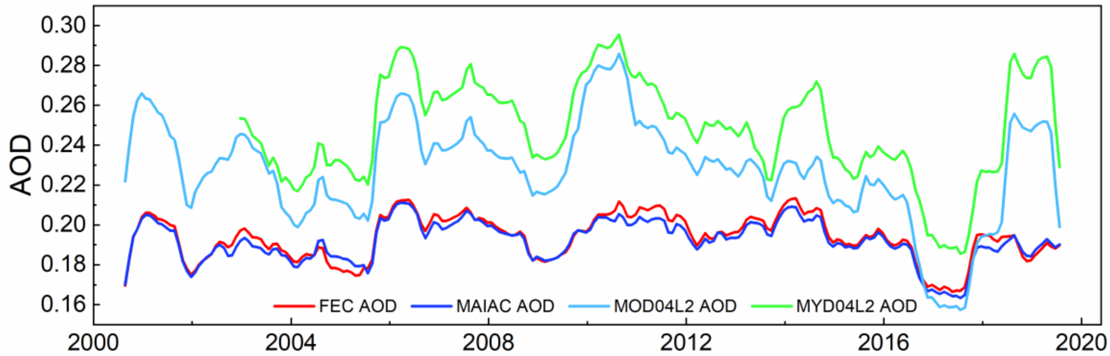

Figure 5. The long-term change trends of four AOD products by removing seasonal cycles.

Minor comments:

1. Figure 1: Descriptions on AERONET should be also added in the caption.

Response: Thank you for your careful reading. In revision, we added the AERONET site in Figure 1 caption, namely “Figure 1. Study area. The figure shows typical arid and semi-arid areas and AERONET site distribution, five provinces/autonomous regions in northwest China” (Page 6/Lines:145-147).

2. Line 167: Reference is not related to MOD04 aerosol products.

Response: Thank you for your careful reading. In revision, we have replaced the reference to ensure that is related to both MOD04 and MYD04 aerosol products (Page 7/Line:168).

[1] Zhao, H., Gui, K., Ma, Y., Wang, Y., Wang, Y., Wang, H., Zheng, Y., Li, L., Zhang, L., Che, H., and Zhang, X.: Climatological variations in aerosol optical depth and aerosol type identification in Liaoning of Northeast China based on MODIS data from 2002 to 2019, Science of The Total Environment, 781, 146810, https://doi.org/10.1016/j.scitotenv.2021.146810, 2021.

3. Line 187: reference for the new version AERONET data should be provided.

Response: Thank you for your careful reading. In revision, we have added references about the new version AERONET data (Page 8/Line:189).

[1] Giles, D. M., Sinyuk, A., Sorokin, M. G., Schafer, J. S., Smirnov, A., Slutsker, I., Eck, T. F., Holben, B. N., Lewis, J. R., Campbell, J. R., Welton, E. J., Korkin, S. V., and Lyapustin, A. I.: Advancements in the Aerosol Robotic Network (AERONET) Version 3 database – automated near-real-time quality control algorithm with improved cloud screening for Sun photometer aerosol optical depth (AOD) measurements, Atmospheric Measurement Techniques, 12, 169-209, https://doi.org/10.5194/amt-12-169-2019, 2019.

[2] Yan, X., Zang, Z., Li, Z., Luo, N., Zuo, C., Jiang, Y., Li, D., Guo, Y., Zhao, W., Shi, W., and Cribb, M.: A global land aerosol fine-mode fraction dataset (2001–2020) retrieved from MODIS using hybrid physical and deep learning approaches, Earth System Science Data, 14, 1193–1213, https://doi.org/10.5194/essd-14-1193-2022, 2022.

4. Line 322 and Figures 4 and 5: Confusing. The authors choose MOD04 and MYD04 for comparison, but both Terra and Aqua MODIS have MAIAC AOD products.

Response: Thank you for your careful reading. Actually, Terra and Aqua MODIS have MAIAC AOD products, but we have conducted preprocess in this paper, which was also mentioned in the main text (Section 2.2, Page 7/Lines: 162-164). Specifically, our study is to produce a monthly AOD dataset based on MAIAC AOD, so we adopted some preprocesses necessary to ensure more coverage and effectiveness. We combine Terra and Aqua multiple earth observations by computing the average. As we all know, Terra and Aqua both have multiple observations in the same location at different times, and effective AOD retrieval is very limited. By daily average, we can acquire as many valid AOD pixels as possible for a more comprehensive characterization of regional AOD coverage, and also build a data foundation for further modeling.