EGU22-6578
https://doi.org/10.5194/egusphere-egu22-6578
EGU General Assembly 2022

Assessment of present-day aerosol optical depth from modern aerosol-climate models, reanalyses, and satellite products

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Despite the implication of aerosols for radiative forcing, there are di erences in aerosol estimates from both, observations and models. This study quanti es di erences between current estimates of aerosol optical depth (AOD) to address two questions: (1) How well do we know the large-scale spatio-temporal pattern of present-day AOD across state-of-the-art data? (2) Has the representation of AOD improved across phases of aerosol-climate model intercomparison projects? To answer these questions, we analyze spatio-temporal patterns of the present-day monthly mean AOD from 94 global datasets. The data is taken from eight satellite retrievals, four aerosol-climate model intercomparison projects, two global reanalyses, one operational ensemble product, one climatology and one merged satellite product covering periods between 1998 and 2019. The evaluation includes new satellite data from SLSTR and aerosol-climate models of CMIP6 and AeroCom-III. The comprehensive data assessment allows us to evaluate the performance of individual products and models concerning di erent spatial and temporal aspects. Our assessment is based on metrics for a detailed investigation with respect to di erent spatio-temporal characteristics of AOD.

Our results highlight spatio-temporal di erences in AOD across datasets, were the performance of individual data sets varies with respect to the di erent spatio-temporal metrics assessed. Global mean AOD of individual satellites ranges between -11% to +17% around a satellite mean of 0.14. The ensemble means from the aerosol-climate model intercomparison projects fall within the satellite range, but individual models can di er considerably. Reanalyses and climalologies are typically closer to the satellite mean than aerosol-climate models. No systematic improvement from earlier to later phases of CMIP and AeroCom is found, although some regional biases have been reduced. Compared to the satellite and reanalysis data, all aerosol-climate ensemble means tend to overestimate AOD along extra-tropical storm tracks and underestimate AOD in regions of

high aerosol load in South America, South Africa, India, and Southeast Asia. The identi ed di erences may be used to guide further e orts to improve satellite retrievals and model simulations for aerosols. In addition, the uncertainty in observed AOD implies that a model evaluation based on a single satellite product might draw biased conclusions. This underlines the need for continued e orts to improve both model and satellite estimates of AOD to facilitate a better understanding of aerosol e ects in the Earth system. At the same time, our analysis suggests that an assimilation of multiple satellite products for AOD would be bene cial to account for observational uncertainty.

Reference: Vogel, A., Alessa, G., Scheele, R., Weber, L., Dubovik, O., North, P., Fiedler, S. (2022). Uncertainty in aerosol optical depth from modern aerosol-climate models, reanalyses, and satellite products. Journal of Geophysical Research: Atmospheres, 127, e2021JD035483. https://doi.org/10.1029/2021JD035483