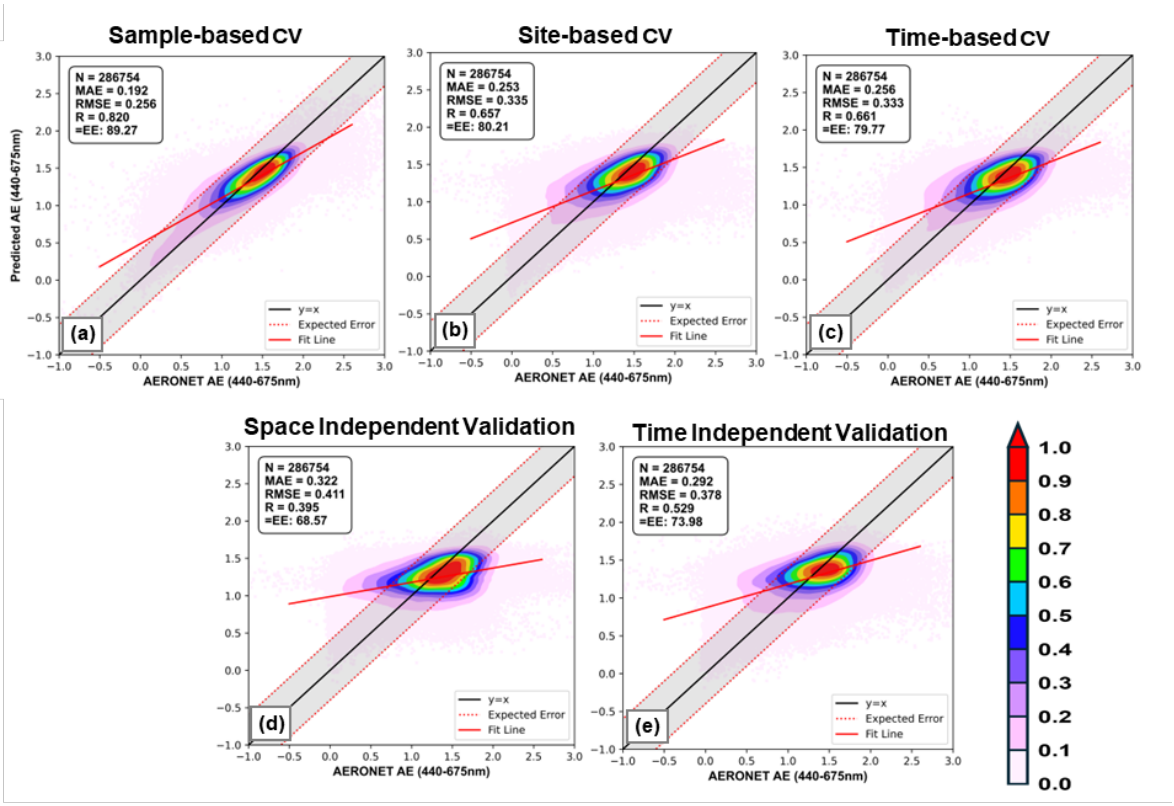


Fig. S1. Density scatter plots of the retrieved Ångström exponent at 440–675 nm against AERONET ground-based measurements under five evaluation strategies: (a) sample-based 10-fold cross-validation, (b) site-based cross-validation, (c) time-based cross-validation, (d) space-independent validation, and (e) time-independent validation. The color bar indicates normalized data-point density. The solid black line represents the 1:1 match, while the red dotted lines denote the expected-error envelope.

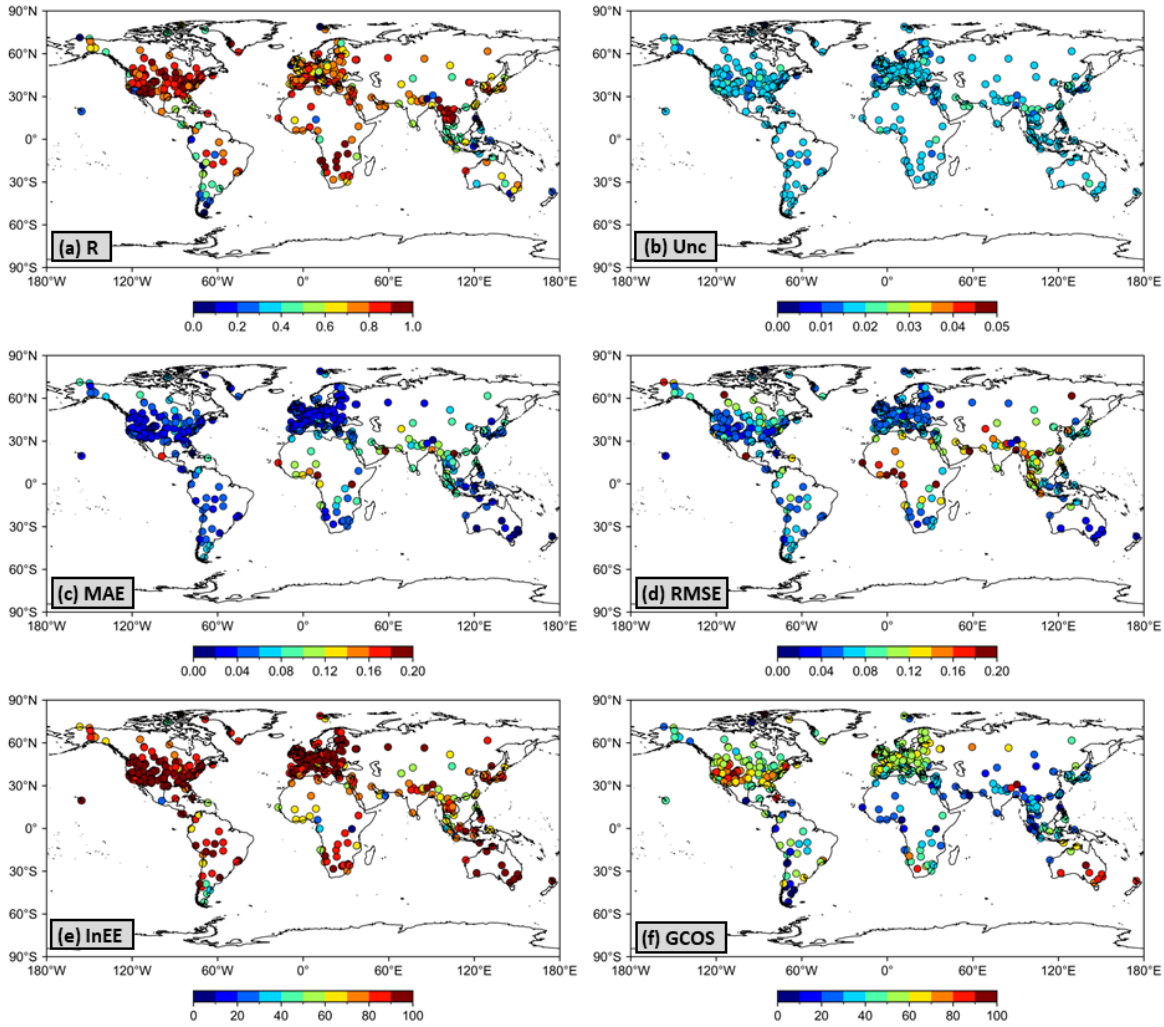


Fig. S2. Global spatial distribution of validation metrics for the retrieved aerosol optical depth under the site-based 10-fold cross-validation strategy. The metrics are (a) correlation coefficient, (b) retrieval uncertainty, (c) mean absolute error, (d) root mean square error, (e) fraction within expected error, and (f) Global Climate Observing System compliance.

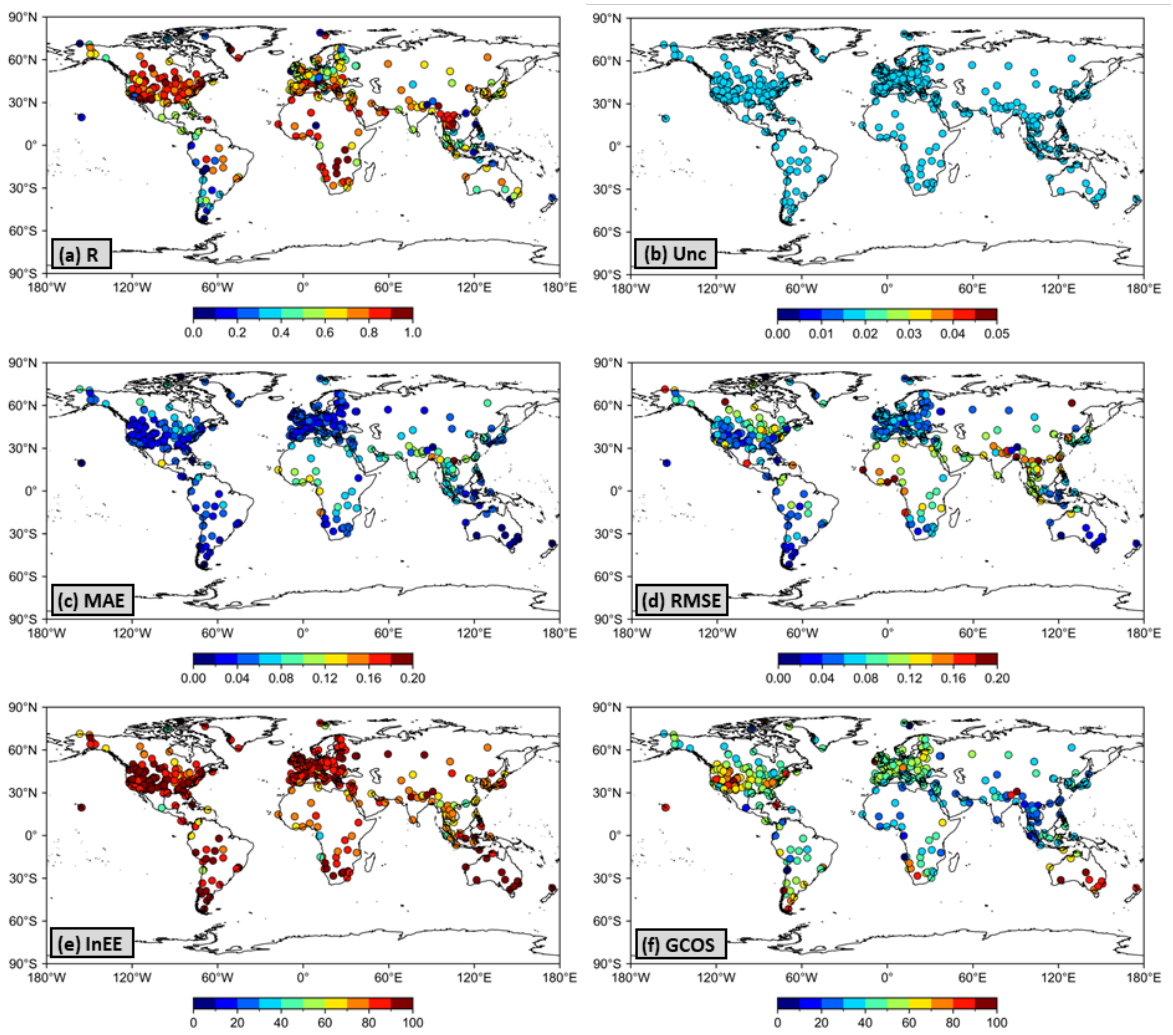


Fig. S3. Global spatial distribution of validation metrics for the retrieved aerosol optical depth under the time-based 10-fold cross-validation strategy. The metrics are (a) correlation coefficient, (b) retrieval uncertainty, (c) mean absolute error, (d) root mean square error, (e) fraction within expected error, and (f) Global Climate Observing System compliance.

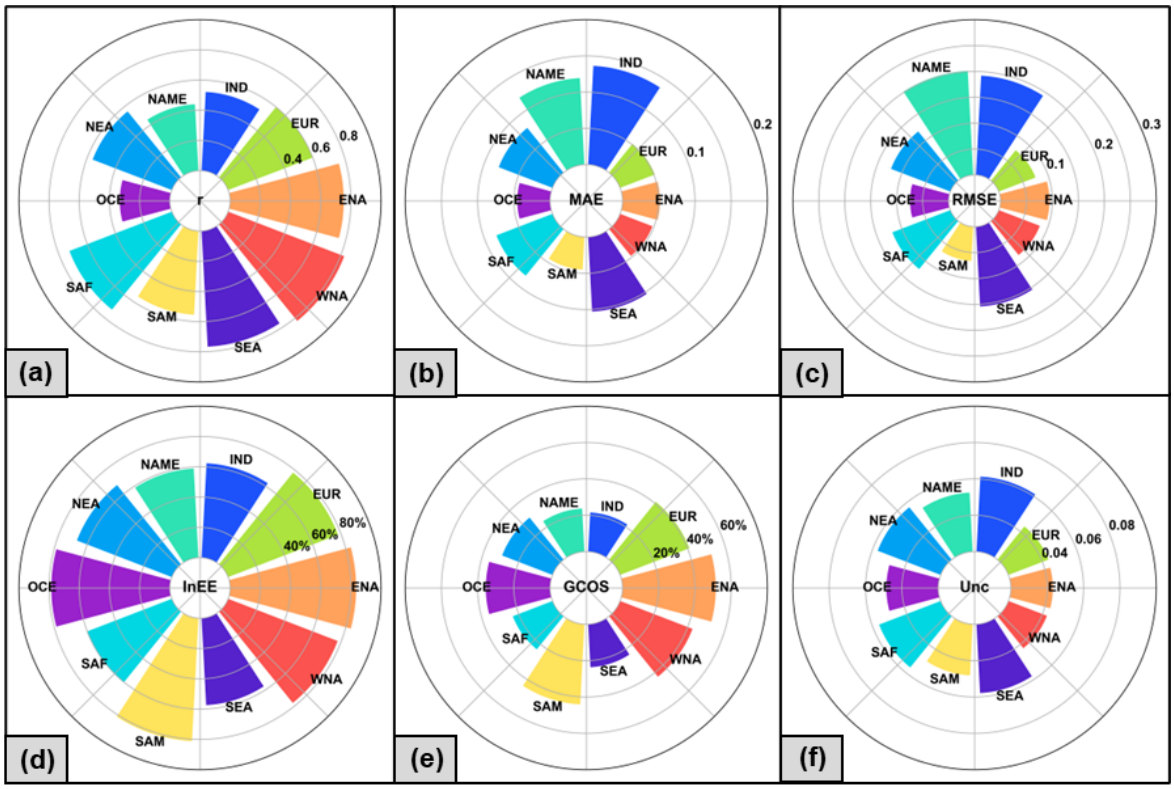


Fig. S4. Regional validation metrics for the retrieved aerosol optical depth under the space-independent validation strategy. The metrics are (a) correlation coefficient, (b) mean absolute error, (c) root mean square error, (d) fraction within expected error, (e) Global Climate Observing System compliance, and (f) retrieval uncertainty.

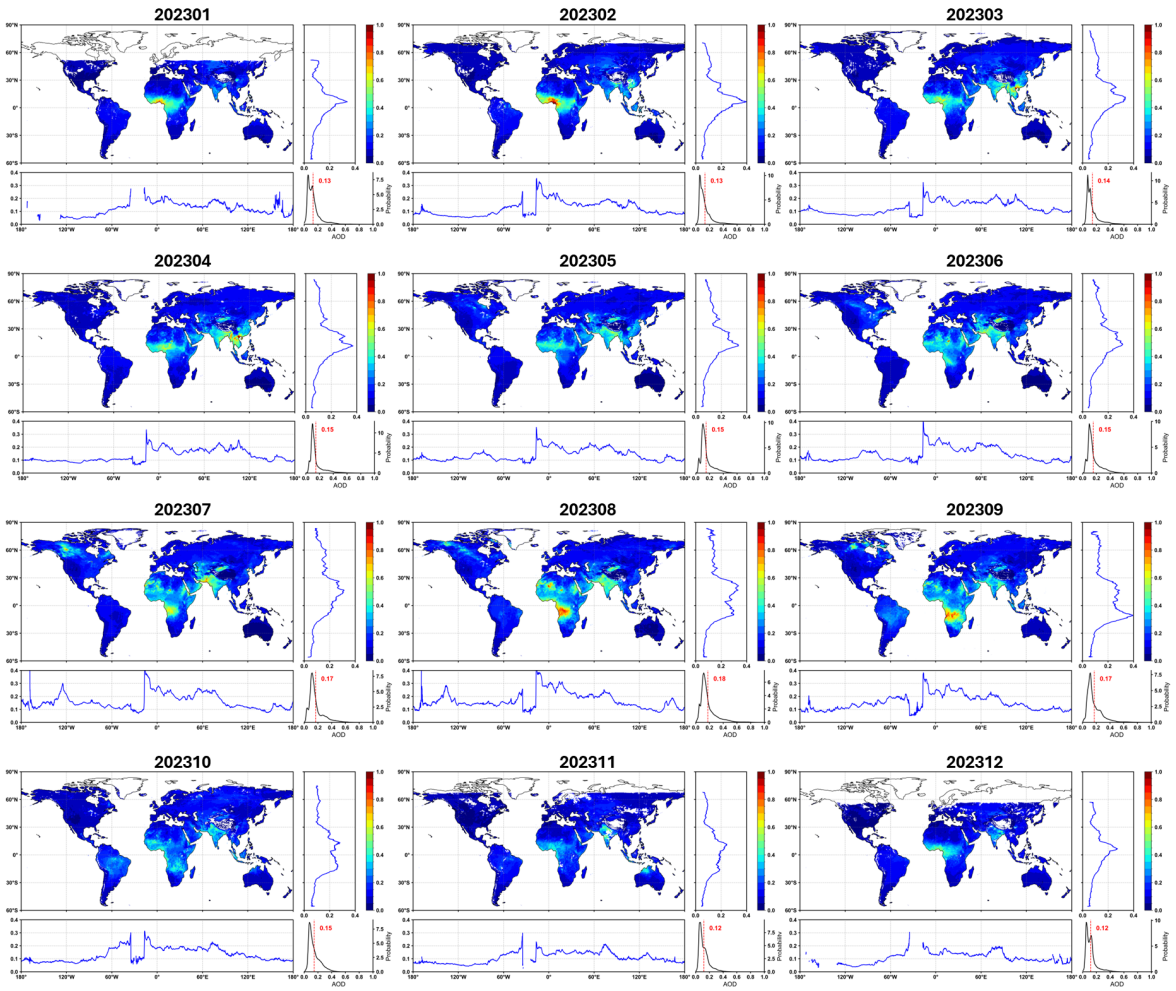


Fig. S5. Spatiotemporal distribution of the global monthly mean aerosol optical depth at 550 nm for 2023 derived from the EPIC Aero algorithm.

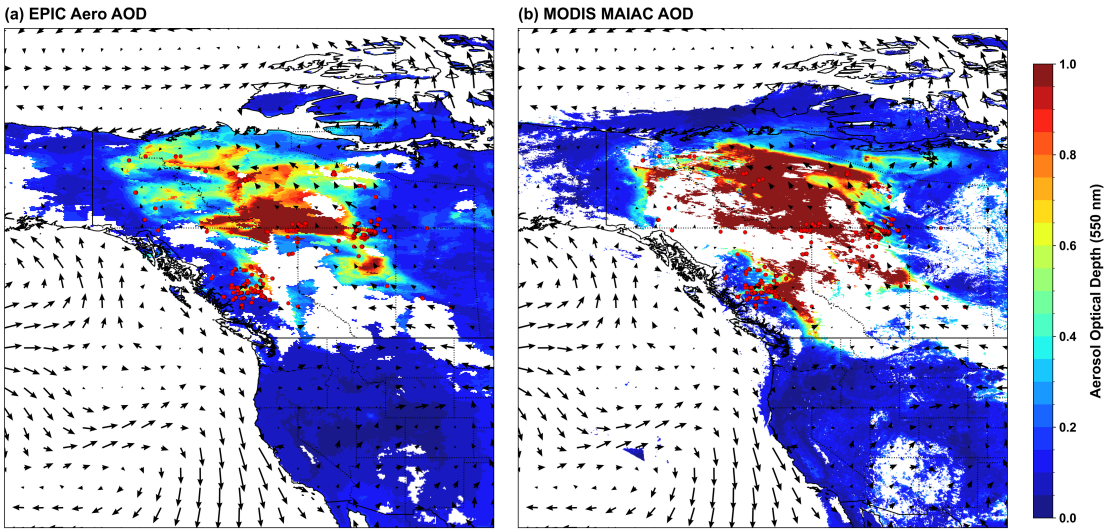


Fig. S6. Comparison of the daily averaged spatial distribution of aerosol optical depth at 550 nm during the 11 July 2023 Canadian wildfire event. (a) The diurnal composite aerosol optical depth retrieved from the EPIC Aero algorithm. (b) The daily aerosol optical depth product from MODIS MAIAC for spatial validation. Both maps are overlaid with active fire spots from MODIS FIRMS and daily averaged wind-field vectors from the ECMWF ERA5 reanalysis.

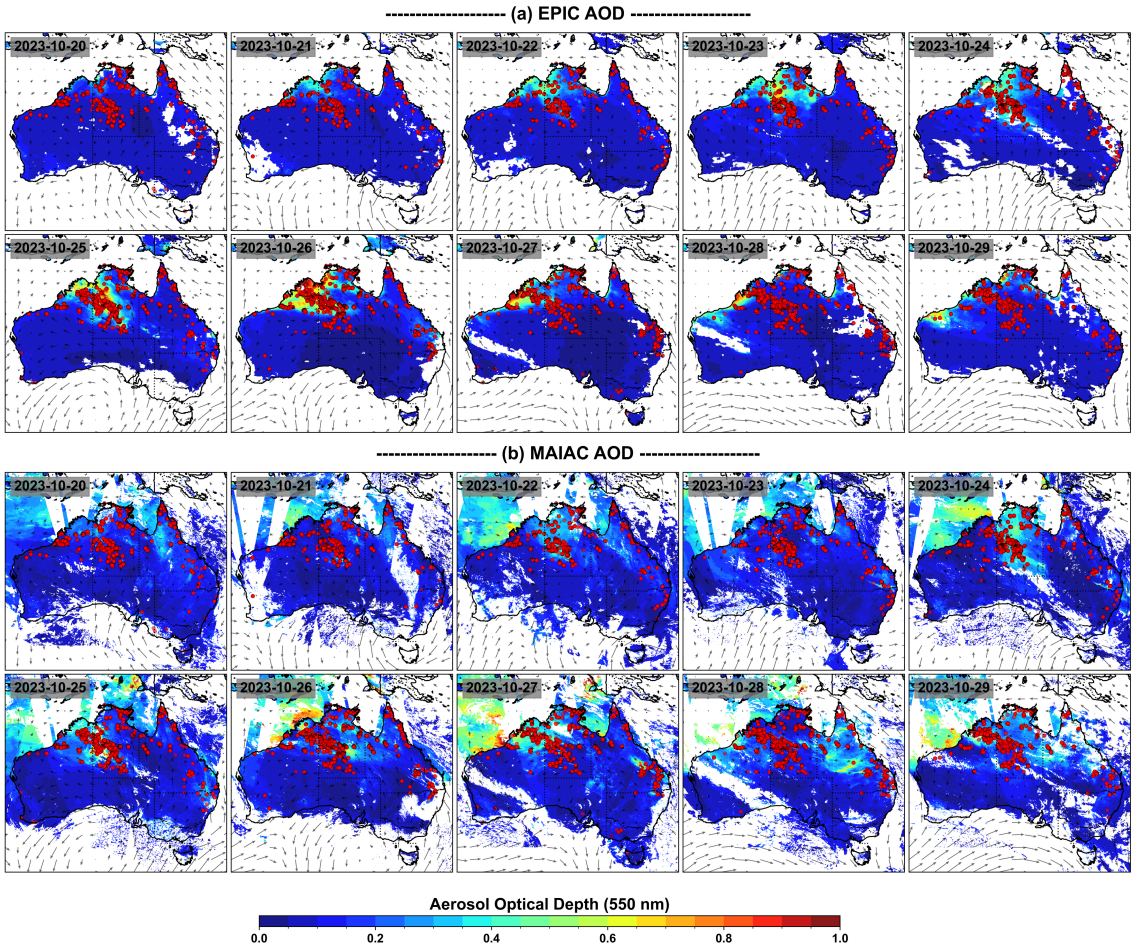


Fig. S7. Synoptic-scale comparison of daily averaged aerosol optical depth at 550 nm over Australia during the extensive wildfire event from 20 to 29 October 2023. (a) The daily composite retrieval from the EPIC Aero algorithm, showing comprehensive spatial coverage. (b) The corresponding daily MODIS MAIAC product for spatial validation; white areas indicate orbital gaps or retrieval failures caused by clouds. Both maps are overlaid with active fire spots from MODIS FIRMS and daily wind-field vectors from the ECMWF ERA5 reanalysis.

Table S1. Time-independent interannual validation metrics for the retrieved aerosol optical depth against ground-based measurements for the completely unseen years 2020 and 2023.

Year	R	MAE	RMSE	InEE	GCOS	Unc
2020	0.790	0.054	0.098	81.03	46.37	0.020
2023	0.700	0.062	0.113	78.09	43.65	0.018