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An AI-based algorithm for retrieving aerosol optical depth and single scattering albedo using All-Sky Imager observations

Heyang Ni et al.

Correspondence to: Jing Li (jing-li@pku.edu.cn)

Table S1. Comparison of representative ASI-based aerosol retrieval studies

Study	Main input features	Retrieval target(s)	Validation/reference	Notes
Olmo et al. (2008)	All-sky CCD images; spectral radiance reconstructed from sky images with a linear pseudoinverse step	AOD and cloud optical depth at 500 nm	Side-by-side sun photometer comparison; the paper reports differences similar to nominal AOD uncertainty	Early physically based inversion using radiative transfer code
Cazorla et al. (2009)	Calibrated all-sky imager radiance from the principal plane	AOD at three wavelengths and the Angstrom exponent	Training and validation with CIMEL CE318 / AERONET measurements at the ARM SGP site	Neural-network retrieval based on image radiance features
Román et al. (2022)	Normalized sky radiances from an all-sky camera at three wavelengths	AOD and additional aerosol properties / type information, especially at low and moderate loads	Compared with co-located AERONET measurements; synthetic sensitivity analysis also reported	Physical inversion with GRASP
Scarlatti et al. (2023)	Principal-plane signals derived from calibrated RGB all-sky images	Spectral AOD and AE	Validated against AERONET observations	Gaussian process regression; tested alternative input choices
Logothetis et al. (2023)	RGB channels and sun saturation area from an all-sky imager	AOD at 440, 500, and 675 nm; AE at 440-675 nm; FMF at 500 nm; aerosol type classification	Compared against AERONET reference measurements	Supervised machine learning with aerosol-type output
This study	Global RGB means, RBR, SZA, and annulus RGB samples from ASI images	Simultaneous AOD and SSA at 440, 675, 870, and 1020 nm	Independent validation against AERONET at Beijing_PKU and SGP with chronological holdout splitting	XGBoost regression; first simultaneous AOD+SSA retrieval from low-cost ASI imagery in this manuscript

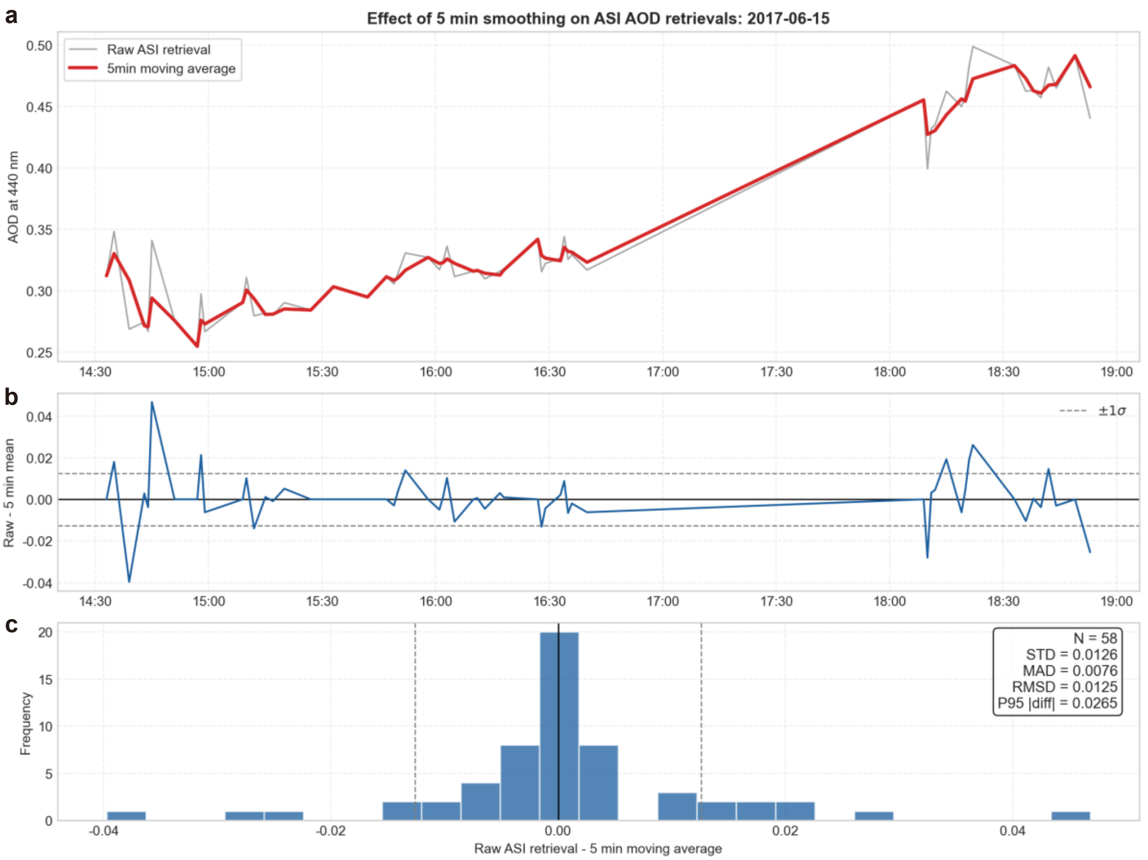

Figure S1. Quantification of the 5 min smoothing effect for ASI-retrieved AOD at 440 nm on 15 June 2017. Panel (a) compares the raw ASI retrievals with the 5 min moving average, the middle panel shows the difference between the raw and smoothed retrievals, and the lower panel shows the distribution of the difference. The standard deviation of the raw-minus-smoothed difference is 0.0126, with a mean absolute difference of 0.0076 and a 95th percentile absolute difference of 0.0265.

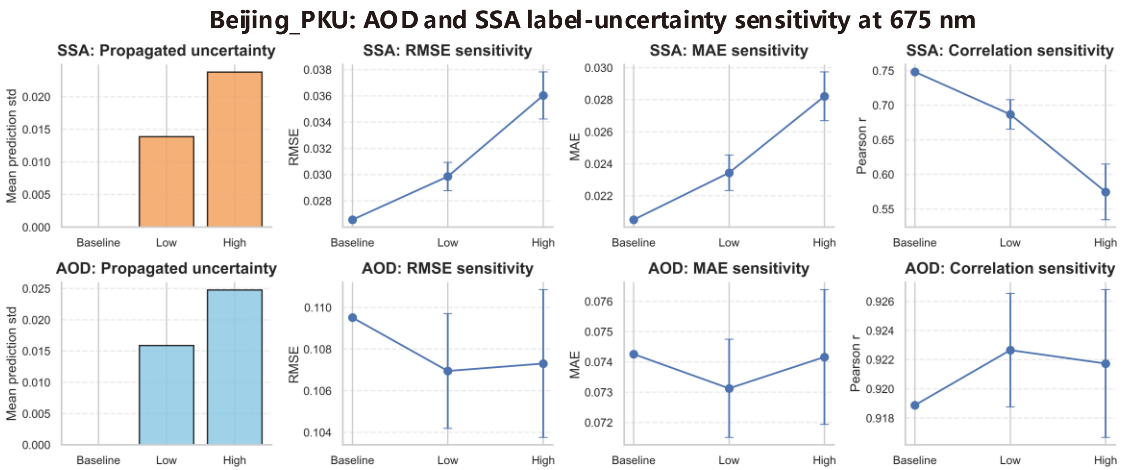

Figure S2. Sensitivity of Beijing_PKU AOD and SSA retrievals to assumed AERONET label uncertainty at 675 nm. Gaussian perturbations were added to the AOD and SSA training labels under three scenarios: Baseline (σSSA = 0, σAOD = 0), Low uncertainty (σSSA = 0.03, σAOD = 0.02), and High uncertainty (σSSA = 0.06, σAOD = 0.04). The model was retrained 100 times for each scenario. The first column shows the mean standard deviation of the predicted values, representing the propagated retrieval uncertainty. The remaining columns show the mean RMSE, MAE, and Pearson correlation coefficient across the Monte Carlo runs, with error bars indicating ±1 standard deviation. The perturbation amplitudes are used as assumed uncertainty scenarios rather than official AERONET Level 1.5 or Level 2.0 uncertainty values.