Evaluation of ATLID observations with AERONET and comparison with CAMS global atmospheric composition forecasts

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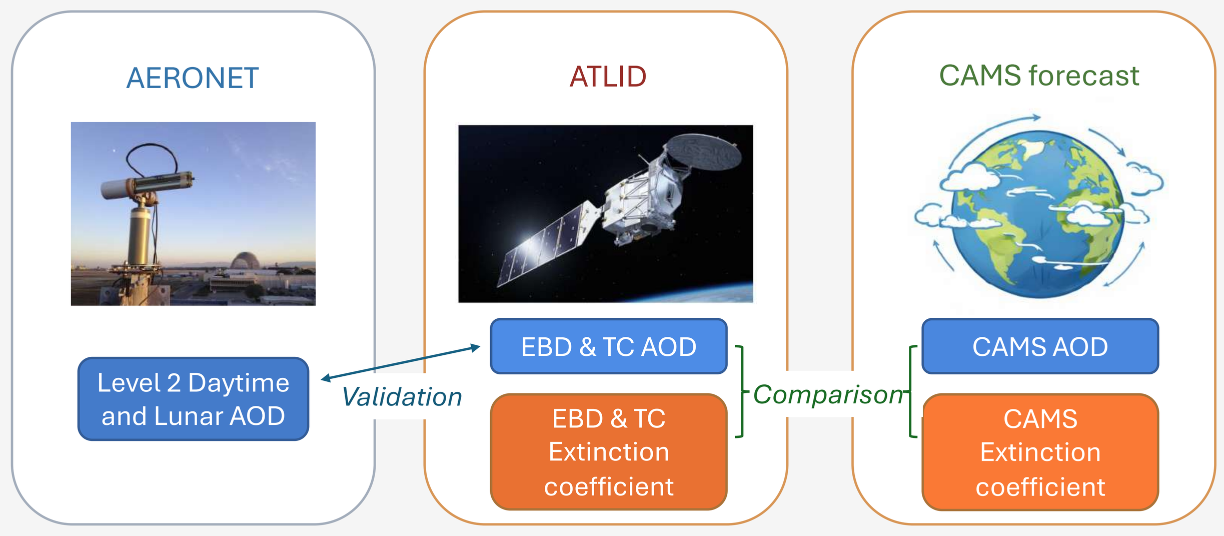
Introduction

Aerosols influence the global climate by modulating Earth's radiation budget. However, aerosol vertical distributions in global models remain highly uncertain. The ATmospheric LIDar (ATLID) onboard the EarthCARE satellite provides high-quality vertical profiles of aerosols and thin clouds at 355 nm. Aerosol extinction coefficients retrieved from ATLID Level 2 A-EBD (Extinction Backscatter and Depolarization) and A-TC (Target Classification) products offer new constraints that can potentially improve the performance of global models. The Copernicus Atmosphere Monitoring Service (CAMS) global atmospheric composition forecasts run operationally and provide forecasts of atmospheric pollution, aerosols, and greenhouse gases globally with data assimilation. However, the vertical distributions of aerosols remains poorly evaluated at global scale.

In this study, we validate aerosol optical depth (AOD) retrieved from ATLID against AERONET ground-based observations between December 2024 and November 2025. We then use ATLID AOD and aerosol extinction coefficient profiles to evaluate CAMS forecasts with and without data assimilation (DA) to identify model biases and investigate potential improvements for the model.

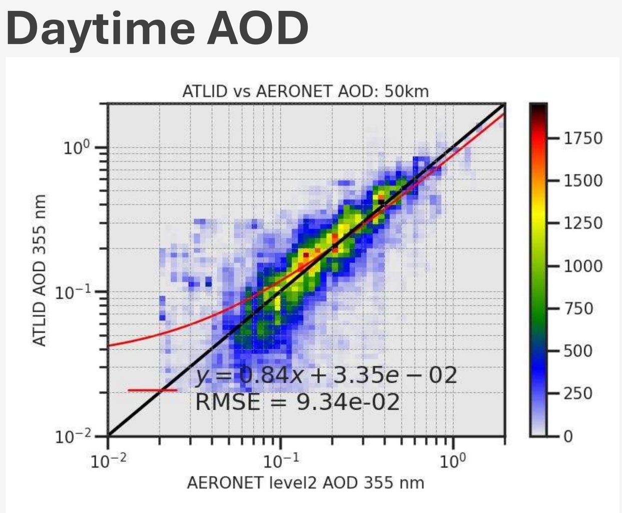
Methods



Only retrievals of aerosol from ATLID are used.
CAMS forecast with DA and CAMS control run without DA
ATLID-AERONET collation: within 50 km & 30 min
ATLID-CAMS colocation: nearest neighbour

Validation of ATLID AOD

Daytime AOD



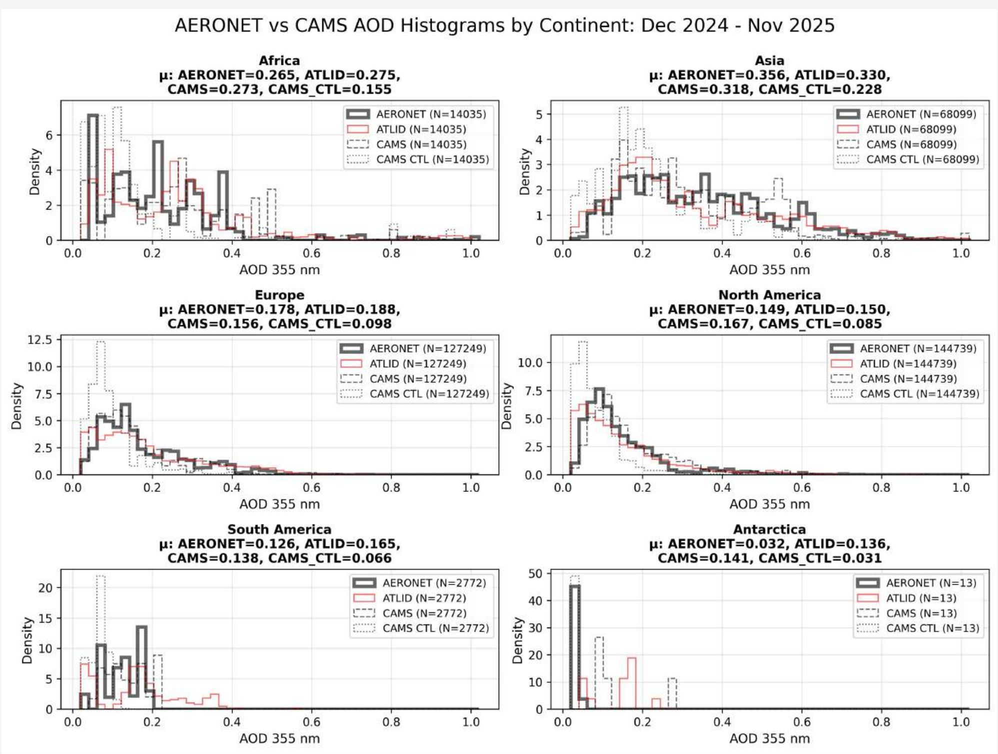
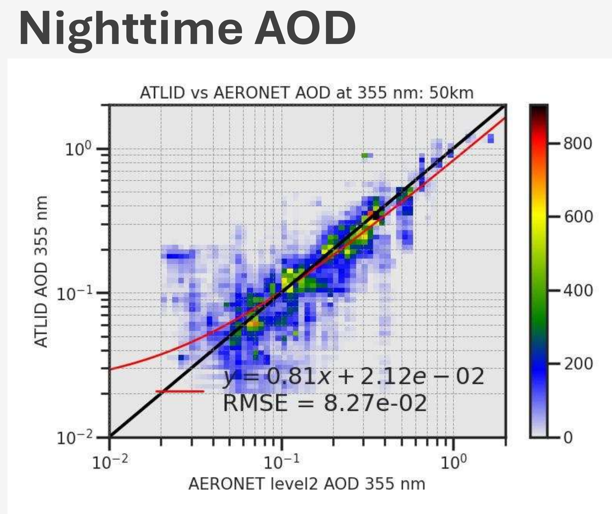


Fig. 1 Density plots of AOD in AERONET and ATLID (left) and the histograms of AOD in AERONET, ATLID, CAMS in several regions (right) in Dec 2024 – Nov 2025.

- ATLID has an overall good agreement with AERONET (mean AOD difference: 0.007, 13.3% of AERONET AOD).
- Best agreement in North America and Europe, where AERONET station density is highest, which has a large influence on the statistics.
- Mean AOD over Africa is similar between ATLID and AERONET, but the distribution differs in specific AOD ranges, likely attributable to large colocation distances (50 km) and cloud contamination in ATLID retrievals.

Nighttime AOD



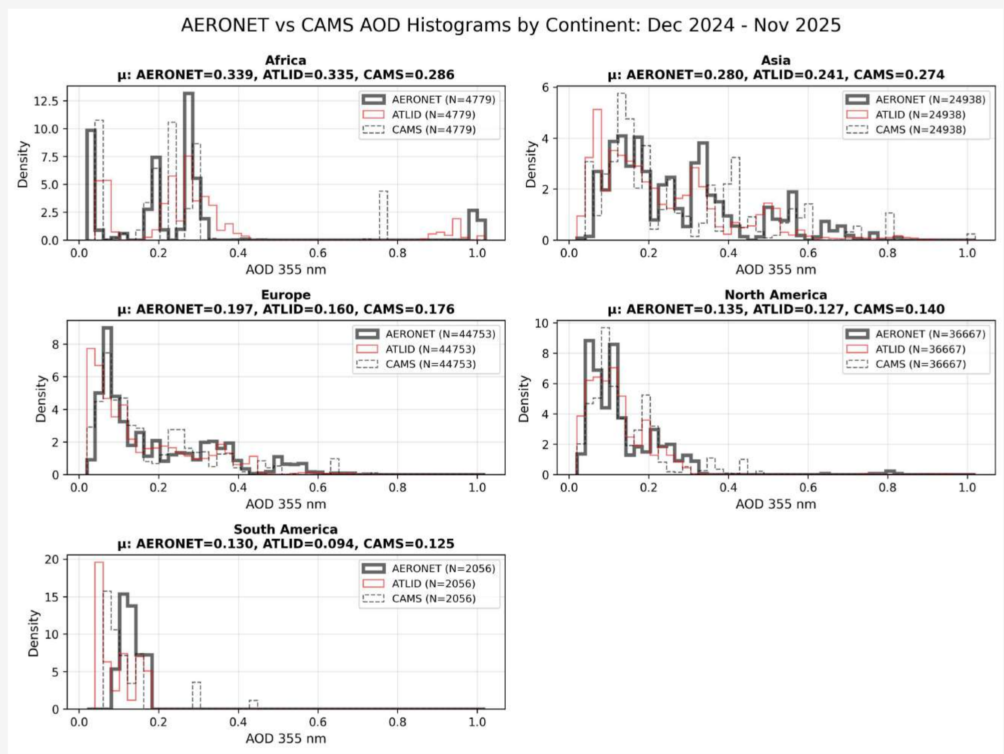
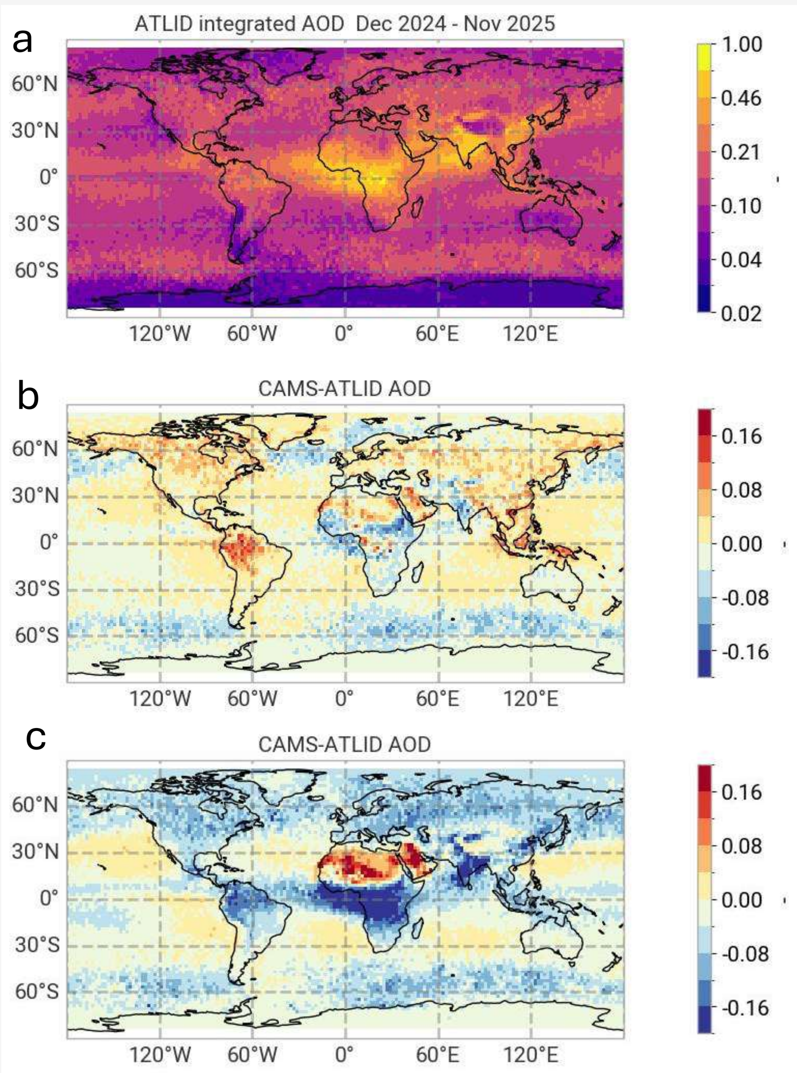


Fig. 2 Same as Fig. 1 but for Lunar AOD. No data is available in Antarctic.

- AERONET's Lunar AOD is considerably smaller and noisier than daytime.
- Linear regression fit shows comparable slope and RMSE to daytime AOD, but with a systematic negative bias (mean diff: −0.02, 5.7% of AERONET AOD).
- Good agreement in Europe and North America. Mean AOD is similar in Africa.
- ATLID does not detect nighttime AOD in 0.02-0.04 bin as AERONET does in Africa but shows much more data in Asia in this range than AERONET.

Evaluate CAMS AOD and extinction coefficients

AOD



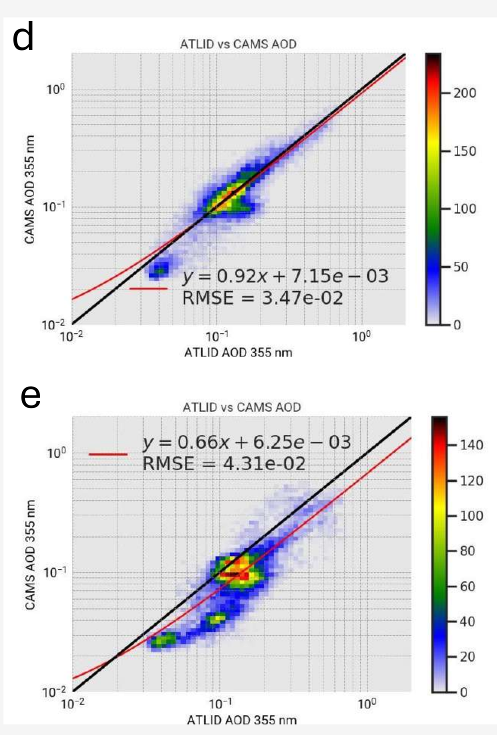
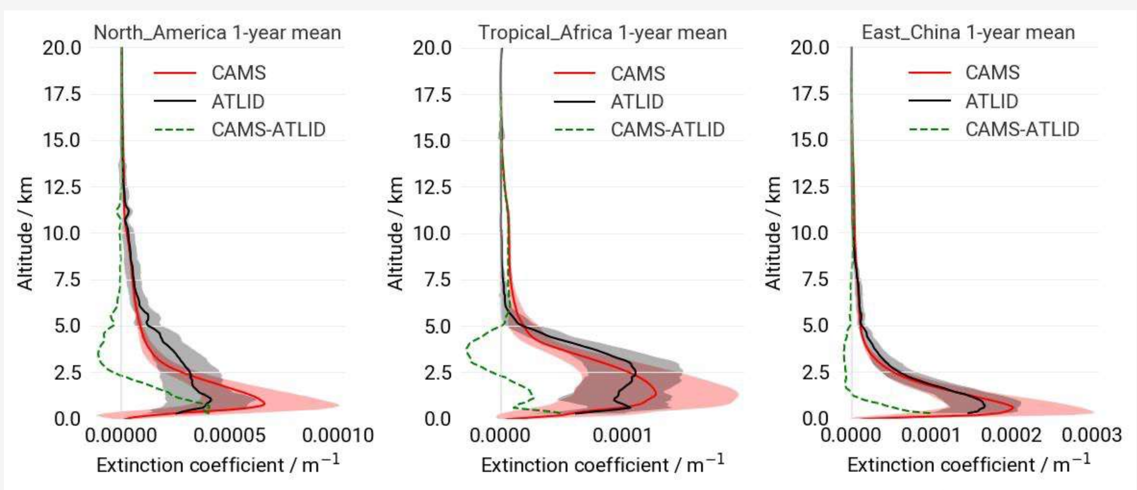
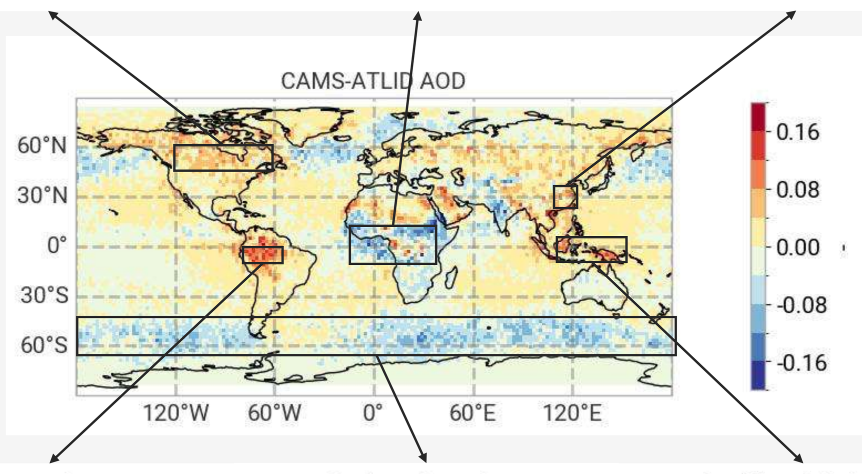


Fig. 3 Global maps of AOD in (a) ATLID, (b) CAMS with DA, and (c) CAMS control (CTL) run without DA. The density plots of AOD between (d) CAMS and ATLID, and (e) CAMS_CTL and ATLID.

- Both ATLID and CAMS capture the spatial patterns of high-AOD regions (Africa, India, and East China) and low-AOD regions (Arctic and the Southern Ocean).
- CAMS underestimates global AOD with a mean difference of -0.0052 (-4.3% of ATLID), but the regional discrepancies are larger.
- When comparing ATLID and AERONET (Fig.1) against the CAMS CTL run (without DA), we found substantially larger biases than the run with DA. It highlights room for improvements in the model's aerosol modules.

Extinction coefficients





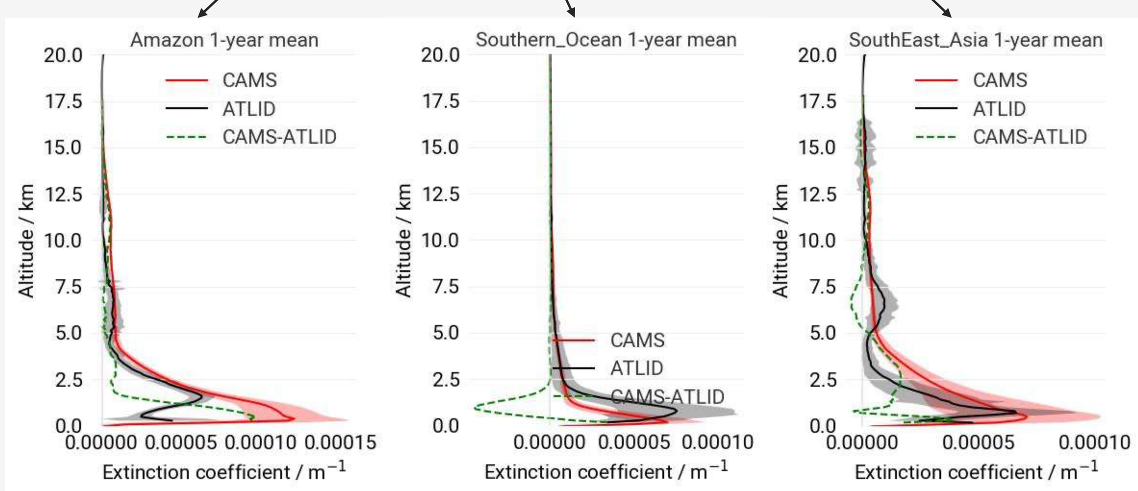


Fig. 4 Spatial- and 1-year-mean aerosol extinction coefficients profiles in several regions in ATLID (black), CAMS (red), and their differences (green dashed). The shades are 1 standard deviations.

- The meanprofiles show high aerosol extinction coefficients near surface aerosol sources, and it quickly drops above the boundary layer.
- Discrepancies between CAMS and ATLID are most pronounced close to the surface.
- CAMS forecasts exhibit a shallower aerosol layer across most selected regions, suggesting insufficient vertical mixing or transport.

Conclusions

One year of ATLID observations show good agreement with AERONET Level 2 AOD, especially in North America and Europe which have high AERONET station density, demonstrating ATLID as a reliable tool for evaluating aerosol properties globally.

CAMS underestimates global AOD from ATLID by 4.3% and the CTL run has substantially larger biases. CAMS extinction coefficient profiles exhibit shallower aerosol layers than ATLID in many regions, implying insufficient vertical mixing or transport. The results show the added value of ATLID for constraining aerosol profiles in models.

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