Ground Validation of EarthCARE ATLID Aerosol Products at the Arctic Lidar Observatory for Middle Atmospheric Research

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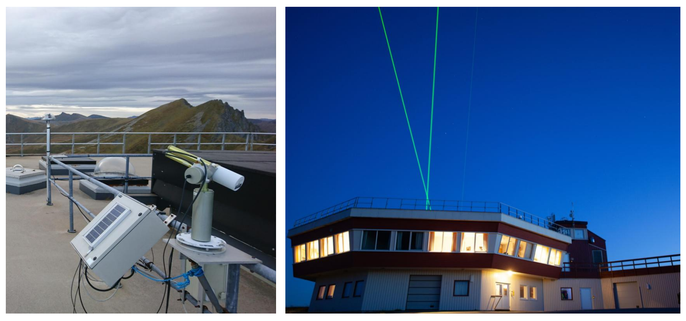
The Arctic Lidar Observatory for Middle Atmospheric Research (ALOMAR) is an advanced laboratory, specialized in both passive and active remote sensing of all layers in the Arctic atmosphere. Located north of the Arctic Circle (69°N, 16°E), ALOMAR is one of the few observatories in this region that routinely measures cirrus clouds, tropospheric aerosol concentrations, as well as wind speed and temperature in the middle atmosphere using lidar remote sensing. ALOMAR hosts two RMR lidar systems. The RMR lidars are capable of performing measurements during daylight and nighttime. Additionally, ALOMAR hosts a CIMEL sun/moon photometer, which routinely measures aerosol and water vapor content in the troposphere.

As part of the Vesterålen archipelago in Northern Norway, Andøya is situated at the crossroads of air masses entering and leaving the Arctic. This unique location results in frequent encounters with pristine Arctic air masses and elevated polluted layers from long-range transport of wildfire smoke, Saharan dust, and volcanic aerosols. Given the scarcity of high-latitude observatories, remote sensing measurements at ALOMAR offer an excellent opportunity to validate ATLID aerosol products. Furthermore, ALOMAR's frequent cirrus cloud occurrences make it an ideal location for validating EarthCARE's retrievals of Arctic cirrus clouds.

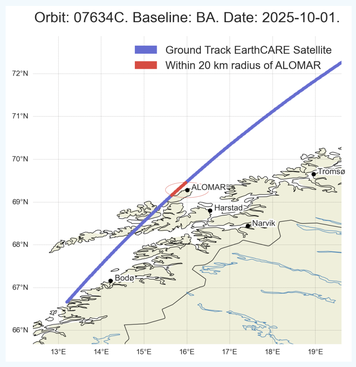


(Left) The CIMEL sun photometer at ALOMAR and (Right) the ALOMAR Observatory, with the two IAP RMR lidar beams and the ATL lidar beam.

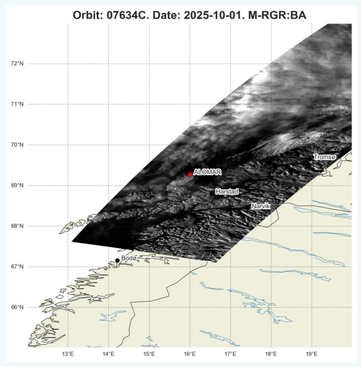
EarthCARE Overpasses Near ALOMAR: Lidar Case Studies and Validation Insights

Two EarthCARE overpass cases are presented: two daytime overpasses with different distances to ALOMAR. Comparisons between Backscatter Coefficient Profiles from ALOMAR Tropospheric Lidar (ATL) and the A-AER and A-EBD retrievals show generally good agreement in the 4–7 km altitude range. The large ATLID variability in the lower 2 km is due to the inherently complex, turbulent and source-driven nature of the boundary layer, amplified by ATLID's high vertical sensitivity. The October case shows disagreement in the data above 7 km, likely due to the presence of the cirrus cloud layer between 7 – 10 km.

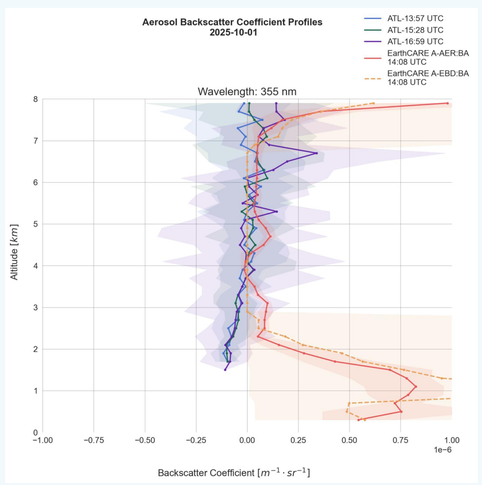
October 1st, 2025 – Orbit 07634



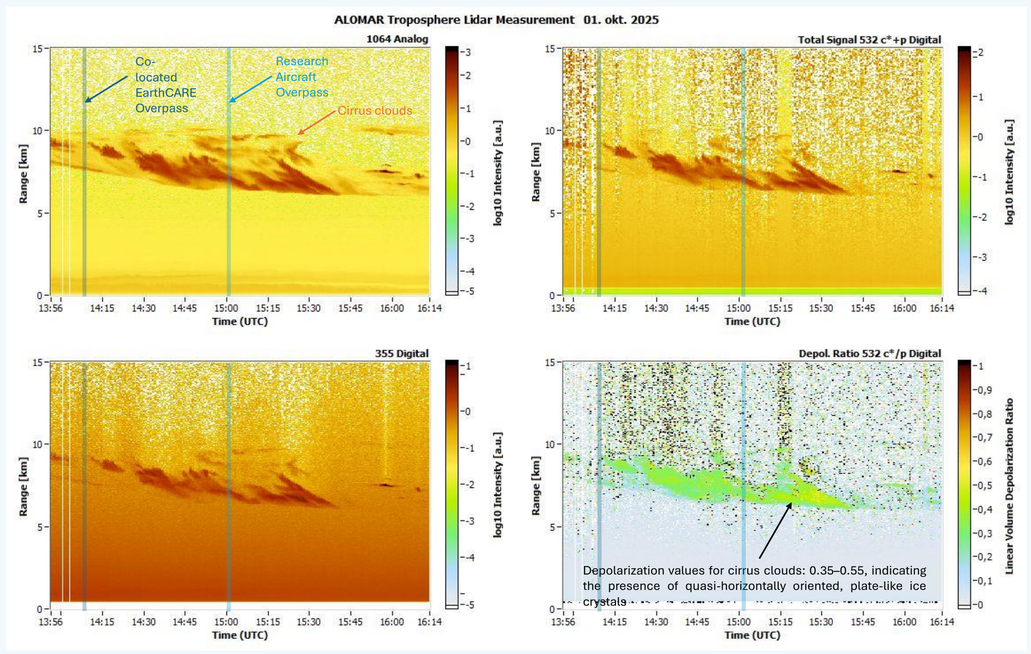
Ground track of the satellite overpass 1 October, 2025. Red represent the A-AER product with BC within 20 km radius of ALOMAR.



M-RGR product during the overpass on October 1, 2025. Cirrus clouds are clearly visible over the sea and along coastal regions.



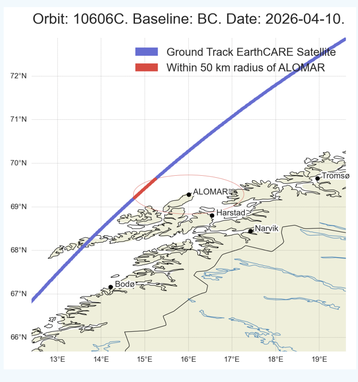
Backscatter Coefficient profiles of 355 nm October 1, 2025, within 20 km radius of ALOMAR. Red represent the A-AER product with baseline BA. Orange the A-EBD product with baseline BA. Three different colors of ATL products for different time spans.



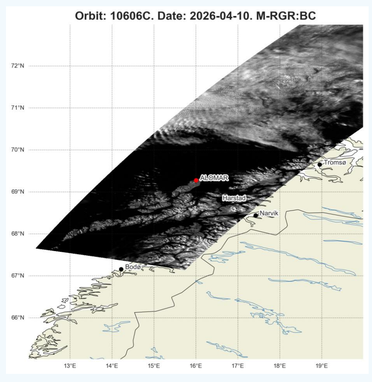
ATL quicklook from October 1, 2025, during CELLO-Arctic. A cirrus cloud layer is clearly visible between 7 and 10 km above mean sea level. Blue shading marks the time of co-located EarthCARE and research aircraft overpasses. Polarization at the VIS 532 nm channel indicates clean air without aerosols (values around 0.1) and the cirrus layer (values between 0.35–0.55).

The April case has little to no cloud contamination during the overpass, but the satellite passes at a longer distance from ALOMAR than in the October case. The backscatter coefficients are in general agreement, and both EarthCARE products display the same increase in the 5–6 km altitude range. However, the A-EBD product shows higher values than A-AER, which may be due to differences in the retrieval methods.

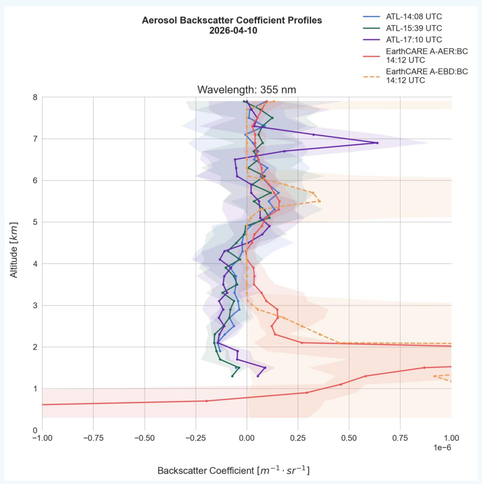
April 10th, 2026 – Orbit 10606



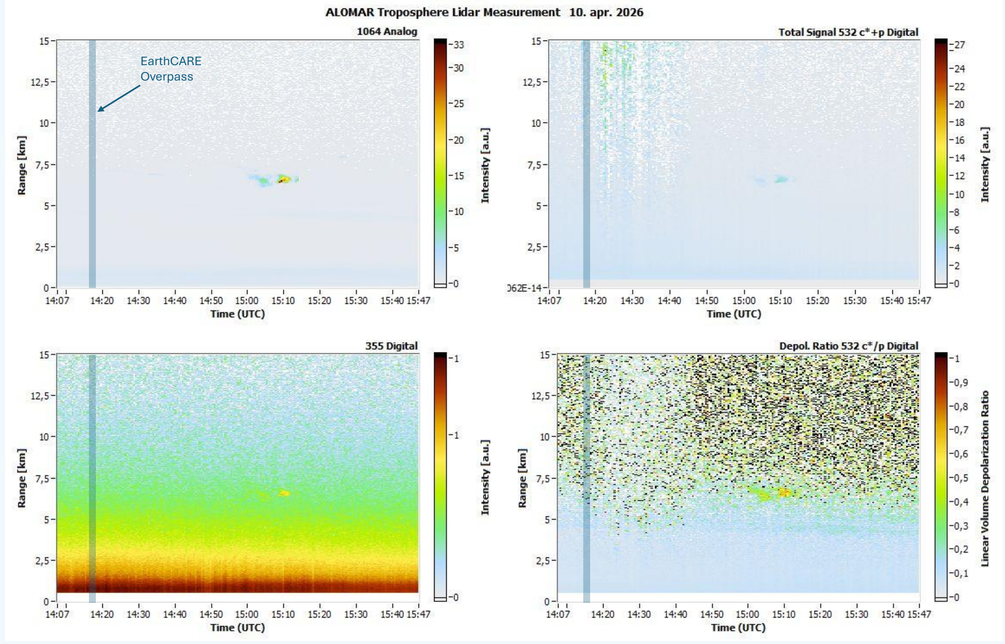
Ground track of the satellite overpass 10 April, 2026. Red represent the A-AER product with BAC within 50 km radius of ALOMAR.



M-RGR product during the overpass on April 10, 2026. Cirrus clouds are clearly visible over the sea.

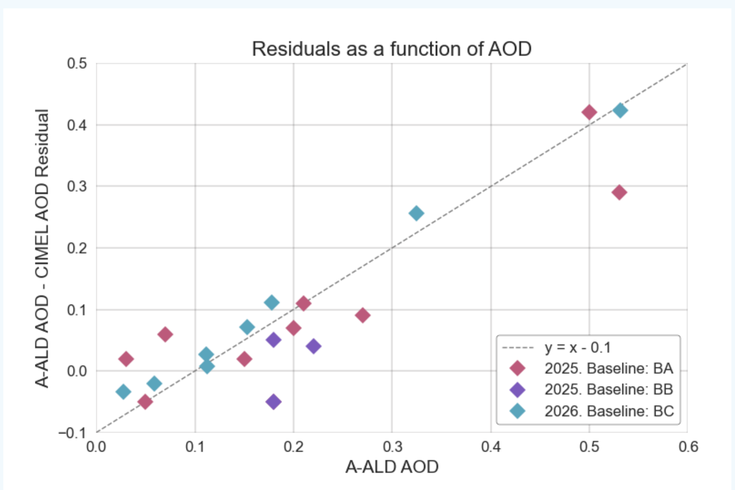


Backscatter Coefficient profiles of 355 nm April 10, 2026, within 50 km radius of ALOMAR. Red represent the A-AER product with baseline BC. Orange the A-EBD product with baseline BC. Three different colors of ATL products for different time spans.



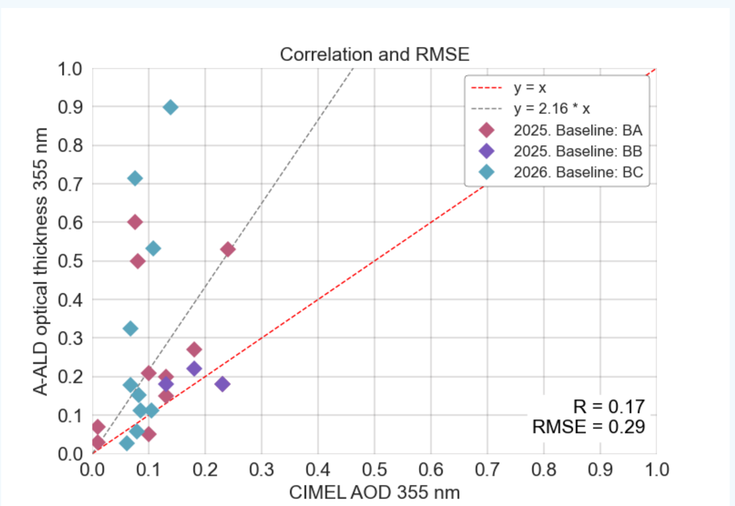
ATL quicklook from April 10, 2026. Panels show 1064, 532 and 355 nm signals and 532 depolarization ratio. Blue shading marks the time of the EarthCARE overpass. A small enhanced scattering is seen around 6-7 km.

EarthCARE Overpasses Near ALOMAR: Statistics from CIMEL AOD comparisons 2025 and 2026



Residuals (A-ALD – CIMEL AOD) as a function of A-ALD AOD. A linear regression line is plotted to show the trends during correlated overpasses between May 2025 and May 2026.

Residuals, plotted as a function of A-ALD AOD, show a clear positive trend: as A-ALD AOD values increases, the discrepancy between the A-ALD optical thickness product and ground-based CIMEL AOD measurements also increase. Residuals are predominantly positive, indicating a systematic overestimation by the satellite retrieval. This behavior is consistent with the regression (y = x – 0.1), suggesting that the bias increases approximately linearly with AOD rather than remaining constant.



Comparison of AOD derived from the CIMEL at ALOMAR and A-ALD optical thickness product during correlated overpasses between May 2025 and May 2026 .

Comparison between CIMEL AOD and the A-ALD optical thickness product shows weak agreement, with low correlation (R = 0.17) and substantial scatter (RMSE = 0.29). Most observations lie above the 1:1 line, indicating a systematic overestimation of the A-ALD optical thickness product. This bias is further reflected in the regression slope (y = 2.16x). The 2026 dataset spans a broader range and includes higher A-ALD values compared to 2025, potentially reflecting differences in measurement conditions, i.e., clouds at the ATLID track, or retrieval performance.