

Validation of EarthCARE aerosol products using data recorded in Northern-Norway

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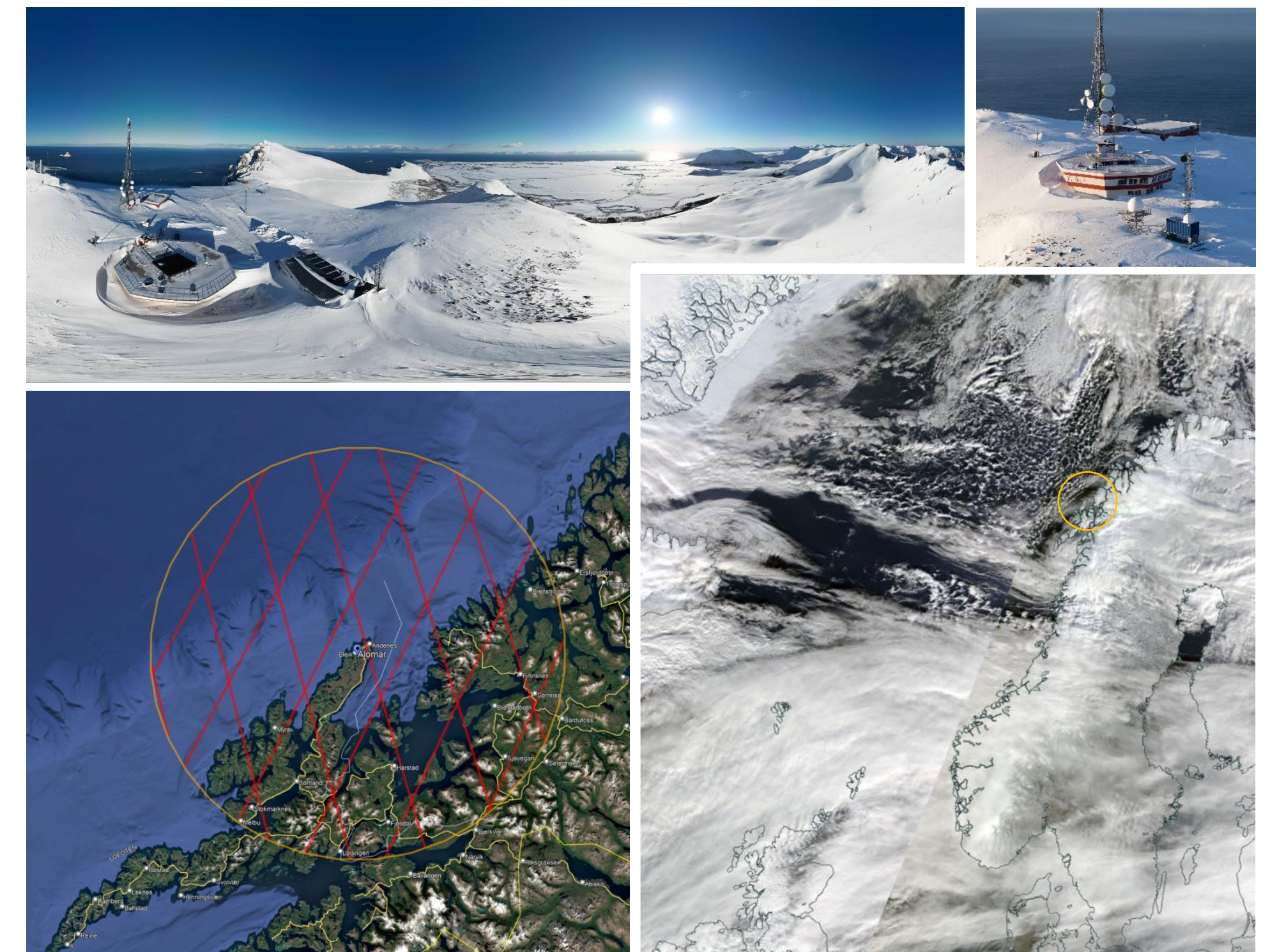
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EVID 18

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, stratospheric ozone, as well as wind speed and temperature in the middle atmosphere using lidar remote sensing. ALOMAR hosts two RMR lidar systems and an ozone lidar system. 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.

Measurements from the ALOMAR tropospheric lidar system (ATL) and CIMEL photometer contribute to validation of EarthCARE products as part of the *Cloud and EarthCARE caL/vaL Observations (CELLO)* project (EVID 18). The location of Andøya is ideal for the validation of polar orbiting satellites, with a nearby overpass number that is 2–4 times higher compared to low- and mid-latitude sites. For instance, the EarthCARE satellite has 3–4 overpasses per week within a 100 km radius of ALOMAR.

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.



(Upper left and right) The ALOMAR observatory, located on top of the 378 m high Ramnan mountain at Andøya. (Lower left) EarthCARE satellite tracks within a 100 km radius of ALOMAR for the period 12-FEB-2025 to 08-MAR-2025. (Lower right) NASA Worldview satellite picture from 05-MAR-2025 showing the different cloud types that approached ALOMAR this day.

The ALOMAR tropospheric lidar system (ATL)

The ALOMAR tropospheric lidar system uses a seeded Nd:YAG power laser at 1064 nm (primary wavelength), 532 nm (second harmonic) and 355 nm (third harmonic). At 532 nm, the light is polarized and two detectors, one with orthogonal and one with parallel polarization are used to determine the depolarization at 532 nm. The ATL also has a Raman detector at 387 nm. To cover a larger range of distances the ATL uses two simultaneous detection channels for every wavelength (except at 387 nm), an analog mode for stronger signals (especially in the near range) and a photon-counting mode for weaker signals (mostly for the far range). These two channels can be joined through a gluing algorithm.

To match with the configuration of EarthCARE's ATLID, the outgoing light of the ATL at 355 nm will also have to be linearly polarized. The ATL receiver will be equipped with orthogonal and parallel polarization channels.

Comparison between ATL at ALOMAR and EarthCARE		
	ATL	ATLID
Wavelength	1064, 532, 355 nm	354.8 nm
Power	1600, 800, 375 mJ	35 mJ / pulse
Emitted polarization	Linear	Linear
Frequency	33,333 Hz	51 Hz
Vertical resolution	7.5 m	103 m (up to 20.2 km)
Altitude range	0.5 – 16 km	-0.5 – 40 km
Detection channels	355 nm, 532 nm co and cross, 1064 nm, 387 nm	MieCoPo/MieCross/Rayleigh



(Left) The ATL laser generator and (Right) the ATL beam guiding mirrors and receiver telescope.

The CIMEL CE318-T on the roof at ALOMAR.

The CIMEL CE318-T

The CIMEL CE318-T is a high-precision multiband sun/moon photometer operated by the University of Valladolid (Spain) and Andøya Space. It uses direct measurements of the sun and moon irradiance to determine the attenuation in the air by aerosols and water vapor. By making these measurements at ten different wavelengths a better characterization of the aerosol and their scattering properties can be conducted. Although the CIMEL is capable of measuring radiation from the moon, it is not possible to retrieve the Aerosol Optical Depth at night due to the limited UV radiation reflected by the moon. The instrument is part of the AERONET network.

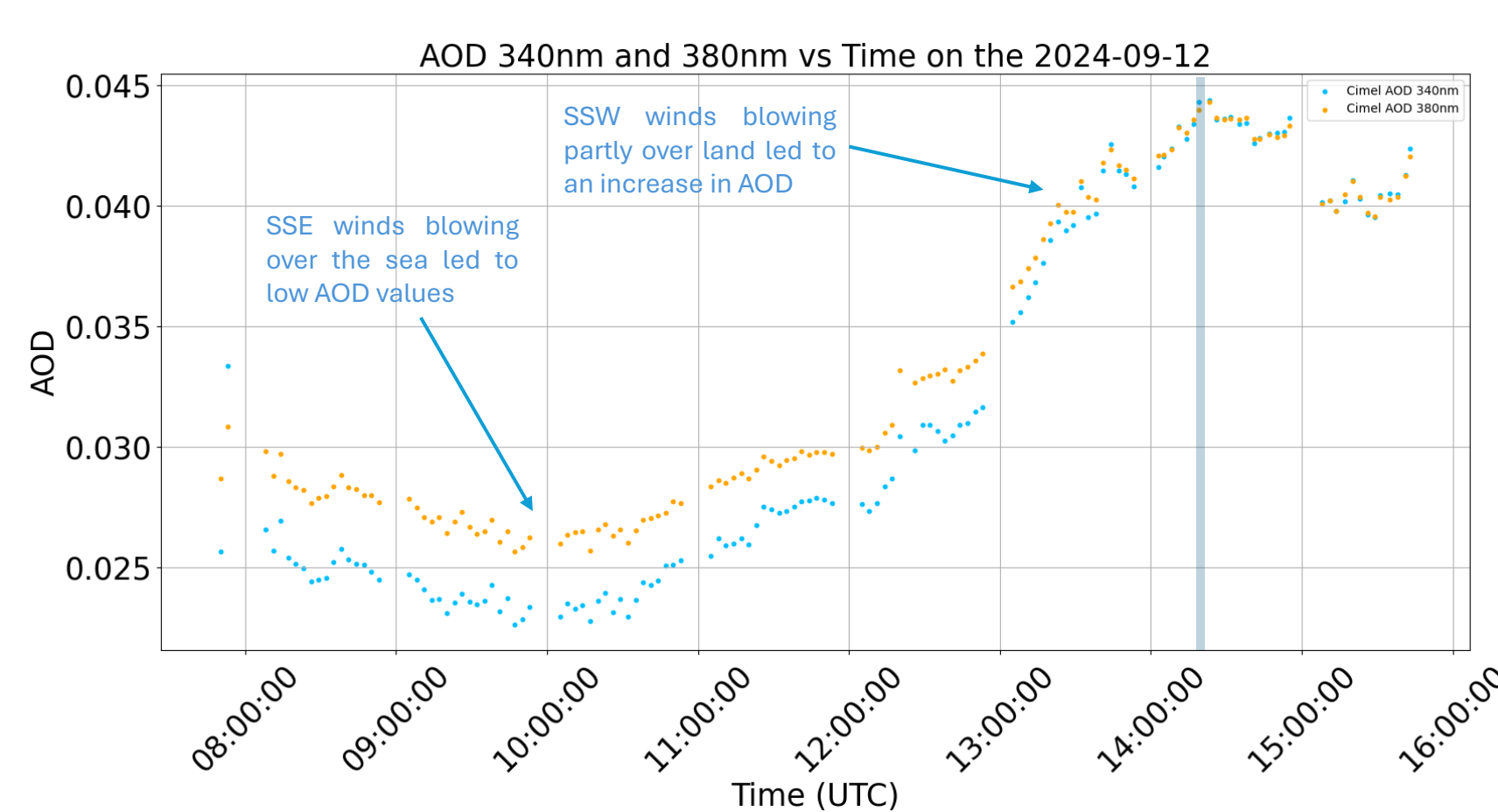
Validation of EarthCARE

ALOMAR intends to perform correlated EarthCARE measurements with the ATL and the CIMEL at least once per week, if weather permits.

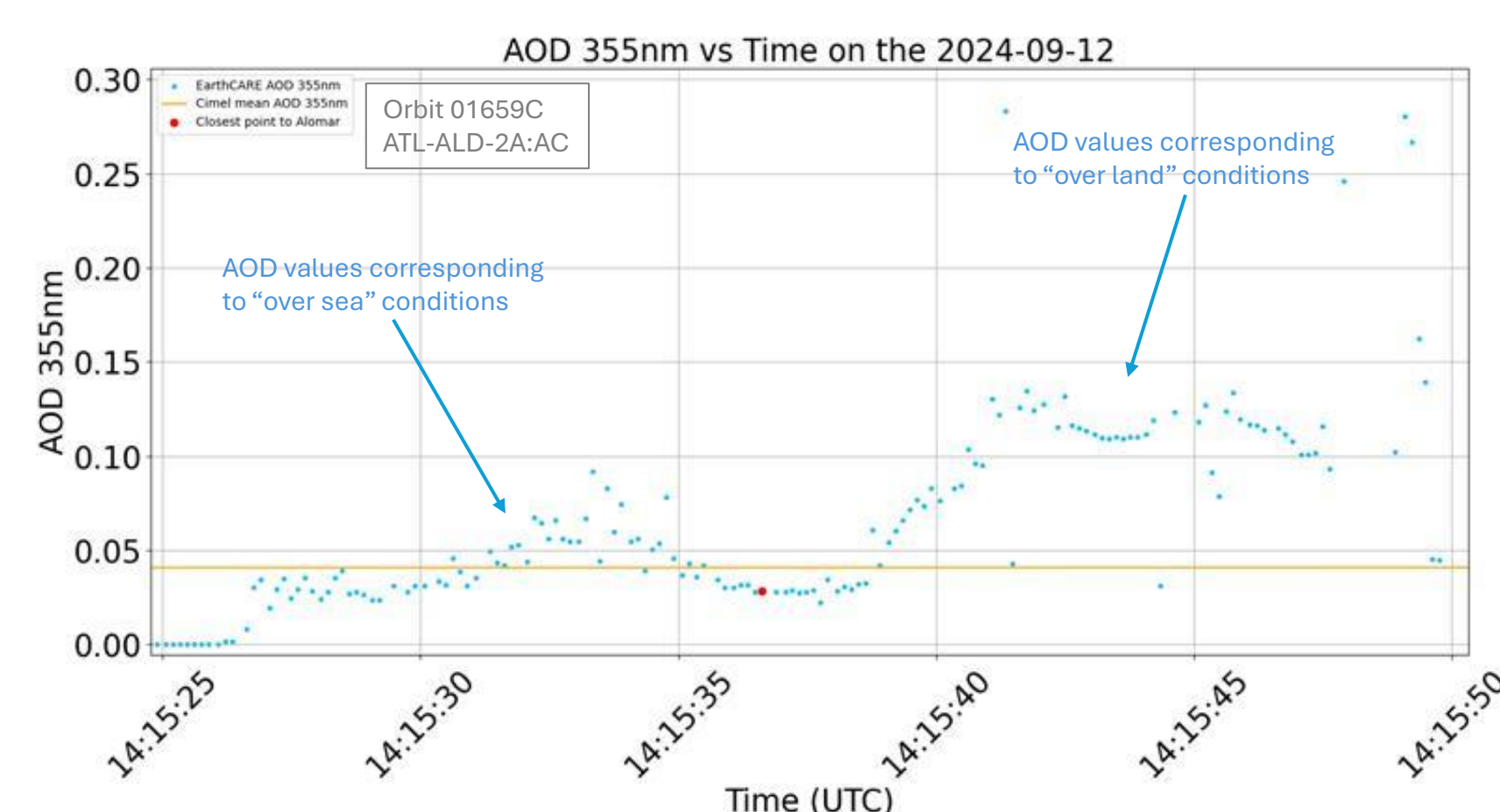
Correlated measurements between the CIMEL and EarthCARE on 12-SEP-2024 show good agreement with the EarthCARE ATL_ALD_2A optical thickness product for the part of the ATLID ground track (descending orbit, 01659C) that was over the ocean. The optical thickness derived from ATLID data shows an expected increase for the part of the ground track that was over land.

Table: EarthCARE products that will be validated by the ATL and the CIMEL at ALOMAR. Products validated by the ATL only are highlighted in light green. Products validated by the CIMEL only or in combination with the CIMEL and the ATL highlighted in green.

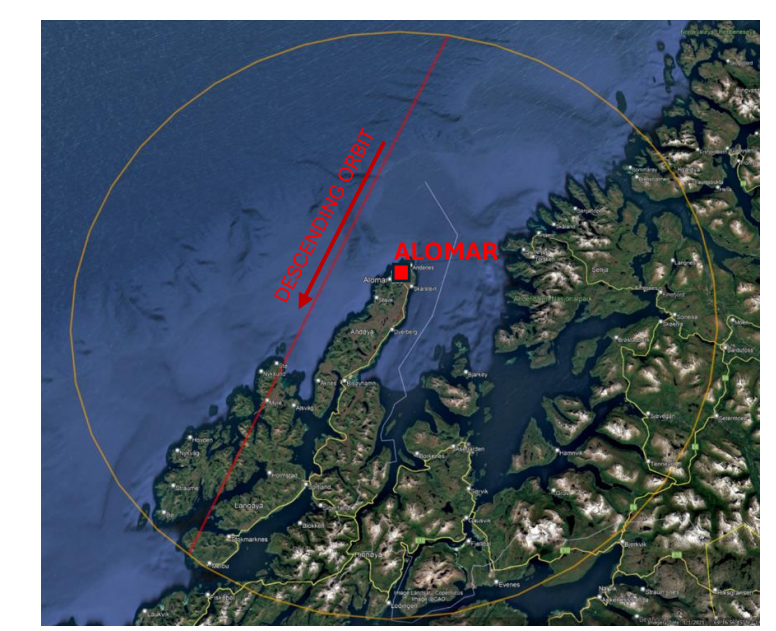
Product	Validation analysis addressed	Remarks
Level 2 - Cloud-top, vertically integrated and layer-wise retrieval product		
Target classification	Cloud-top height	YES ATL for optically thin cirrus, in situ cloud probes
	Cloud-top phase	YES ATL for optically thin clouds
	Aerosol layer height/depth	YES ATL
	Aerosol layer classification	ATL
Cloud detection, Cloud aerosol discrimination	YES	ATL
	YES	ATL, CIMEL
Ice cloud & snow	Optical thickness	YES ATL, CIMEL
	Aerosol optical thickness	YES ATL, CIMEL
Aerosol (per species)	Ångström exponent	YES CIMEL
	Particle linear depolarization ratio	YES ATL (new 355 channel)
Level 2 - Vertical profiles at nadir		
Target classification	Cloud/precipitation fraction	YES ATL for cirrus
Ice cloud & snow	Extinction-to-backscatter ratio	YES ATL
Aerosol (per species)	Particle linear depolarization ratio	YES ATL (new 355 channel)



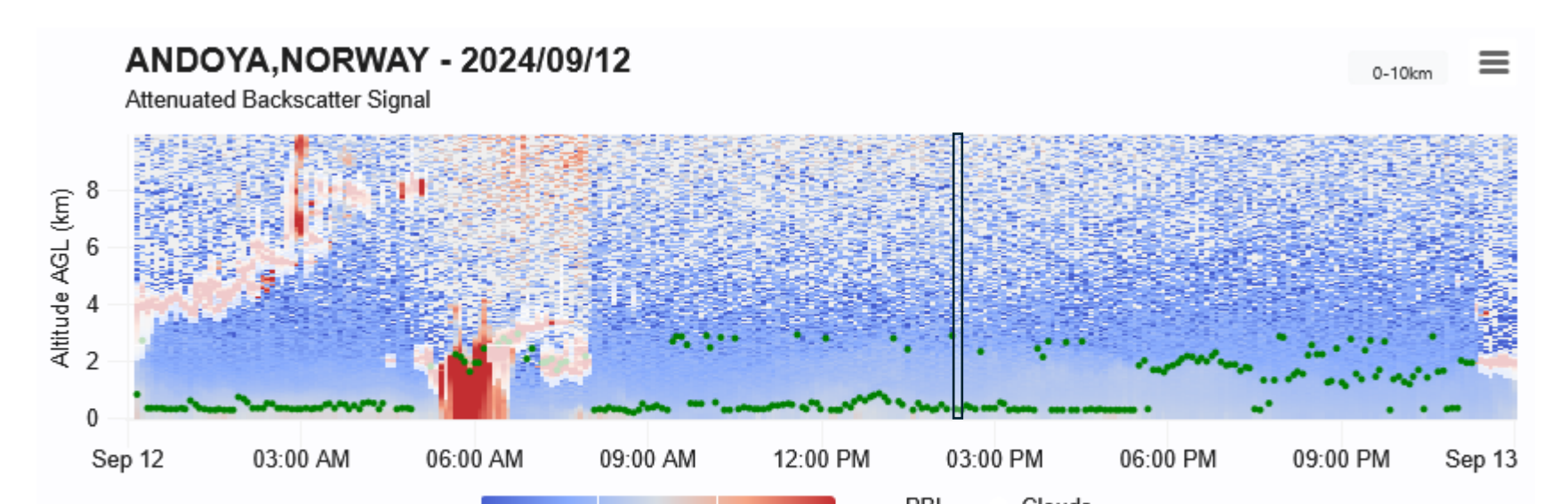
Aerosol optical depth (AOD) values at 340 nm and 380 nm derived from the CIMEL at ALOMAR on 12-SEP-2024. The blue shading indicates the time for the correlated EarthCARE overpass at ALOMAR.



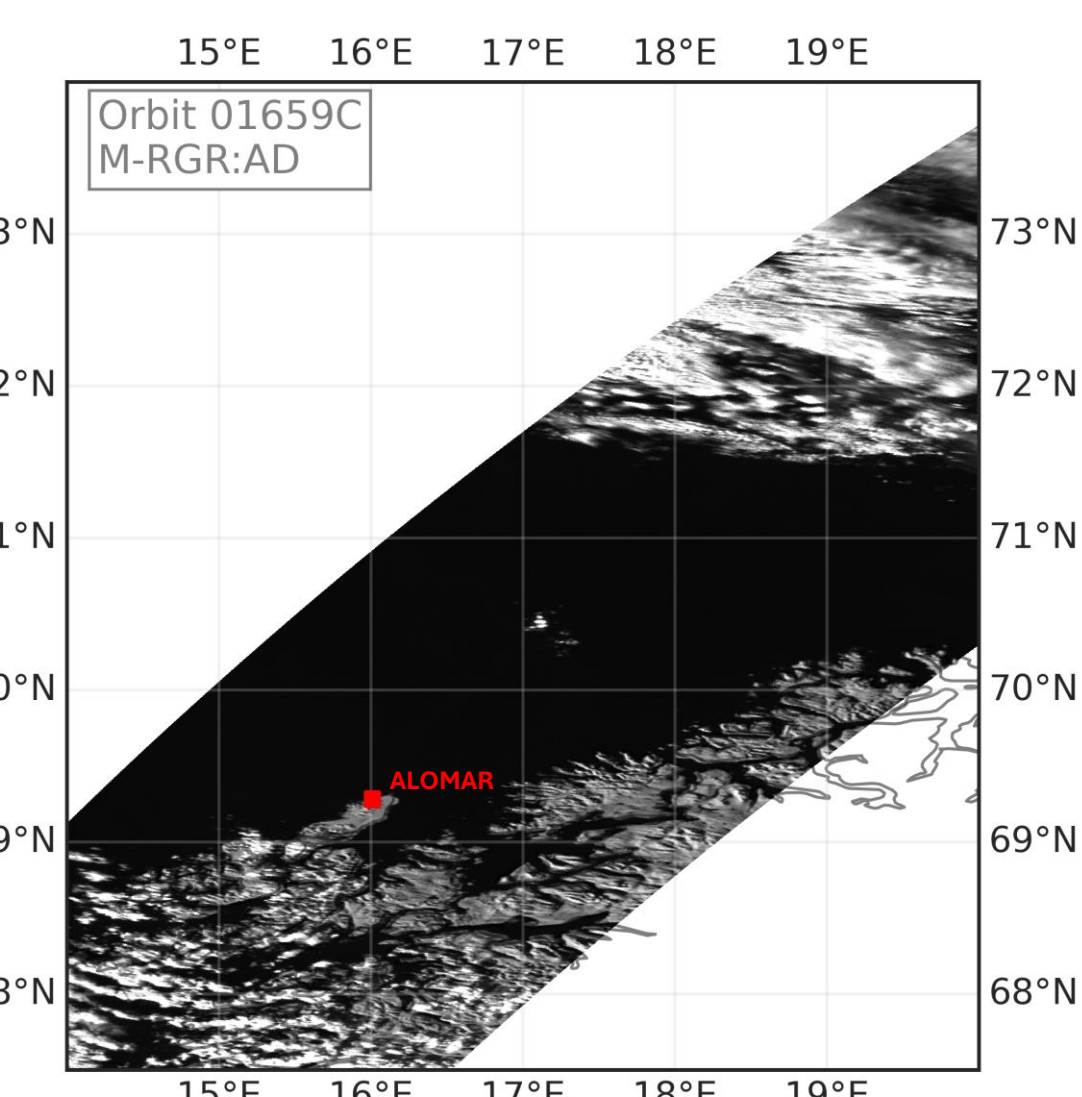
Aerosol optical depth (AOD) value at 355 nm derived from the CIMEL at ALOMAR compared to EarthCARE ATL_ALD_2A optical thickness product (baseline AC, orbit 01659C) during the correlated EarthCARE overpass on 12-SEP-2024.



The ATLID ground track (descending orbit, 01659C) within a 100 km radius from ALOMAR during the EarthCARE overpass on 12-SEP-2024. The minimum horizontal distance between the ATLID ground track and ALOMAR was approx. 29 km.



Attenuated Backscatter Signal from the Norwegian Met-Office Ceilometer for 12-SEP-2024, located approximately 6 km to the north of ALOMAR. The black box indicates the time for the correlated EarthCARE overpass at ALOMAR.



EarthCARE MSL_RGR_1C product (baseline AD, orbit 01659C) during the correlated EarthCARE overpass on 12-SEP-2024. No clouds were present at ALOMAR during the EarthCARE overpass.