ATLID and MSI Level 2 products validation with ground-based measurements at Lampedusa and Rome Italian observatories (EVID 11)

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Introduction

The ENEA Climate Observatory at Lampedusa island (35.52° N, 12.6° E, *www.lampedusa.enea.it*) and the CNR Institute of Atmospheric Sciences and Climate Rome Atmospheric Supersite, CIRAS (41.50° N, 12.39° E, *www.isac.cnr.it/en/infrastructures/ciras*) participate in the validation activities of the EarthCARE (EC) mission Commissioning phase in the framework of the EC-ValMed.it project, funded by the Italian Space Agency (ASI).

Lampedusa and Rome-Tor Vergata sites differ in latitude, geographic features, atmospheric processes, quantity and types of aerosols, and can therefore offer data of interest for the validation of EC products. The observatories are equipped with aerosol and cloud remote sensing instruments (**Table 1**), mostly running continuously.

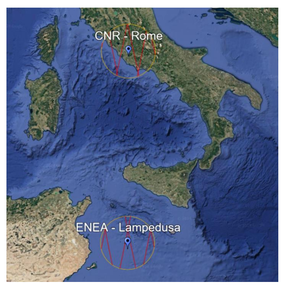


***Table 1**. Instruments deployed at the two observatories for the EC validation*

Rome	Lampedusa
Micro Rain Radar	MWR HATPRO RPG
Disdrometer	Disdrometer
Wind lidar	AERONET photometer
SKYNET photometer	All sky camera
AERONET photometer	Raman-Mie-Rayleigh Lidar
All sky camera	Cloud Doppler Radar 35 GHz
Raman-Mie-Rayleigh Lidar	CHM15k ceilometer
C-band Doppler weather radar	
CHM15k ceilometer	

Methodology

This study focuses on the parameters extracted from the Level 2A ATLID (A-CTH, A-ICE, A-ALD) and MSI (M-AOT) products (**Table 2**). The number of overpasses from 28 July 2024 to 28 February 2025 is 51 for both Lampedusa and Rome.

The comparison between EC and ground-based parameters is done by averaging satellite data in various temporal intervals centred at the time of the minimum distance EC-ground site, while ground-based measurements are temporally averaged in different intervals according to the examined parameter. The reported results are limited to the comparison on only single intervals for the ground-based and the EC data.

***Table 2**. EC Level 2A products, availability and parameters investigated.*

EC instrument	L2A product name	Percent availability Rome	Percent availability Lampedusa	List of examined variables	Baseline
ATLID	A-ALD	76%	80%	AOD@ 355 nm	AC/AD*
	A-CTH	76%	80%	Cloud top height	AC/AD*
	A-ICE	76%	86%	Ice water content, ice effective radius	AC/AD*
MSI	M-AOT	24% **	22%**	AOD@675 nm, AOD@870 nm	AB

*AD baseline for overpasses since 17 February 2025
**MSI data available since mid January 2025

Cloud Top Height (A-CTH) - Lampedusa

The cloud top height (CTH) from ATLID is selected based on the following criteria:

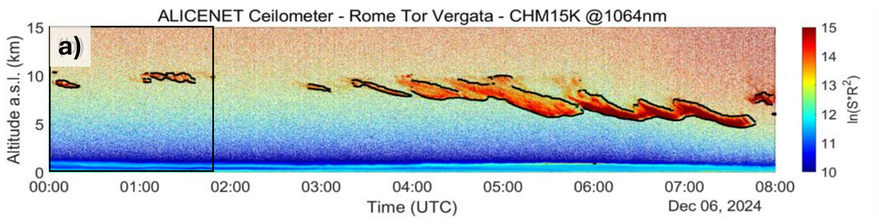
- data quality status 0 (i.e., the data are of good quality) and 1 (i.e., the data are valid, but the level of confidence is lower than the default value 5);
- level of consistency 3 (cloud is present either in A-CTH and A-TC);
- CTH difference between A-CTH and A-TC ≤200 m.

The results of the comparison are presented in **Table 3** for the days with simultaneous EC and surface data. The ATLID CTH values are generally higher than those derived from the ground radar, as expected especially for the high cloud top occurring in the examined cases corresponding to distances to mid-swath below 20 km.

***Table 3**. Comparison of ATLID CTH and derived from the ground-based ACTRIS cloud remote sensing measurements. The mean with one standard deviation and the number of data are shown. The mean EC-ACTRIS difference is also calculated.*

		ACTRIS 10 min			EC ATLID 4 sec			
Date	Distance to mid-swath (km)	Mean	St. Dev.	N	Mean	St. Dev.	N	Difference
17/08/2024 00:54	63.5	6502.2	114.3	10	6078.4	174.6	8	-423.8
22/09/2024 13:30	1.3	10820.5	746.7	10	13926.1	113.5	20	3105.6
17/10/2024 13:30	2.8	6698.6	21.8	10	7298.1	314.9	13	599.5
11/11/2024 13:30	2.4	7400.2	669.9	10	8630.2	1	2	1230
27/11/2024 00:46	83.2	1323.3		1	3004.3	49.5	22	1681
13/12/2024 00:48	13.0	6145.7	795.5	9	7716.9	51.5	12	1571.2
15/12/2024 13:25	73.7	9875.8	41.7	10	7732.2	141.7	14	-2143.6
31/12/2024 13:28	10.9	2876.1	1588.4	5	4414.8	61.3	9	1538.7
07/01/2025 00:48	15.6	8257.6	110.2	10	9634.1	49	10	1376.5
16/01/2025 13:32	89.8	8204.6	36.2	10	7603.8	116.8	17	-600.8
10/02/2025 00:44	91.7	1746.5	340.1	7	2674.1	67.9	14	927.6
19/02/2025 13:28	5.4	8821.9	22	2	11507.4	138	18	2685.5
28/02/2025 13:24	76.2	9582.7	74.1	10	10821.7	130.5	26	1239

Cloud Top Height (A-CTH) - Rome



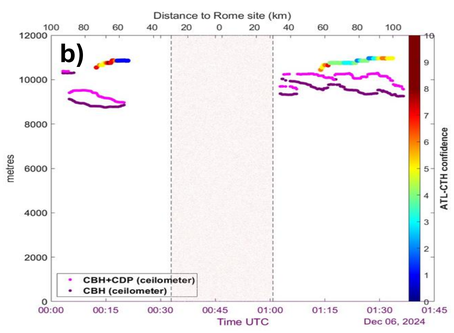


***Figure 3.** Selected case for Dec 6, 2024:*
***a)** ALICENET ceilometer signal over Rome–Tor Vergata from midnight to 8.00 UTC, with relevant determination of the cloud base height (CBH) and of the cloud top height (CTH) as black dots. Note that CTH is obtained as the sum of CBH, and the cloud depth (CDP), i.e. CTH = CBH+CDP. The black box indicates the time window of the satellite overpass (see plot b).*
***b)** Comparison of the ATLID CTH (A-CTH, in colour, referring to product confidence), with the relevant CTH from ceilometer data (light magenta). Ceilometer CBH is in dark magenta.*

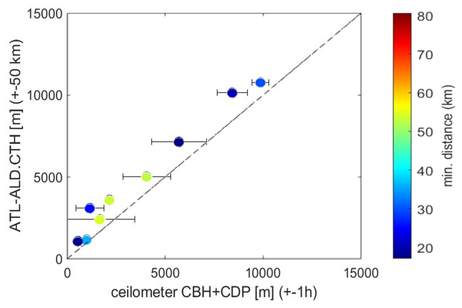


***Figure 4.** A-CTH comparisons with relevant CTH obtained from ceilometer data over the Rome-Tor Vergata site for the overpasses covering the whole period addressed, excluding those with minimum distance to the Rome site greater than 90 km. Cases where low clouds completely extinguished the laser beam, preventing the ceilometer from detecting anything beyond the base of the cloud and making it unable to estimate its thickness, were not considered. Minimum distance between satellite track and site location is given in color.*

The 7 January 2025 case

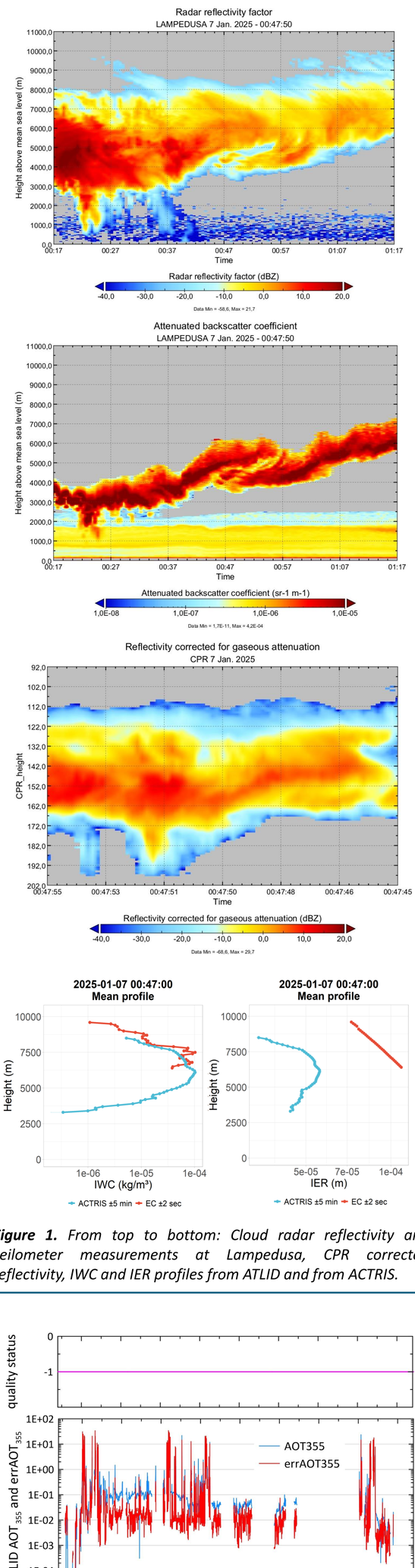


***Figure 1.** From top to bottom: Cloud radar reflectivity and ceilometer measurements at Lampedusa, CPR corrected reflectivity, IWC and IER profiles from ATLID and from ACTRIS.*

***Figure 2**. EC AOT_{355} and $errAOT_{355}$ (bottom) and quality status (top) in the EC segment of 31 December 2024 orbit 3370 D.*

Ice water content and effective radius profiles (A-ICE)

The ice water content (IWC) and the ice effective radius (IER) profiles from ATLID are analysed considering the 0 and 1 quality status indices.

The cloud remote sensing instruments at Lampedusa allow to derive the IWC and IER through the ACTRIS retrieval. As the ACTRIS profiles are provided at a larger vertical resolution than the ATLID ones, they are averaged within ±50 m of reference altitudes at 100 m intervals.

Table 4 reports the statistics summarized for the total vertical profile.

Both IWC and IER show that EC tends to overestimate the ACTRIS data, with overestimation increasing with higher parameter values.

Results for distances ≤20 km show lower correlations, possibly due to local atmospheric factors affecting measurements. For distances >20 km, the correlation improves, indicating better alignment as local variability decreases.

***Table 4**. Comparison between $IWC_{ATLID,2s}$ - $IWC_{LAMP,5min}$ for the 12 overpasses; n indicates the number of altitudes. The lack of indicators implies that for that time interval there are no IWC measurements from ATLID or Lampedusa.*

		IWC (kg/m³) ACTRIS 10 min EC 4 sec					IER (m) ACTRIS 10 min EC 4 sec					
Date	Distance to mid-swath (km)	Bias	St. Dev.	RMSE	Corr	Corr Pearson	Bias	St. Dev.	RMSE	Corr	Corr Pearson	N
17/08/2024 00:54	63.5	4.46E-06	1.91E-06	4.82E-06	0.709	0.719	9.49E-05	5.90E-06	9.51E-05	-0.842	-0.857	10
20/09/2024 00:53	60.2	-2.40E-08	7.91E-06	7.69E-06	0.518	0.603	4.75E-05	3.89E-06	4.77E-05	0.825	0.807	19
22/09/2024 13:30	1.3	1.14E-05	2.30E-05	2.55E-05	-0.692	-0.493	4.98E-05	1.43E-05	5.18E-05	0.901	0.912	50
08/10/2024 13:33	73.0	4.57E-05	3.94E-05	5.97E-05	-0.448	-0.619	5.61E-05	9.56E-06	5.69E-05	0.925	0.919	20
11/11/2024 13:29	2.4	6.19E-06		6.19E-06			5.24E-05		5.24E-05			1
13/12/2024 00:48	13.0	-4.68E-08		4.68E-08			7.32E-05		7.32E-05			1
15/12/2024 13:25	73.8	3.44E-05	1.47E-05	3.72E-05	0.782	0.886	5.25E-05	1.06E-06	5.26E-05	0.964	0.970	10
07/01/2025 00:47	15.6	1.00E-05	2.43E-05	2.58E-05	0.510	0.607	4.86E-05	2.44E-06	4.87E-05	0.999	0.953	22
16/01/2025 13:32	89.8	2.53E-05	2.55E-05	3.54E-05	-0.291	-0.484	5.22E-05	6.68E-06	5.26E-05	-0.700	-0.737	16
23/01/2025 00:51	67.4	3.23E-05	1.55E-05	3.55E-05	0.433	0.384	6.34E-05	4.37E-06	6.36E-05	0.609	0.623	14
25/01/2025 13:28	8.0	-7.56E-06	6.78E-06	9.87E-06	-0.238	-0.196	3.18E-05	3.30E-06	3.20E-05	-0.095	0.286	8
28/02/2025 13:24	76.2	2.38E-05	1.15E-05	2.63E-05	0.521	0.545	4.19E-05	1.45E-06	4.19E-05	0.938	0.965	14

Aerosol optical thickness at 670 nm and 865 nm (M-AOT)

The AOT at 670 nm and at 875 nm (only over the ocean) have been compared with AERONET measurements at Lampedusa averaged over ±1 hour around the time of the EC minimum distance.

EC data with quality status 0 (i.e., good/nominal quality) are available only for one overpass. The EC data are averaged over two pixel intervals, 25x25 (distance ~7 km) and 51x51 (distance ~15 km) centred at the closest pixel (**Table 5**). This day is characterized by very low aerosol loading and the comparison shows an overestimation by the MSI.

***Table 5**. AOT comparison from MSI and from AERONET measurements at Lampedusa.*

		AOT 670 nm			AOT 875 nm		
Date	Min. distance (km)	AERONET	MSI 25x25	MSI 51x51	AERONET	MSI 25x25	MSI 51x51
19/02/2025 13:28 UT	0.11	0.09±0.03 (5)	0.18±0.01 (4)	0.13±0.03 (299)	0.08±0.03 (5)	0.14±0.01 (4)	0.11±0.03 (299)

Aerosol optical thickness at 355 nm (A-ALD)

The EC AOT at 355 nm (AOT_{355}) can be compared with AERONET measurements. The AERONET AOT at 340 nm and 380 nm is used to derive the AOT_{355} using the Ångström formula.

An issue with AOT_{355} and its error (err AOT_{355}) has been found. AOT_{355} and $errAOT_{355}$ can reach unreasonably large values and the quality status value is constantly equal to -1 (i.e., a cloud is detected in the profile), see **Figure 2**.

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