Monitoring Aerosol, Cloud and Solar Radiation in Cyprus: The CARO NF and ESEL contribution to EarthCARE Cal/VAL

Georgia Charalampous[1,2], Aspasia Pallikaridou[1,2], George Kotsias[1], Kyriaki Papachristopoulou[3], Stelios Kazadzis[3] and Rodanthi-Elisavet Mamouri[1,2]

1. ERATOSTHENES Centre of Excellence, Limassol, Cyprus
2. Cyprus University of Technology, Faculty of Engineering and Technology, Limassol, Cyprus
3. Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center, 7260 Davos, Switzerland

Solar Winter School 2026

Contact: aspasia.pallikaridou@eratosthenes.org.cy

Introduction

High quality solar radiation measurements are essential for various research subjects such as, climate research, atmospheric investigations, calibration/validation of satellite data, and renewable energy applications. In Cyprus, a Mediterranean region rich in solar resources, high-quality irradiance data are crucial for evaluating solar energy potential and enhancing forecasting models. The ERATOSTHENES Centre of Excellence (ECoE) under the EXCELSIOR project has funded the Solar Radiation and Energy Laboratory (ESEL) and the Cyprus Atmospheric Remote Sensing Observatory (CARO) National Facility (NF), in Limassol (LIM) [34.67° N, 33.04°E] operated by the ERATOSTHENES Centre of Excellence. ESEL's research focuses on solar radiation monitoring, radiative transfer modeling, and atmospheric studies., while CARO NF supports aerosol-cloud interaction research through a suite of advanced ground-based instruments, including PollyXT lidar, Doppler lidar, and cloud radar systems. The ERATOSTHENES CoE through the ATmospheric And solaR Research and Innovation (**ATARRI**) project, aims to exploit the full potential of CARO NF and Solar Radiation Station to achieve scientific excellence and foster application development in the atmospheric research enchasing the Earth observation R&I and modelling capacities of the center. The objective of this study is to describe the infrastructure, its significance, and some examples of applications of its operations on EarthCARE (Earth Cloud, Aerosol, and Radiation Explorer) cloud and aerosol data validation.

The ERATOSTHENES CARO NF and the Solar Radiation Station

Pyranometers (EKO MS-80SH): GHI and DHI
Pyrheliometer (EKO MS-57): DNI
Pyrgeometer (EKO MS-21): longwave radiation
SUV-E radiometer (K & Z): erythemal UV radiation
Campbell Scientific CR1000X datalogger
Sun-tracker (EKO STR-22G)

Spectrophotometer (DMc150 Bentham): spectral irradiance (280-600 nm)
Sky Imager (ASI-16 All): cloud cover
CUT-TEPAK AERONET Sun-photometer (CE318): Long-term aerosol observation such aerosol optical thickness measurements

CARO-LIM ACTRIS National Facility
Aerosol Remote Sensing Observational Platform
Cloud Remote Sensing Observational Platform

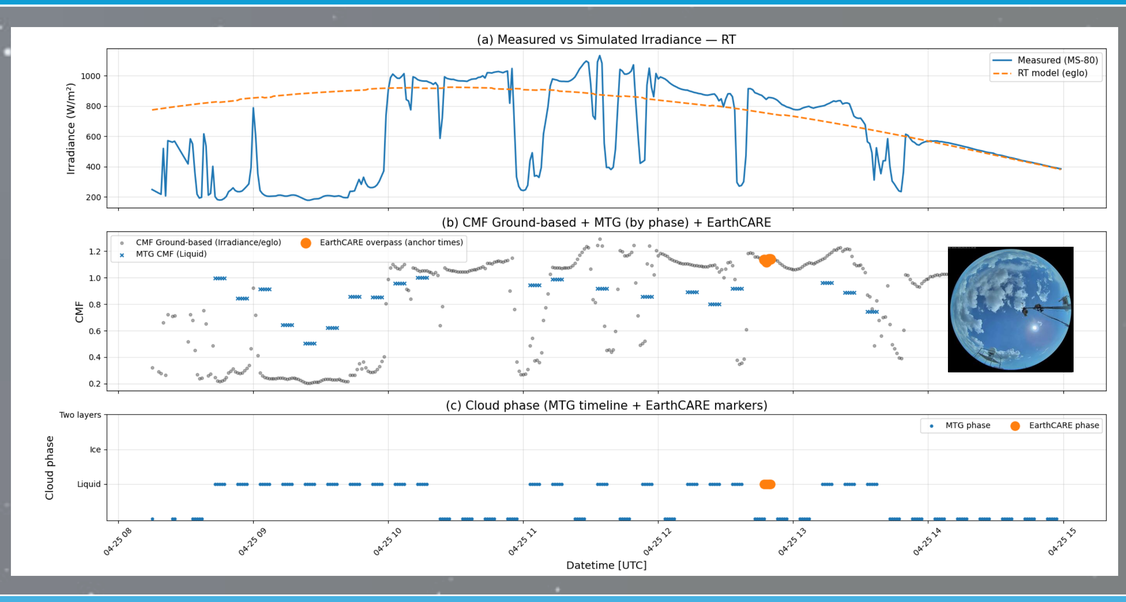
The Limassol solar station is located in an urban environment surrounded by tiled rooftops and mid-rise buildings, while keeping an unobstructed view of the sky. The site operates radiometric instruments compliant with BSRN standards.

Validating Satellite Cloud and Aerosol Retrievals with ESEL

Assessment of Satellite Cloud Optical Thickness Retrievals and characterization of cloud variability using Pyranometer network data

Introduction and Motivation: Cloud Optical Thickness (COT) is a key parameter for quantifying the radiative impact of clouds and their influence on surface solar irradiance. Satellite products (e.g., MTG OCA and EarthCARE MSI M-COP) offer global COT retrievals, but their validation under various atmospheric and surface conditions remains limited. Ground-based pyranometer measurements provide independent observations of shortwave irradiance, allowing for indirect assessment of satellite-derived COT.

Methodology: Ground-based global irradiance measurements at 1-minute resolution were combined with clear-sky radiative transfer simulations to derive a reference Cloud Modification Factor (CMF) at the site. MTG-FCI OCA cloud optical thickness (COT) and cloud phase were extracted from the nearest satellite pixel, converted from log10(COT) to linear values, and used to compute phase-dependent CMF using empirical parameterizations. Temporal collocation was performed using nearest-neighbor matching while preserving the native high-frequency ground measurements to quantify spatio-temporal mismatch. EarthCARE MSI overpasses were used as independent anchor cases, providing cloud phase and cloud type information to interpret discrepancies.



Evaluating MSI and ATLID aerosol products of Aerosol Optical Thickness (AOT) through comparisons with ground-based sunphotometer observations.

Introduction and Motivation: Assessing spaceborne aerosol retrievals is critical for atmospheric research, air-quality monitoring, and climate modeling. EarthCARE's instruments, including ATLID and MSI, improve global estimates of aerosols, clouds, and radiative fluxes for weather and climate models. While its aerosol optical thickness (AOT) retrievals cover land and sea, validation is restricted. Ground-based AERONET sunphotometers, such as ESEL's in Limassol, Cyprus, provide multi-wavelength data to evaluate EarthCARE's AOT.

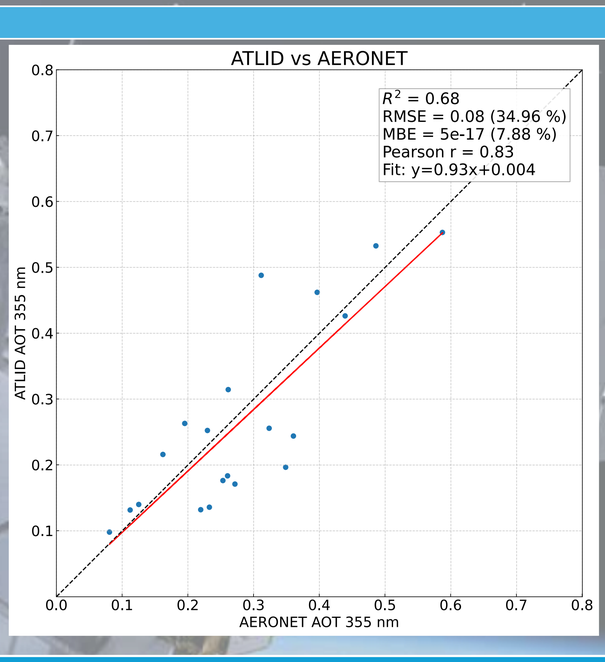
Methodology: Various strategies were tested to optimize agreement between AOT from MSI (M-AOT), ATLID (A-EBD integrated), and AERONET.

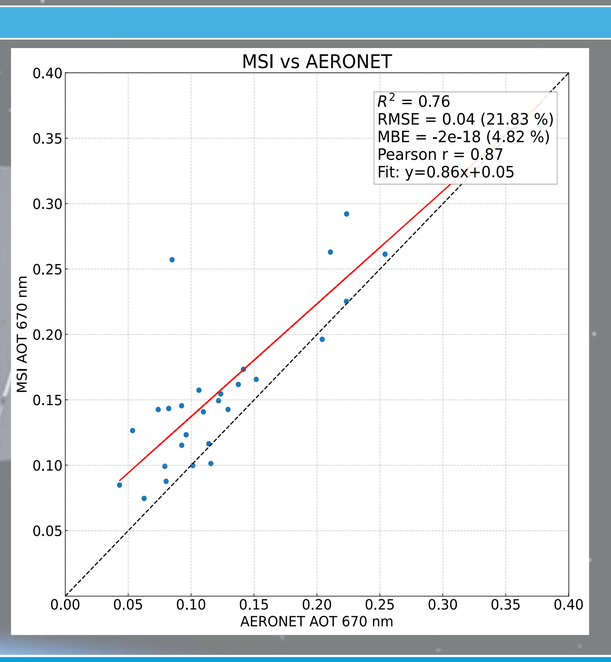
- ***Satellite data:*** closest-point, along-track averaging (±25/50 km), and distance thresholds (<50/60 km).
- ***Ground data:*** instantaneous measurements and temporal averages (±30 min / ±1 h).

Spectral adjustments using Ångström exponent (AERONET):

- AERONET 340 nm → 355 nm for ATLID comparison
- AERONET 675 nm → 670 nm for MSI comparison

Overpass period: 1 Jul 2024 - 30 Sep 2025





Conclusion

Validating MTG-FCI and EarthCARE cloud products using ground-based broadband irradiance measurements, demonstrated good agreement between satellite-derived cloud properties and surface radiative effects. The strongest consistency was observed when MTG cloud phase and optical thickness were combined with ground-based cloud modification factors, while EarthCARE overpass conditions aligned well with moderate surface attenuation. These results highlight the capability of satellite cloud observations to represent radiative impacts at the surface. The analysis will be extended to additional overpasses and stations, enabling a more comprehensive assessment of satellite cloud performance and improving the robustness of cloud-radiative validation approaches. Validating EarthCARE AOT data over Limassol, Cyprus, using CUT-TEPAK AERONET sunphotometer showed good agreement between ATLID and MSI, demonstrating the strong performance and significance of satellite observations. The best agreement was achieved with MSI using spatial averaging within 60 km of the station, ATLID using the closest-point extinction measurement integrated up to 10 km, and AERONET using a 30-minute averaging window. The dataset will be expanded to include additional overpasses providing further insight into the validation and help build a more comprehensive picture of EarthCARE's performance over Cyprus. Moreover, the statistical method followed for Limassol will be applied to more ACTRIS stations, enhancing the accuracy of MSI and ATLID aerosol retrievals. In summary, the CARO National Facility and the solar radiation station in Limassol provide essential long-term reference measurements that strengthen satellite validation and support atmospheric and climate research in the Eastern Mediterranean.

ECoE: Eratosthenes Centre of Excellence, ESEL: Excelsior Solar radiation and Energy Laboratory, EarthCARE: Earth Cloud, Aerosol, and Radiation Explorer, BSRN: Baseline Surface Radiation Network, AERONET: AErosol RObotic NETwork, GHI: Globar Horizontal Irradiance, DHI: Diffuse Horizontal Irradiance, DNI: Direct Normal Irradiance, COT: Cloud Optical Thickness, MTG: Meteosat Third Generation, OCA Optimal Cloud Analysis, COP: Cloud Optical Properties, CMF: Cloud Modification Factor, FCI: Flexible Combined Imager, AOT: Aerosol Optical Thickness, EBD: Extinction, Backscatter and Depolarisation

The CARO NF and solar radiation station supported by the EXCELSIOR' project funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 857510 and from the Government of the Republic of Cyprus and the Cyprus University of Technology. The authors acknowledge the ATARRI Horizon Europe Widespread Twinning Project. ATARRI receives funding from the European Union's Horizon Europe Twinning Call (HORIZON-WIDERA-2023-ACCESS-02) under the grant agreement No 101160258.