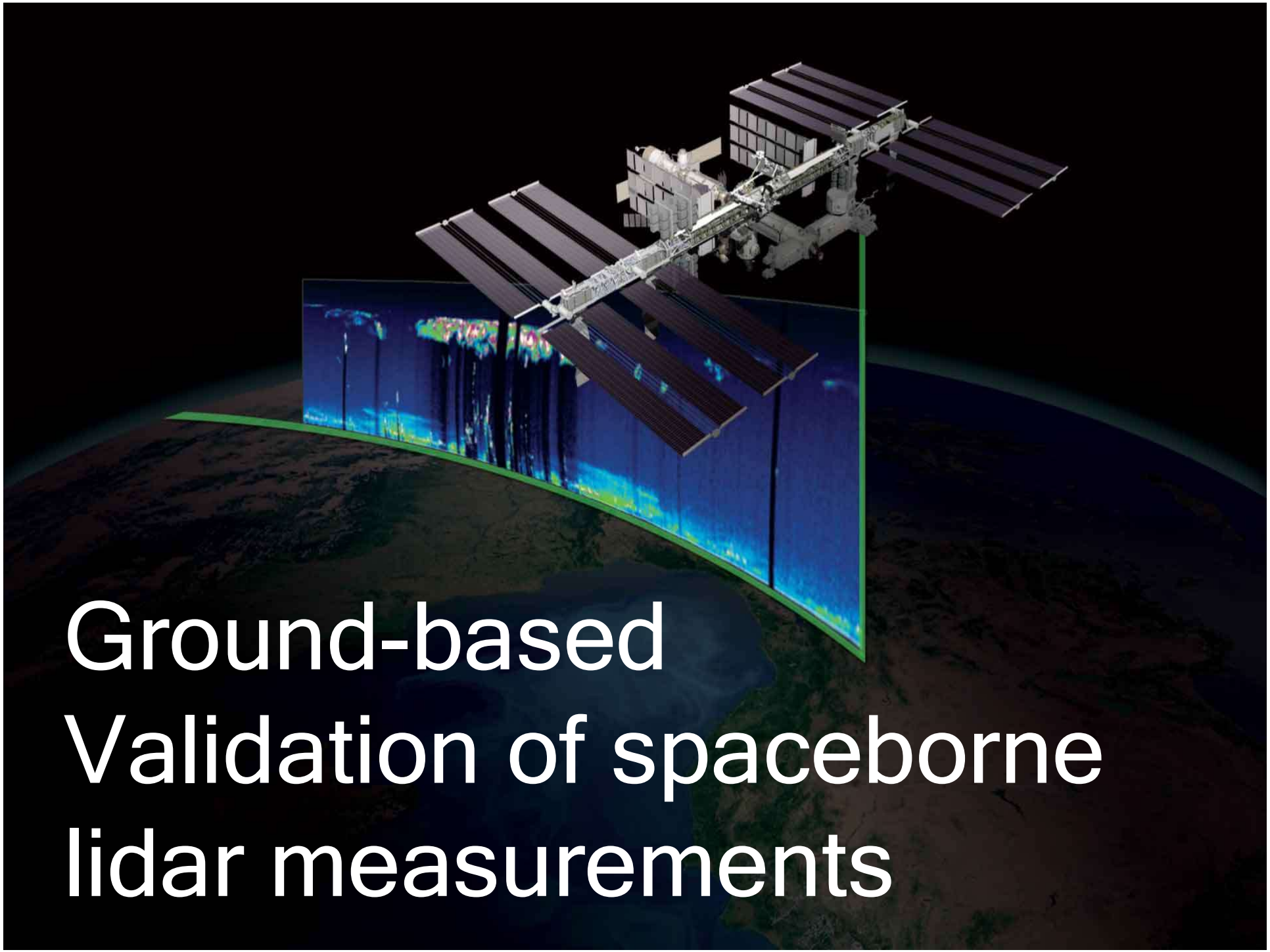
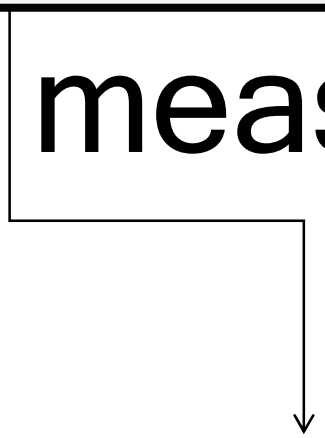

Ground-based
Validation of spaceborne
lidar measurements

Ground-based Validation of spaceborne lidar measurements



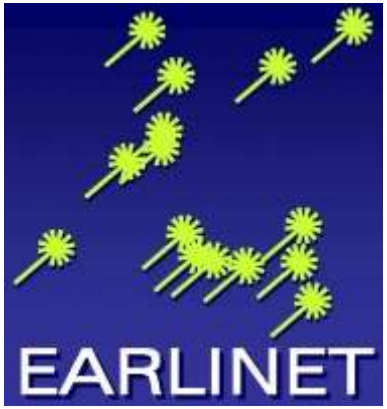
"to make something officially acceptable or approved, to prove that something is correct"

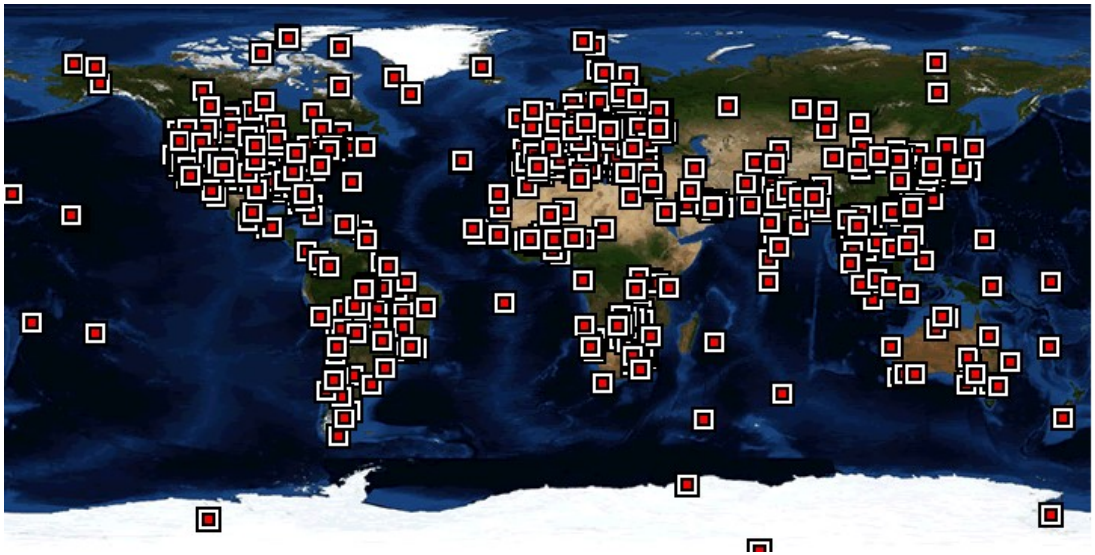
Ground-based

Validation of spaceborne lidar measurements

Ground Truth

Calibration and Validation (Cal/Val) of satellite data and retrieval algorithms





AERONET stations of post field calibrated, automatically cloud cleared and manually inspected.

- Composed from: ground-based network (NASA and PHOTONS) and collaborators.
- Dataset: long-term and dataset globally distributed of aerosol optical, microphysical and radiative properties.
- Purpose: characterization, validation of satellite retrievals, and synergism with other databases.

EARLINET stations

- Composed from: ground-based LIDARS.
- Dataset: long-term and statistically significant - continental scale - of the horizontal, vertical, and temporal distribution of aerosols
- Purpose: information on the large-scale three-dimensional aerosol distribution in the atmosphere

Ground-based

Validation of spaceborne lidar measurements

Ground-based Validation of spaceborne lidar measurements

CALIPSO **CATS** **EarthCARE**

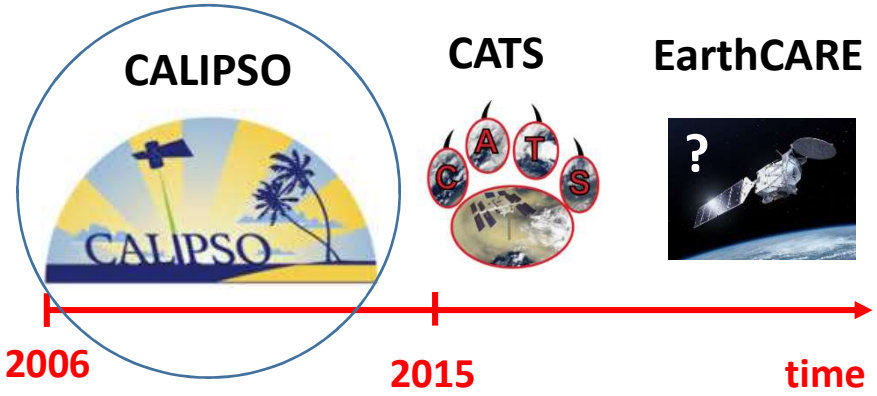
Pre-TECT

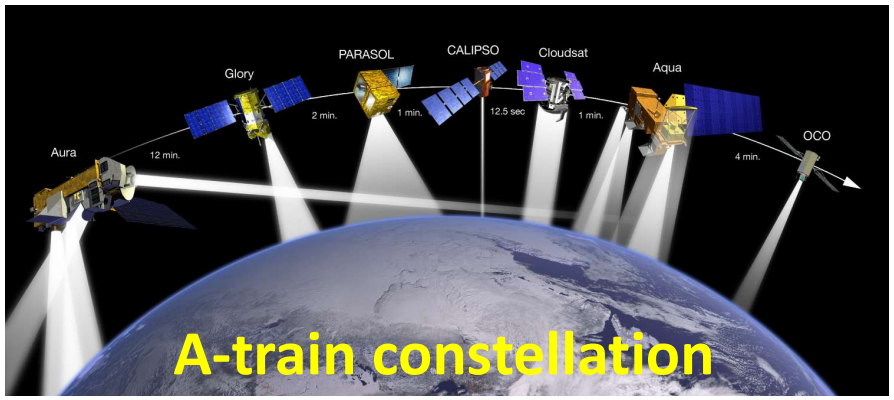
?

time

2006 **2015**

Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)





- Joint NASA/CNES satellite
- Three instruments:
  - **Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP):** Two wavelength polarization-sensitive Lidar that provides high-resolution vertical profiles of aerosols and clouds
  - **Wide Field Camera (WFC):** Fixed, nadir-viewing imager with a single spectral channel covering the 620-670 nm region
  - **Imaging Infrared Radiometer (IIR):** Nadir-viewing, non-scanning imager

Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)

CALIPSO: lidar measurements of aerosol and clouds

Launched: April 28, 2006

Achievements:

- Long term measurements:
more than **10 years** of measurements
- Observations during **day/night** and for all seasons
- Adds the **Vertical Dimension**

Pappalardo, G. et al. EARLINET correlative measurements for CALIPSO: first intercomparison results. J. Geophys. Res. Atmos 115, D00H19, doi: 10.1029/2009JD012147.

Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)

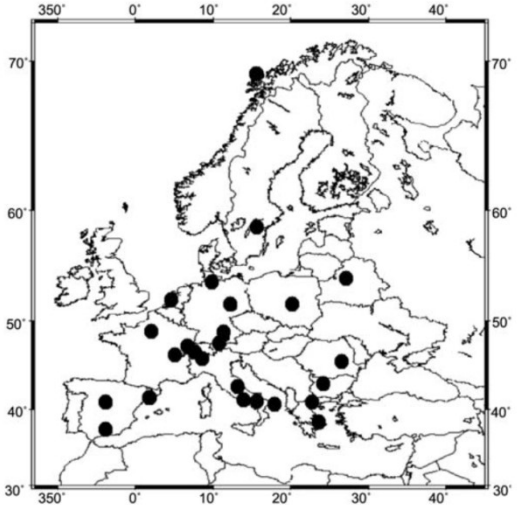


Figure 1: Map of Europe with the distribution of all the EARLINET lidar stations

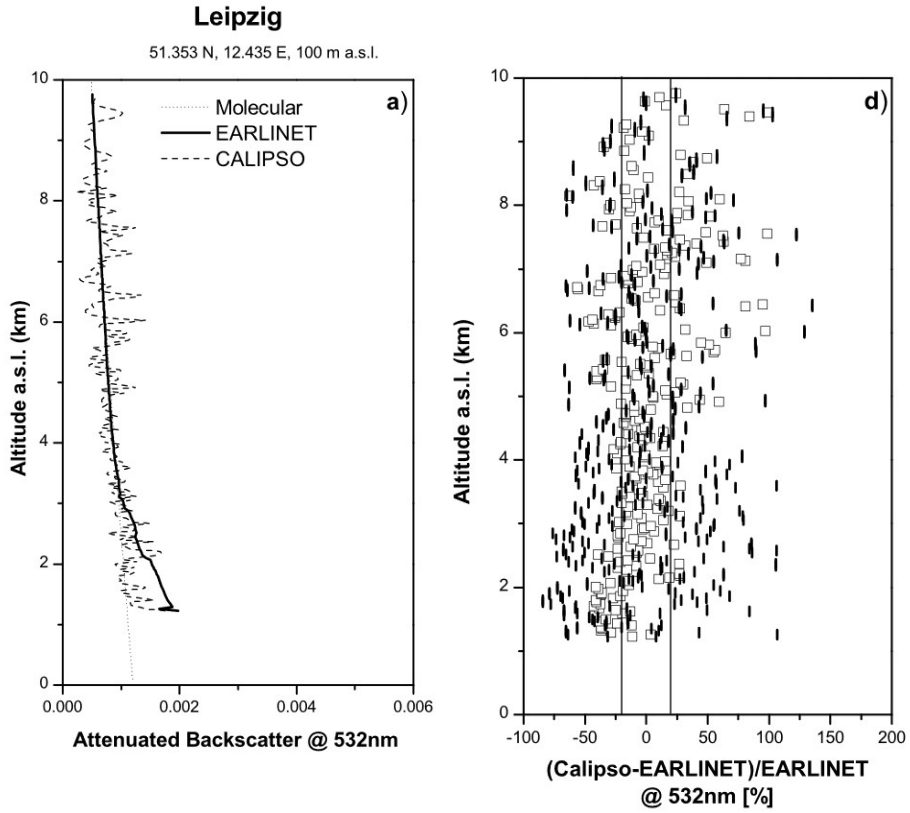


Figure 2: CALIPSO (dashed line) and EARLINET (solid line) mean profiles of attenuated backscatter at 532 nm for the Leipzig Station. Mean percentage difference between CALIPSO and EARLINET attenuated backscatter measured at 532 nm (open squares) as a function of the altitude are also reported.

Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)

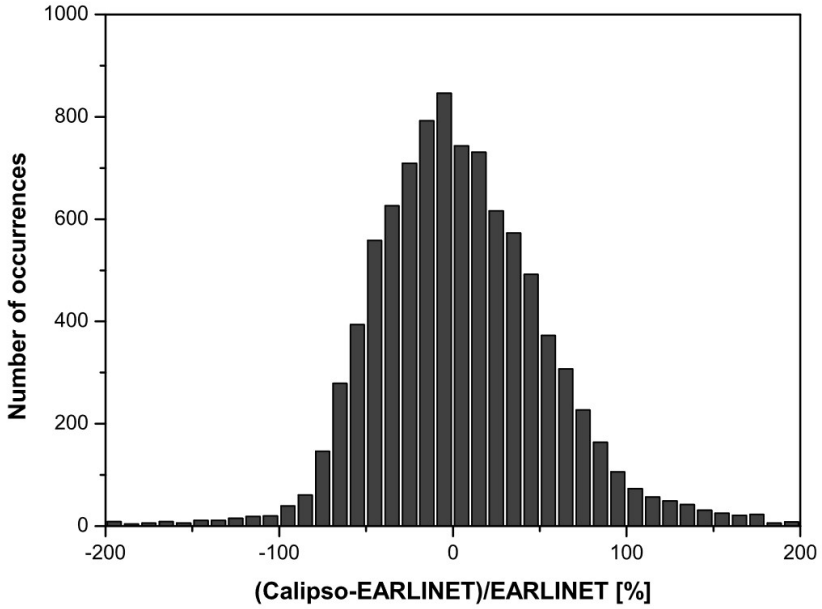
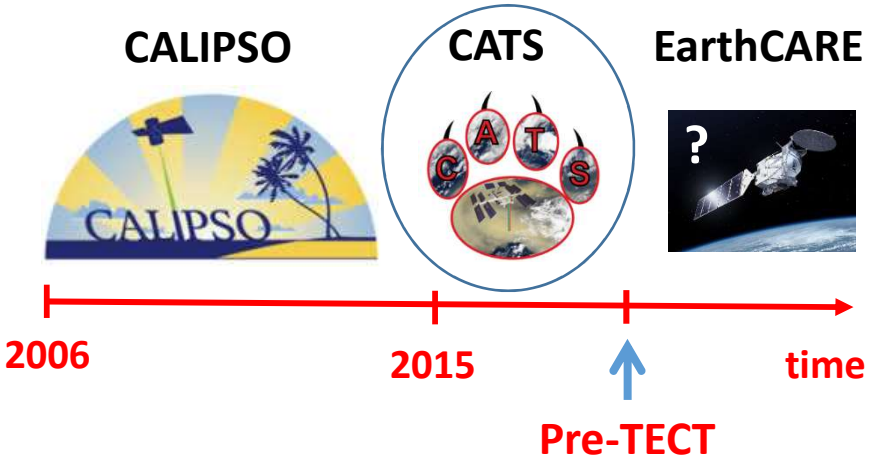


Figure 4: Distribution of the mean relative differences between CALIPSO level 1 and corresponding EARLINET attenuated backscatter measurements.

The relative differences distribution is characterized by:

- **mean difference** = 4.6%
- **median value** = 0.6%
- **standard deviation** = 50%

The Cloud-Aerosol Transport System (CATS)



CATS

- **Low-cost** ISS "cargo" – not a flight mission
- **Lifetime estimation**: 6m – 3y
- 51° **inclination orbit** – 405 km altitude

CATS L2

- 60 m **vertical resolution**
- 5 km **horizontal resolution**
- Backscatter/Depolarization/Extinction **profiles**
- **CALIPSO algorithm applied**

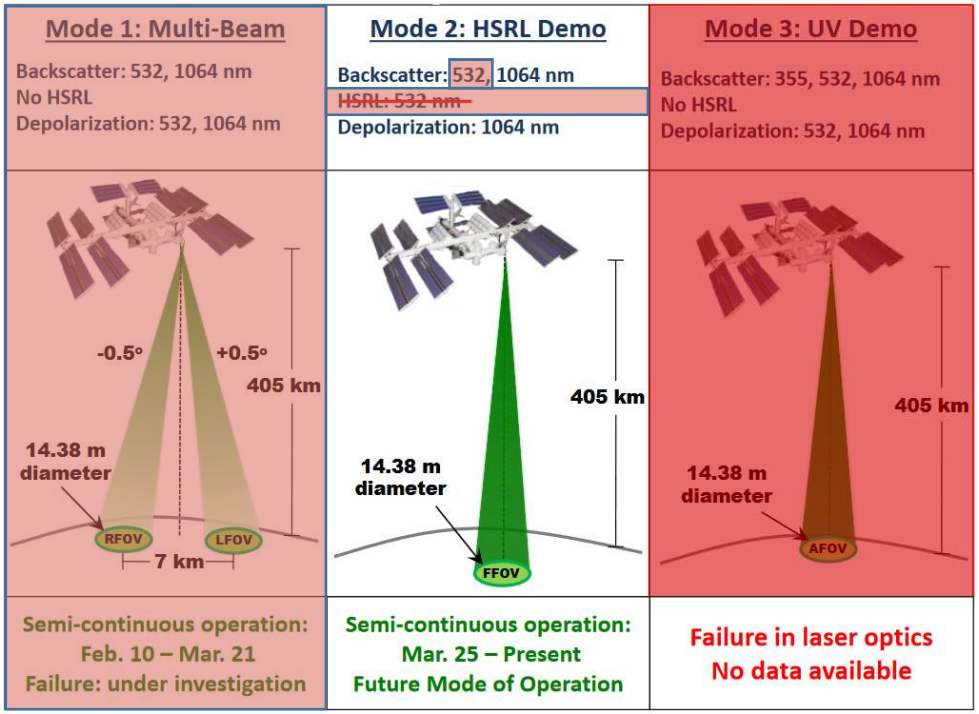


Figure 5. CATS Modes of Operation (source: E. Nowottnick)

European Aerosol Research Lidar Network (EARLINET)

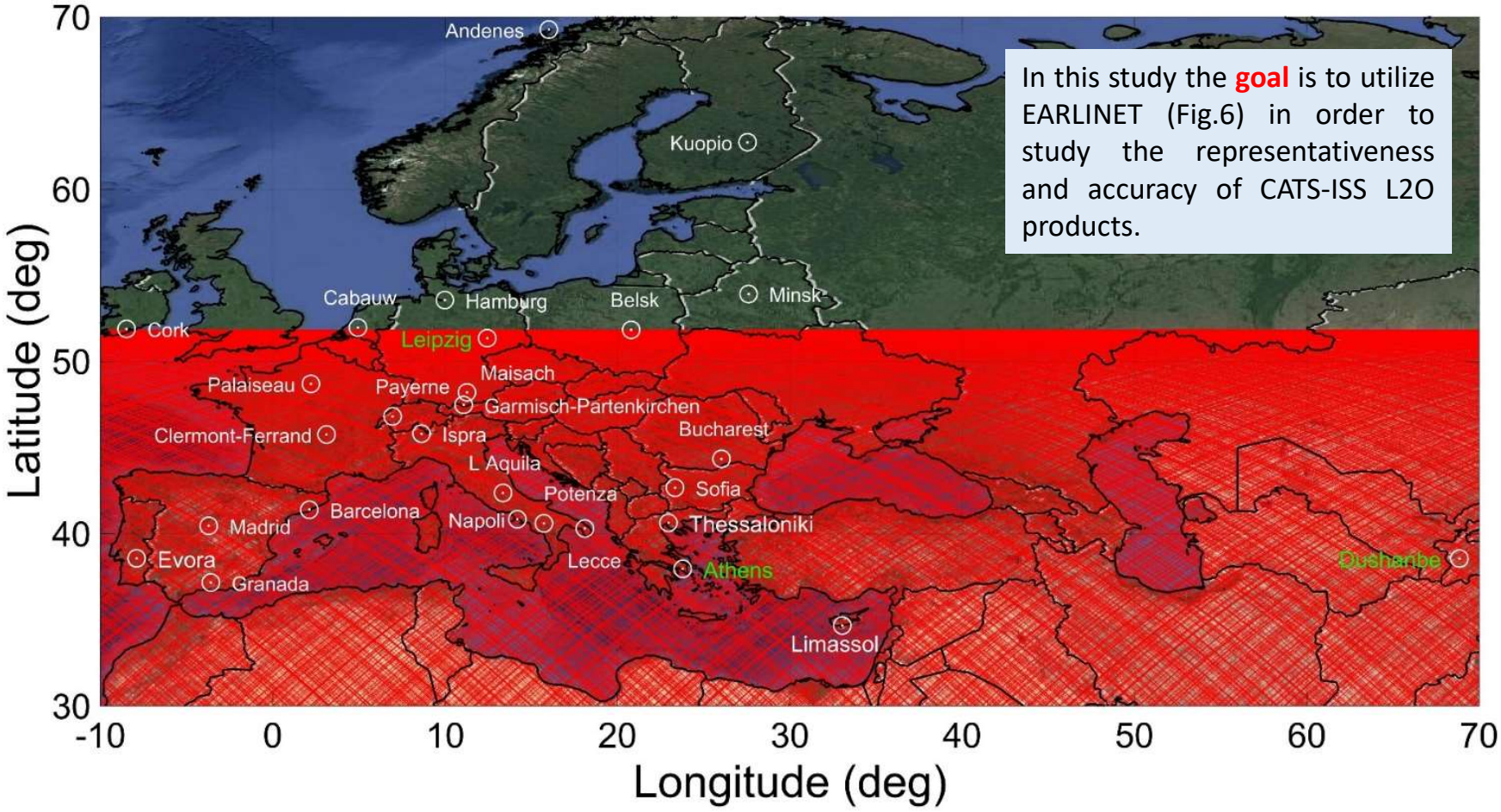
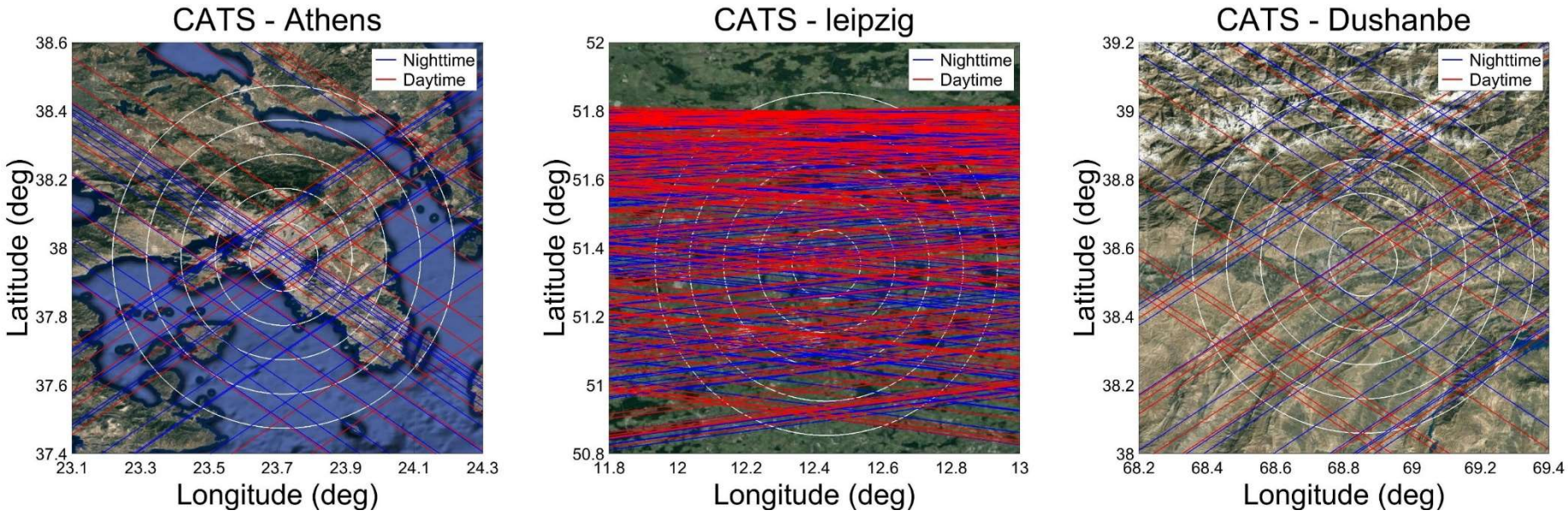


Figure 6. Map of Europe and W. Asia with the distribution of all the EARLINET lidar stations. The CATS orbits between 03/2015 and 09/2016 are shown in red lines, while the stations in green color denote the stations which have been utilized till now (PollyXT-NOA Athens / Leipzig / Dushanbe).

CATS – ISS Athens/Leipzig/Dushanbe overpasses



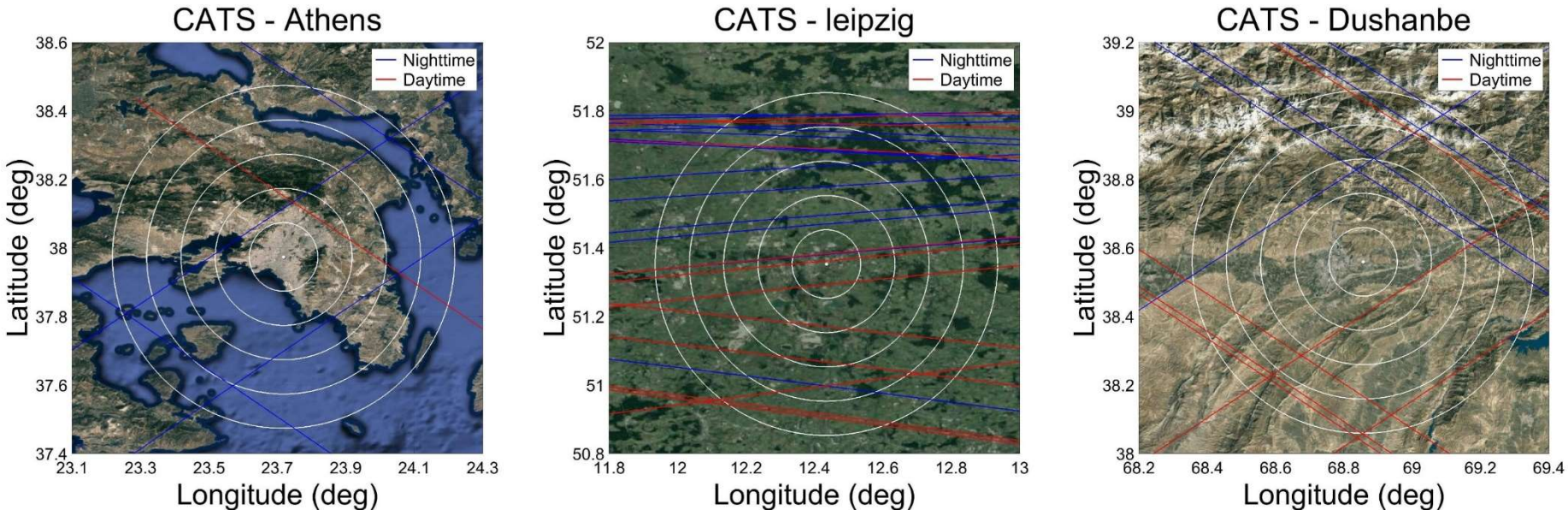
Athens: 44 cases

Leipzig: 357 cases

Dushanbe: 39 cases

Figure 7. CATS-ISS – Athens/Leipzig/Dushanbe overpasses. Daytime (red color) and Nighttime (blue color) orbits are shown. The concentric white circles denote regions of radius 0.1, 0.2, 0.3, 0.4 and 0.5 deg from the center, the ground based LIDAR station position.

CATS – ISS Athens/Leipzig/Dushanbe overpasses (Active LIDAR / Cloud Free Conditions)



Athens: 5 cases

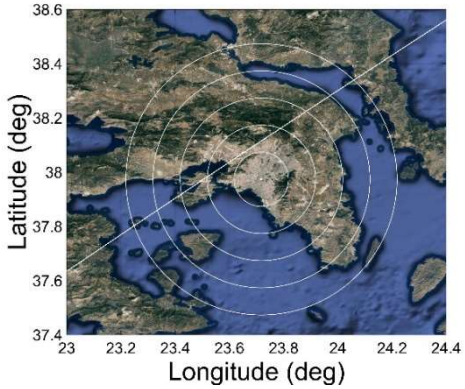
Leipzig: 24 cases

Dushanbe: 11 cases

Figure 7. CATS-ISS – Athens/Leipzig/Dushanbe overpasses. Daytime (red color) and Nighttime (blue color) orbits are shown. The concentric white circles denote regions of radius 0.1, 0.2, 0.3, 0.4 and 0.5 deg from the center, the ground based LIDAR station position.

Study case I

Athens overpass
2016-01-13 Time: 01:16:38UTC



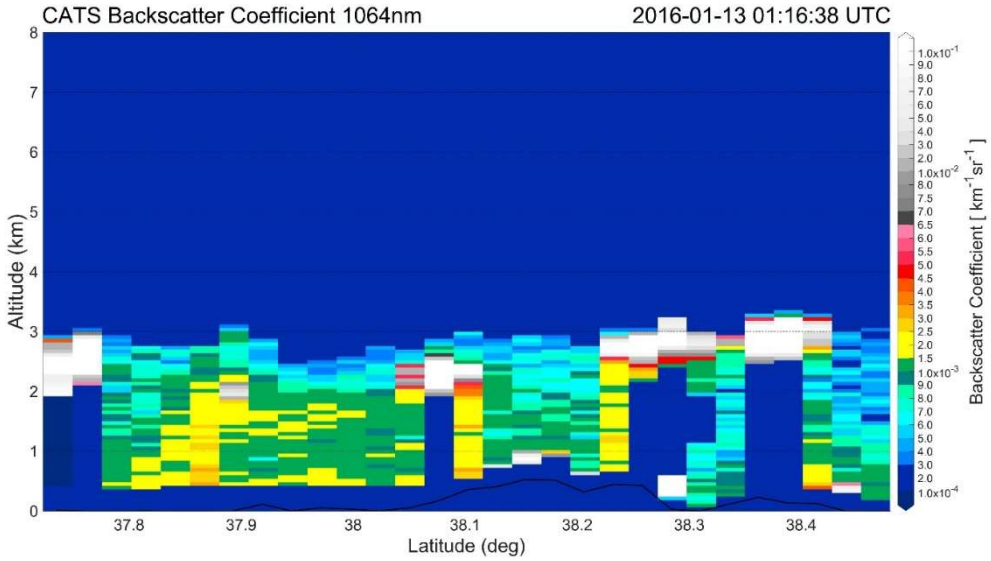


Figure 9a. CATS Particulate Backscatter 1064 Fore FOV

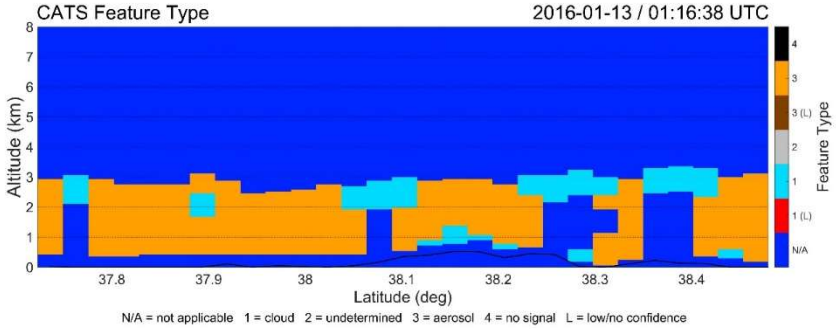


Figure 9b. CATS Feature Type

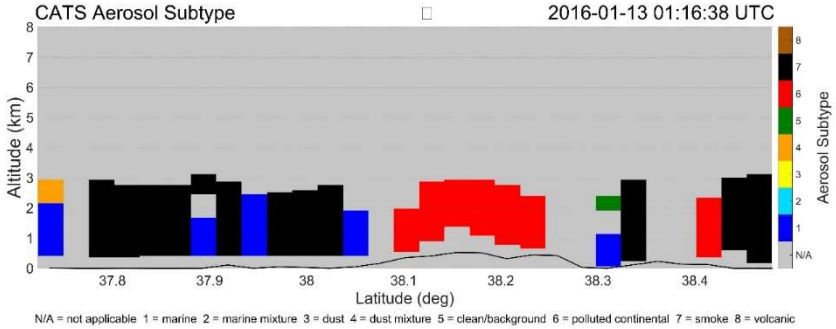
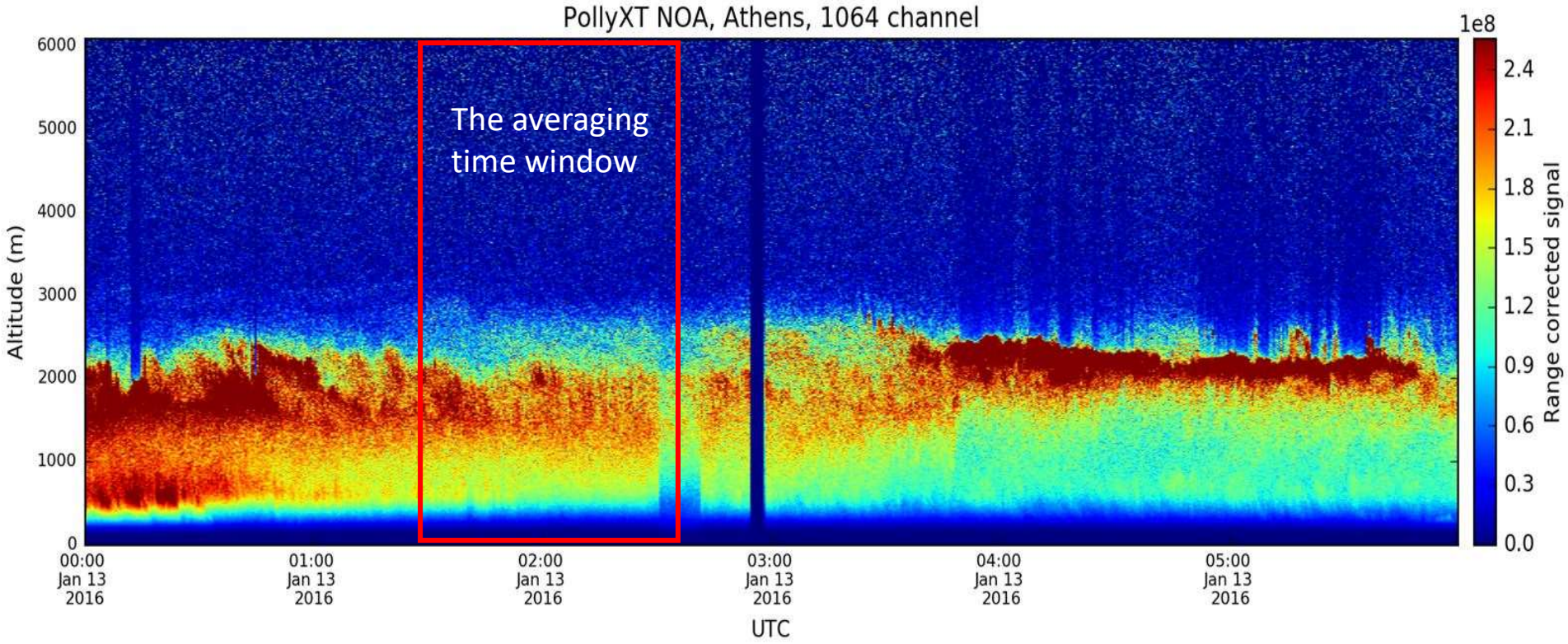


Figure 9c. CATS Aerosol Subtype

The CATS L2O M7.2 V1-05 05kmPro has been used. The case presented here corresponds to the CATS – PollyXT NOA overpass on the 2016-01-13, 01:16:38 UTC. On Figures 9a-c the Particulate Backscatter Coefficient 1064 Fore FOV, Feature Type and Aerosol Subtype of this case are shown.

LIDAR Profile:

- The LIDAR is capable of Raman retrievals. Klett method is used for retrievals during daytime.
- The reference altitude for the aerosol reference backscatter values depends on the atmospheric conditions (cloud-free/aerosol-free, signal-to-noise ratio greater than 3).
- The atmospheric parameters needed for the calculations are simulated by a NOA atmospheric model for Athens' retrievals.
- AERONET provides the Angstrom exponent for the Raman retrievals.



CATS Profile

For each case the mean CATS Backscatter Coefficient profile has been computed.

CAD score equal to -5 has been used for the discrimination of the aerosol layers from the low confidence aerosol layers – possible cloud contaminated.

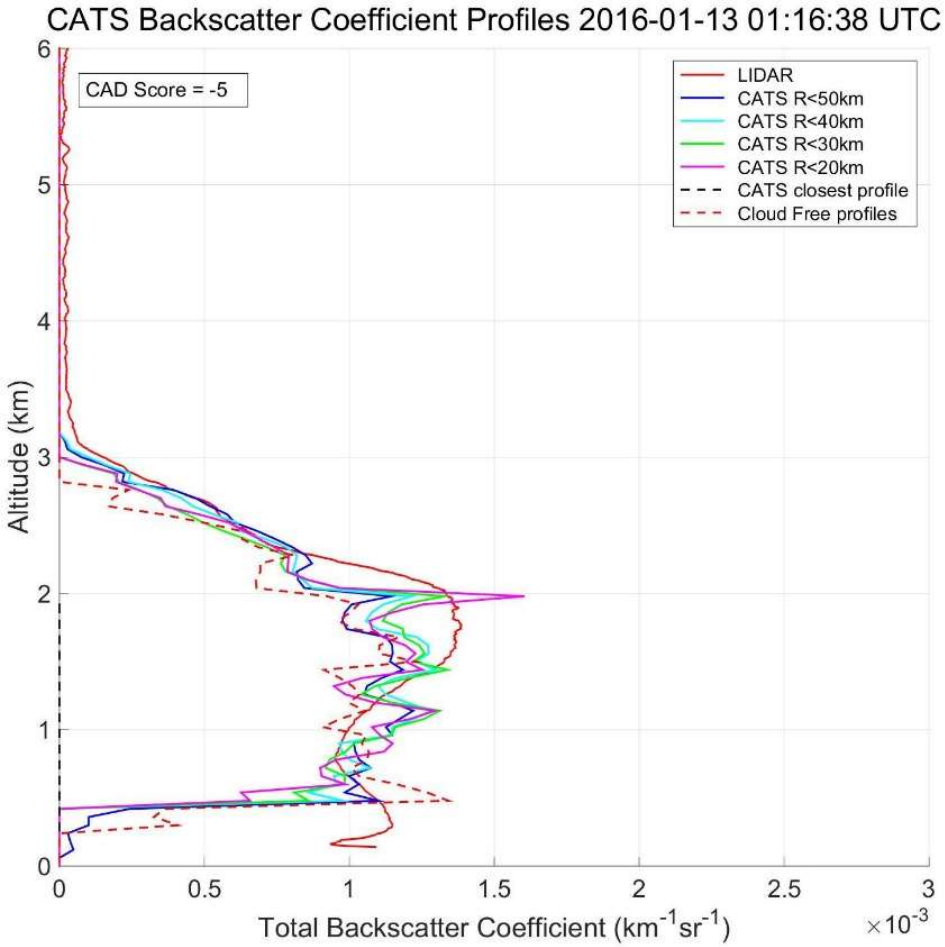


Figure 10. Total Backscatter Coefficient 1064nm profiles

<u>Conclusion I:</u> From the entire nighttime analysis, it is observed that under homogeneous - relatively cloud free - nighttime conditions the Backscatter Coefficient Profile retrieved by CATS is quantitative close to the profile retrieved by ground-based LIDARS.

Study case II

Leipzig overpass 2016-08-24 Time: 11:26:40UTC

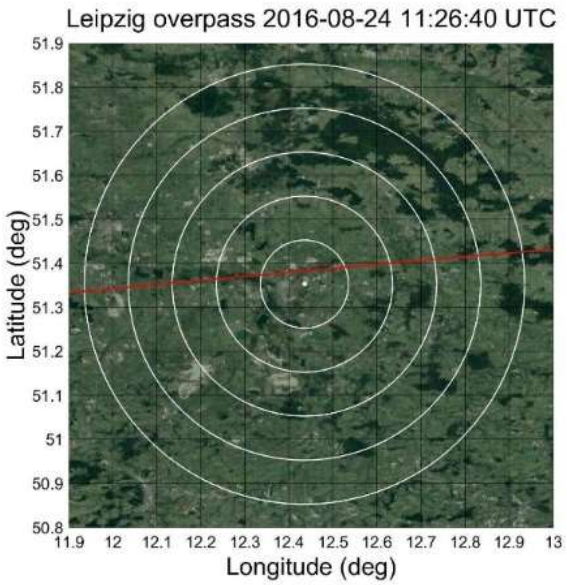


Figure 11a. CATS orbit 2016-08-24 11:26:40 UTC

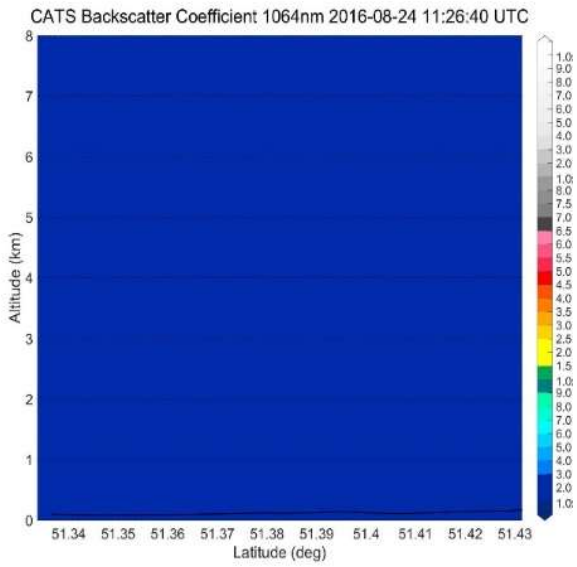


Figure 11b. CATS Particulate Backscatter 1064nm Fore FOV

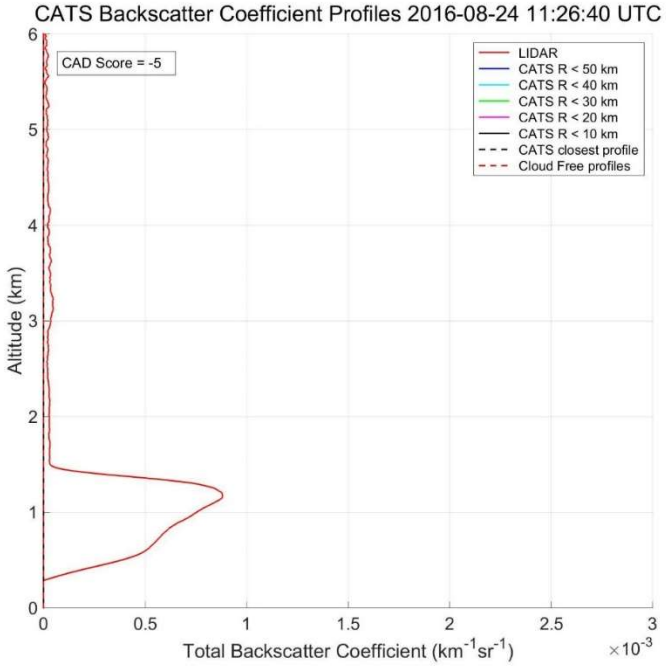
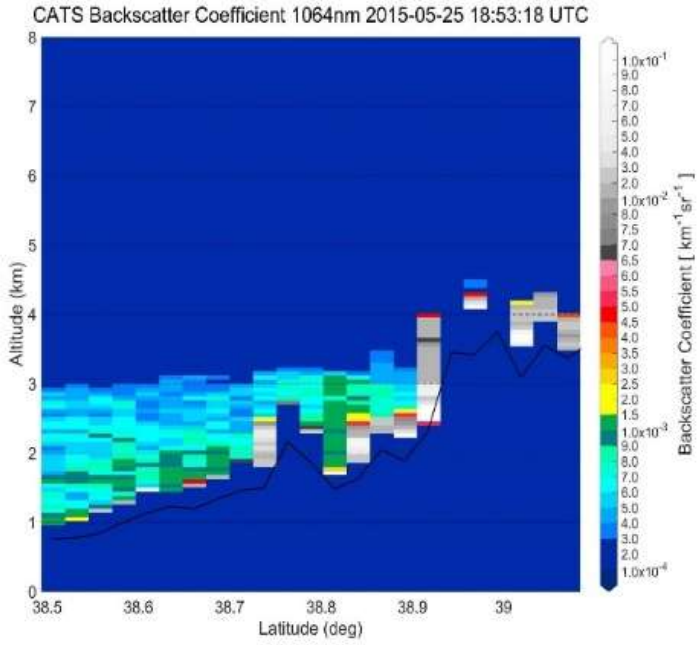


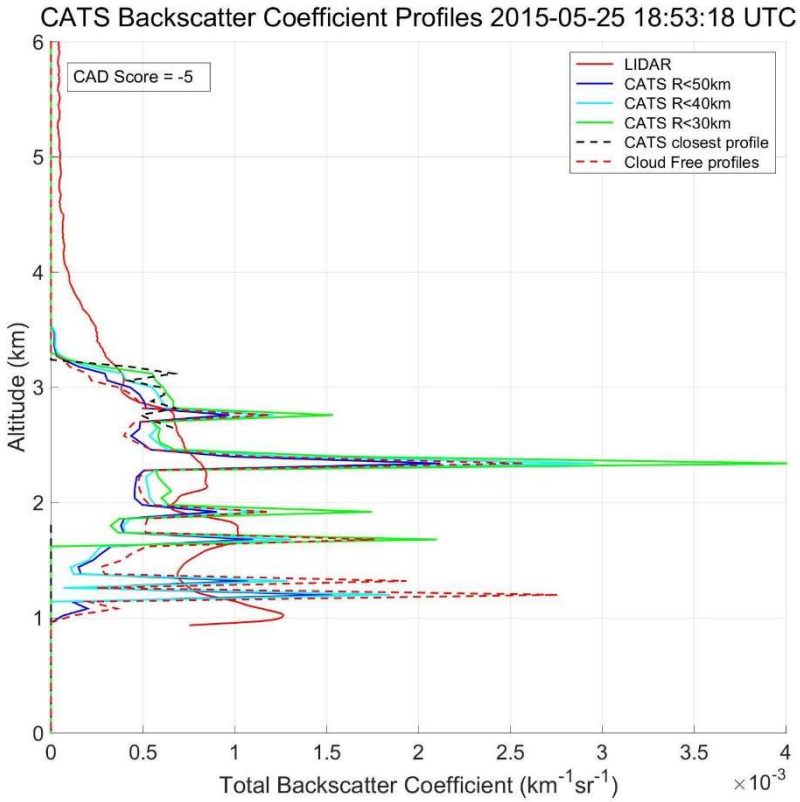
Figure 11c. Total Backscatter Coefficient 1064nm profiles

Conclusion II: **From the entire daytime analysis, it is observed that under daytime conditions CATS seriously underestimated the Backscatter Coefficient Profile conditions of the atmosphere compared to ground-based LIDAR retrievals.**

Study case III

Dushanbe overpass 2015-05-25 Time: 18:53:18 UTC





Conclusion III: **From the entire analysis, it is observed that although the majority of the cloud-aerosol cases can be distinguished by CAD -5, misclassified cases can be observed even when applying strict CAD filters.**

EARLINET – CATS Differences

Distribution of the **absolute** and **relative differences** (Fig 12) between CATS L2 and the corresponding EARLINET backscatter coefficient 1064nm (0-8 km). The calculation has been performed using the forty (40) profiles provided by the stations of Leipzig, Athens and Dushanbe.

The absolute differences distribution is characterized by:

- **mean difference** = 3.2219e-05 $Km^{-1}sr^{-1}$
- **median value** = -3.42e-05 $Km^{-1}sr^{-1}$
- **standard deviation** = 8.07e-04 $Km^{-1}sr^{-1}$
- **min absolute difference** = 2.51e-07 $Km^{-1}sr^{-1}$
- **max absolute difference** = 0.0135 $Km^{-1}sr^{-1}$

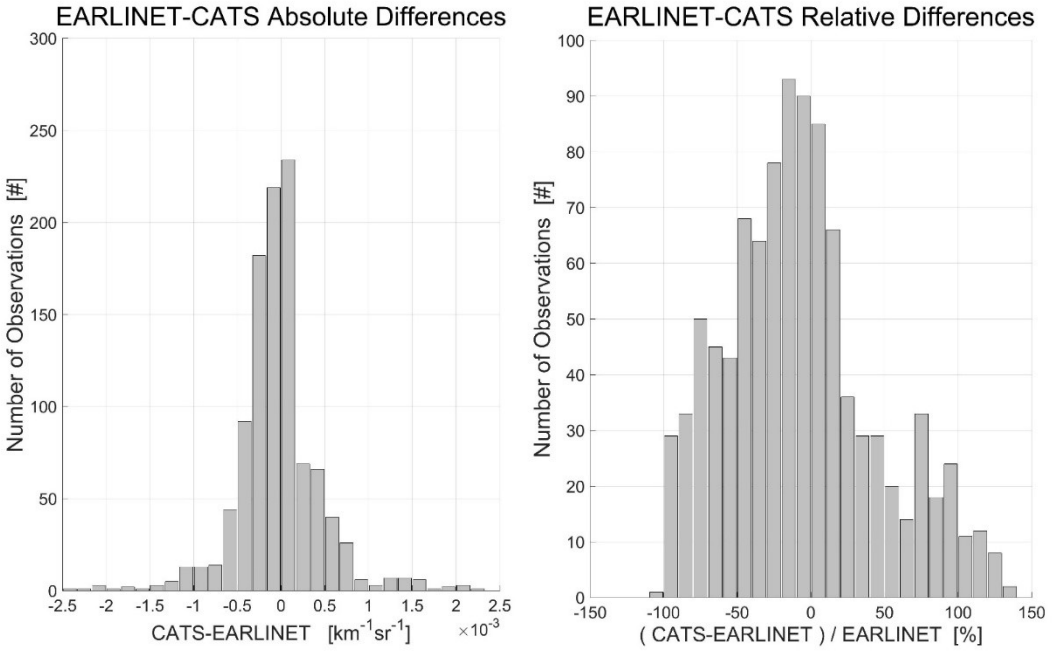


Figure 12. Distributions of the absolute (left) and relative (right) differences between CATS L2 and the corresponding EARLINET backscatter coefficient at 1064nm measurements.

EARLINET – CATS mean Backscatter Profiles 1064nm

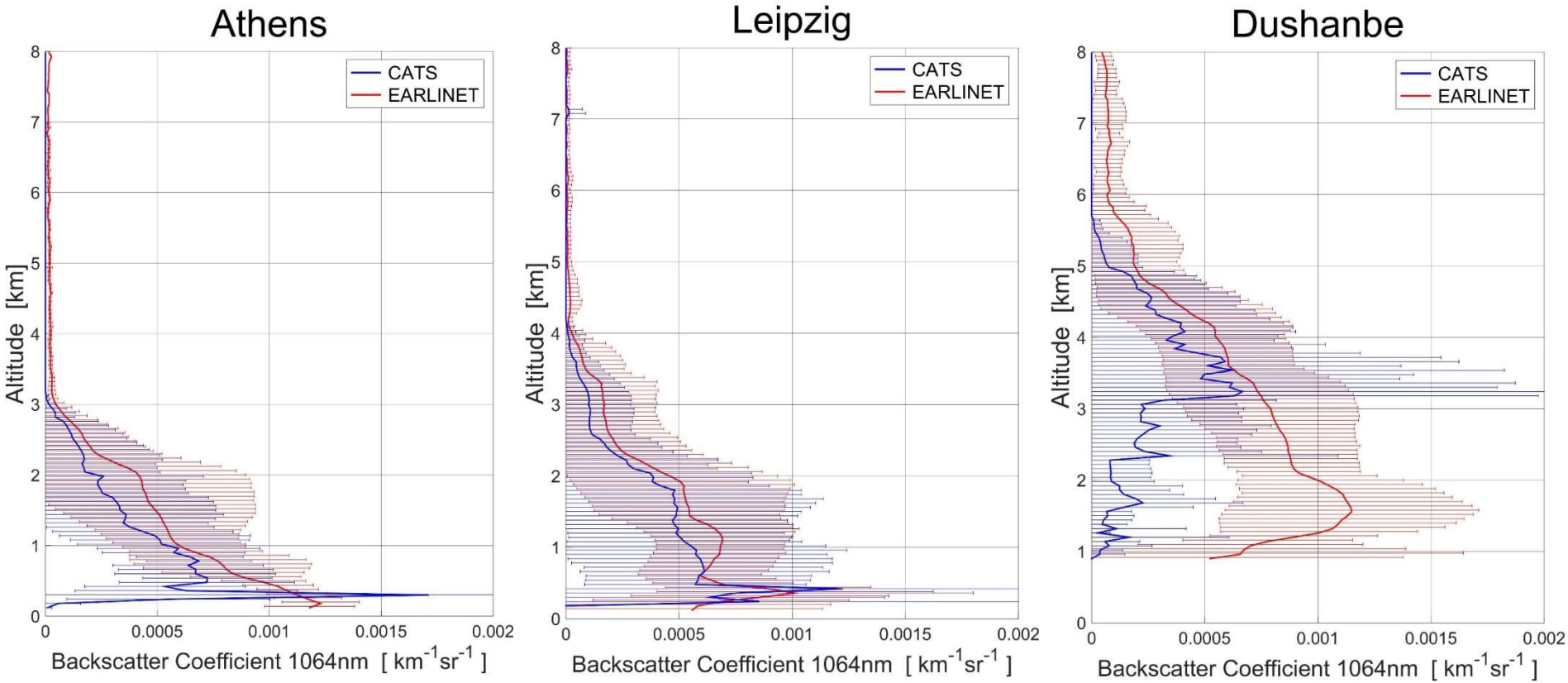


Figure 13. CATS (blue line) and EARLINET (red line) mean profiles of backscatter coefficient at 1064 nm for the (a) Athens, (b) Leipzig, and (c) Dushanbe stations and the corresponding standard deviations, calculated over 5, 24, and 11 available cases respectively.

EARLINET – CATS mean Backscatter Profiles 1064nm

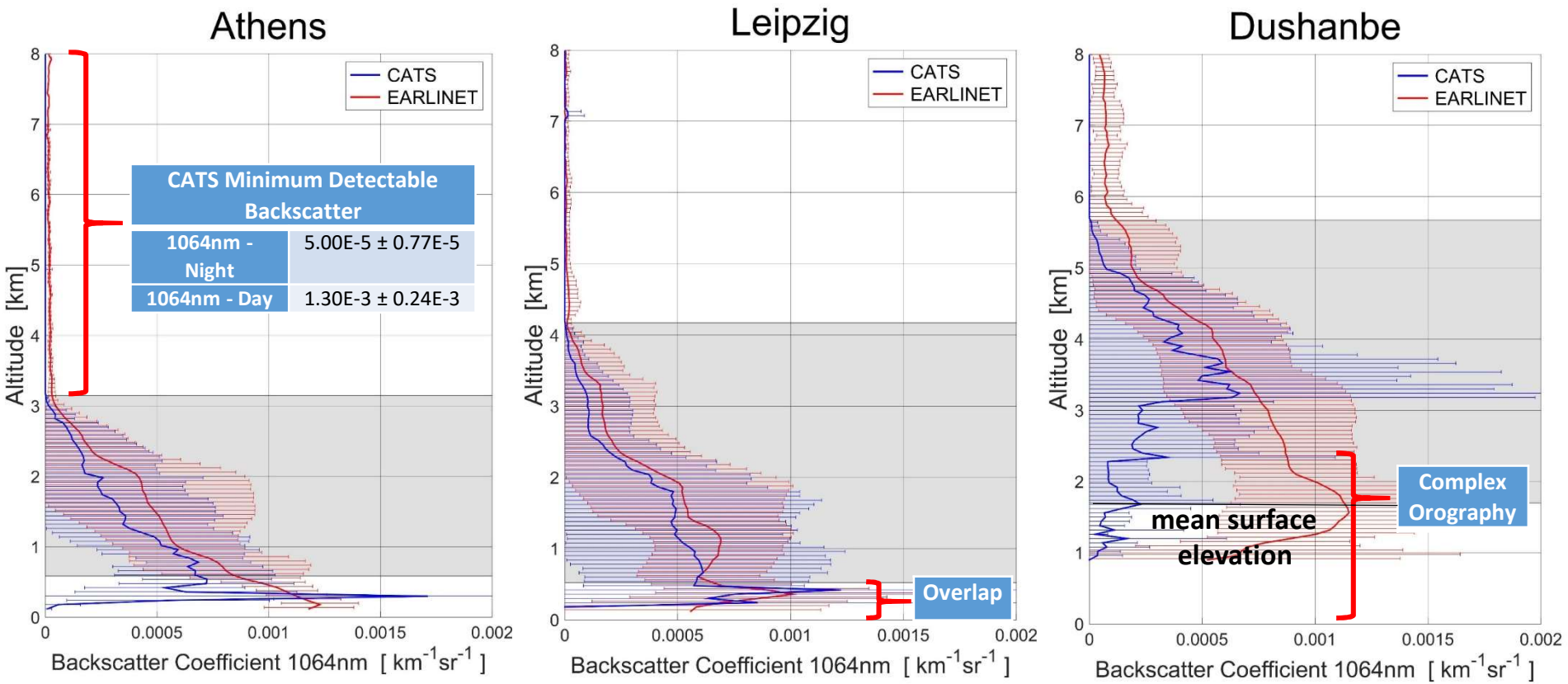


Figure 14. CATS (blue line) and EARLINET (red line) mean profiles of backscatter coefficient at 1064 nm for the (a) Athens, (b) Leipzig, and (c) Dushanbe stations and the corresponding standard deviations, calculated over 5, 24, and 11 available cases respectively.

EARLINET – CATS Backscatter Correlation Coefficient

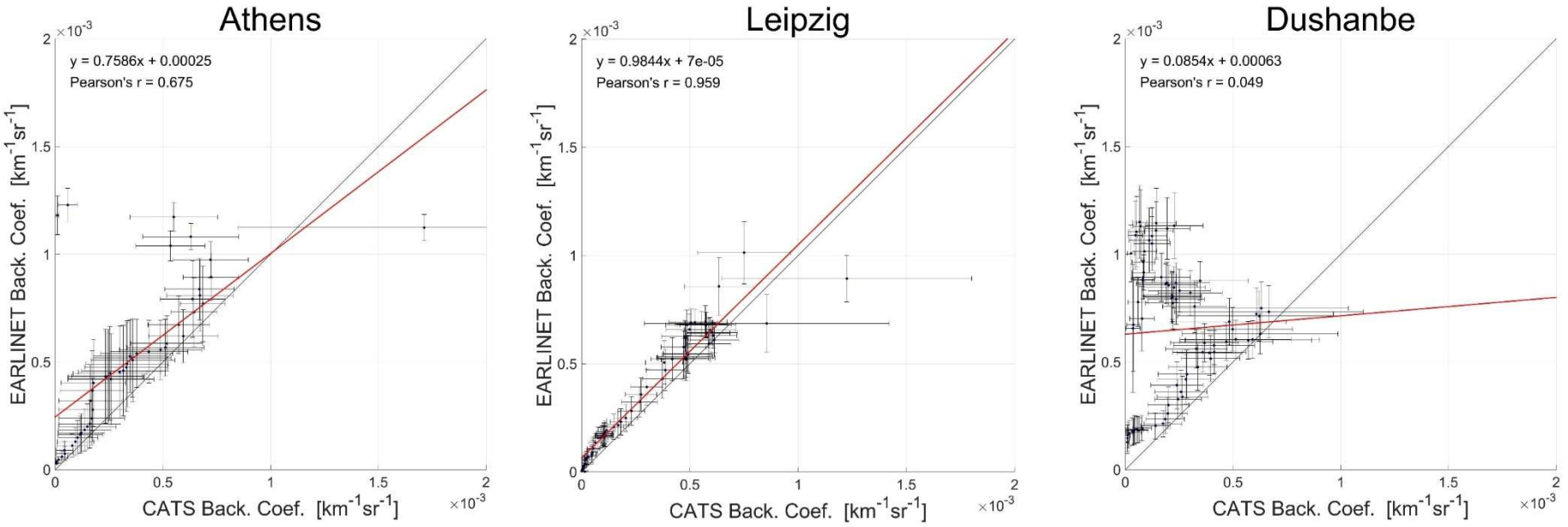


Figure 15. Comparison between CATS L2 and EARLINET mean profiles of backscatter coefficient at 1064 nm calculated for the (a) Athens, (b) Leipzig and (c) Dushanbe stations respectively. The solid red line is the regression line of the CATS-EARLINET observations, the black line is the 1:1 line and the errorbar lines represent the standard error of the mean (SEM). The slope, the intercept of the regression line and the correlation coefficient R are shown for each station.

EARLINET – CATS Backscatter Correlation Coefficient

(taking into consideration: CATS Minimum Detectable Backscatter, Overlap, Orography)

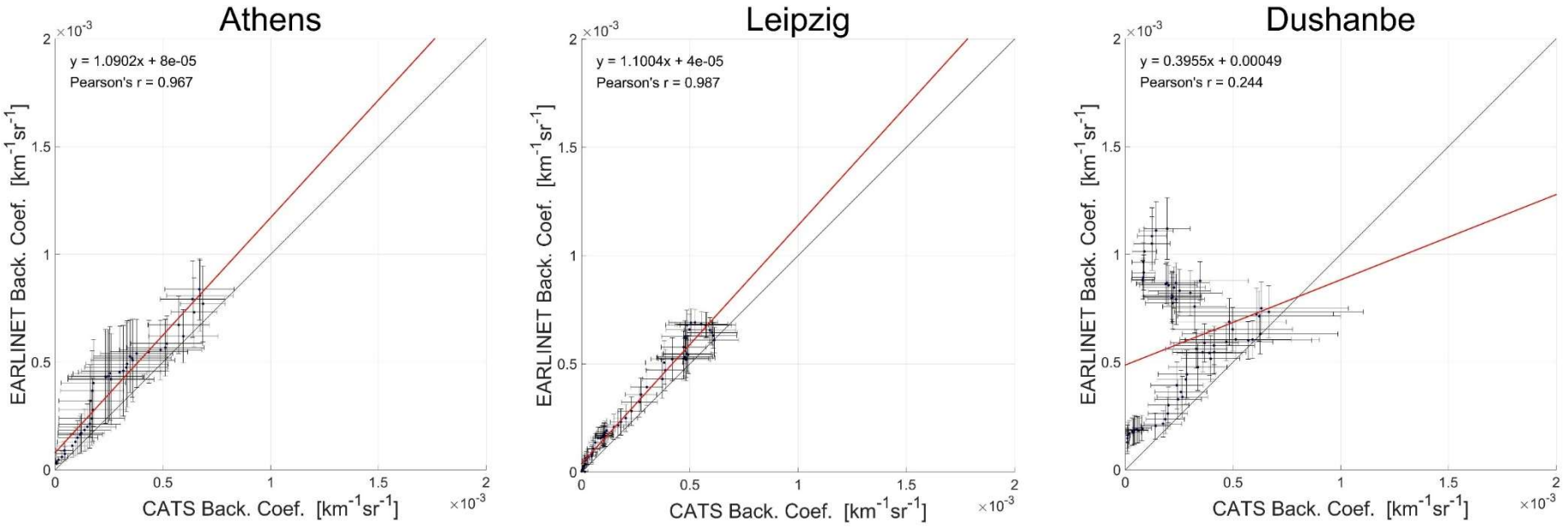
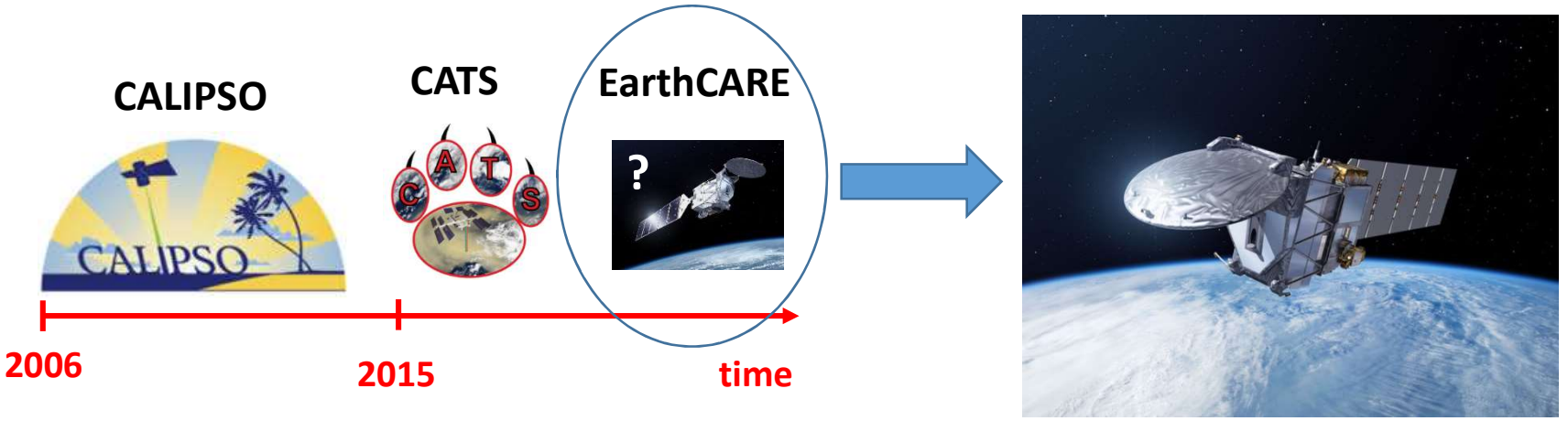
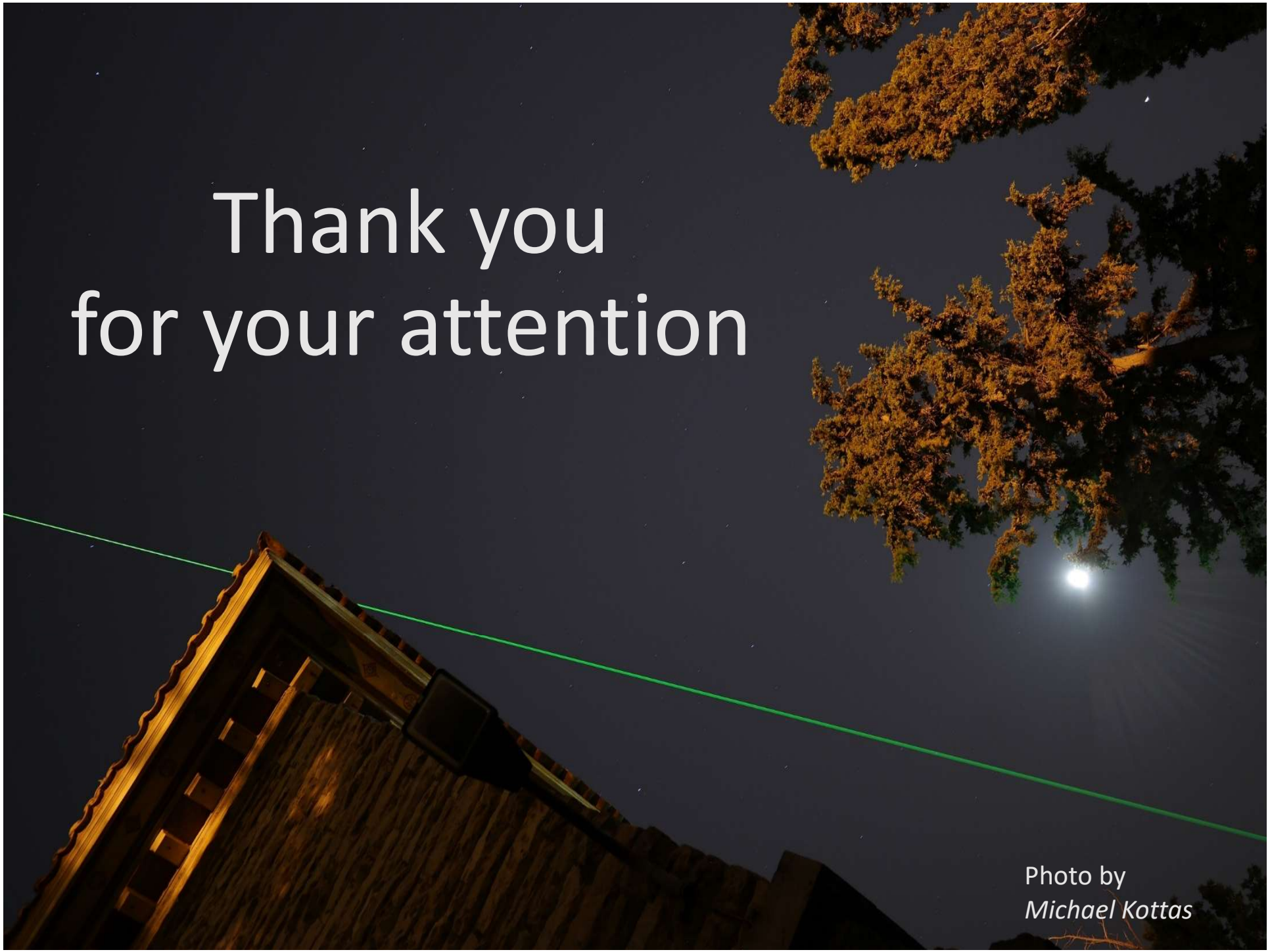


Figure 16. Comparison between CATS L2 and EARLINET mean profiles of backscatter coefficient at 1064 nm calculated for the (a) Athens, (b) Leipzig and (c) Dushanbe stations respectively, taking into consideration the CATS Minimum Detectable Backscatter, the Overlap and the Orography effects. The solid red line is the regression line of the CATS-EARLINET observations, the black line is the 1:1 line and the errorbar lines represent the standard error of the mean (SEM). The slope, the intercept of the regression line and the correlation coefficient R are shown for each station.

The Earth Cloud Aerosol and Radiation Explorer (EarthCARE)



- EarthCARE will provide global profiles of clouds and aerosols along with measurements of solar radiation reflected from the planet and thermal radiation emitted from the planet.
- The satellite carries two large instruments: a lidar to measure vertical profiles of aerosols and thin clouds, and a radar to measure vertical profiles of thick clouds and precipitation.
- The use of these instruments means that 3D cloud and aerosol scenes can be directly related to reflected solar and emitted thermal radiation.


Thank you
for your attention
Photo by
Michael Kottas