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EARLINET VALIDATION OF CATS L2 PRODUCT

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ABSTRACT

The Cloud-Aerosol Transport System (CATS) onboard the International Space Station (ISS), is a lidar system providing vertically resolved aerosol and cloud profiles since February 2015. In this study, the CATS aerosol product is validated against the aerosol profiles provided by the European Aerosol Research Lidar Network (EARLINET). This validation activity is based on collocated CATS-EARLINET measurements and the comparison of the particle backscatter coefficient at 1064nm.

1 INTRODUCTION

The Cloud-Aerosol Transport System (CATS), a lidar remote sensing payload onboard the International Space Station (ISS), provides near-real-time profiles of aerosols and cloud optical properties [1]. Operating since February 2015, CATS's main objective is to study the 4D distribution, evolution, and transport of aerosols and clouds. Furthermore, CATS envisages to bridge space-borne lidar observations, between the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) and future space-borne lidars (e.g ESA's ADM-Aeolus and EarthCARE, NASA's ACE). The retrieval algorithms of CATS are similar to CALIPSO. In contrast with CALIPSO, CATS main products are the backscatter coefficient and depolarization ratio at 1064 nm.

The aim of this study is to validate the CATS retrievals and establish the accuracy of the derived aerosol backscatter profiles. To this end, the lidar systems of the European Aerosol Research Lidar Network (EARLINET) [2], provide the ideal reference dataset. EARLINET consists of a large number of sophisticated lidars, which provide long-term quality-assured multi-wavelength aerosol retrievals. The objective of EARLINET is to provide a climatologically-significant profiling aerosol dataset.

In this study, we present and discuss the methodology for the validation of the profiles of CATS L2 backscatter coefficient at 1064 nm (Section 2). The methodology is demonstrated using a case study of a single CATS-ISS overpass over the Polly^{XT} lidar of the National Observatory of Athens (NOA) on the 13th of January 2016 (Section 3.1). The approach followed is mostly based on the previous expertise and methodologies that have been developed and applied in EARLINET for the CALIPSO cal/val activity [3]. Finally, the first consolidated output from the comparison with a number of EARLINET stations is given in Section 3.2., while Section 4 provides our first conclusions.

2 DATA AND METHODOLOGY

At present, 13 EARLINET stations operating the 1064 nm channel contribute to this study. The permanent stations are located at: Athens (Greece), Barcelona (Spain), Belsk (Poland), Bucharest (Romania), Cabauw (Netherlands), Evora (Portugal), Lecce (Italy), Leipzig (Germany), Potenza (Italy), Rome (Italy) and Thessaloniki (Greece). Furthermore, the non-permanent EARLINET stations at Dushanbe (Tajikistan) and the lidar system of NOA (Athens) have been integrated in the study.

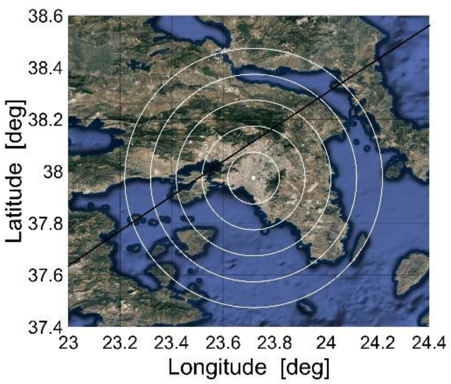

Figure 1. The nighttime ISS orbit over Athens on the 13th of January 2016 (black line). The concentric white circles denote regions of radius 10, 20, 30, 40 and 50 km from the position of NOA-Polly^{XT} lidar system.

For the purpose of demonstrating the methodology applied for the CATS validation, we use the NOA-Polly^{XT} system, which was deployed at the Thiseion site of Athens, between May 2015 and March 2016, in the framework of the ACTRIS JRA1 campaign. The nighttime study case of the CATS-ISS overpass on the 13th of January 2016 is shown in Fig.1.

2.1 CATS-ISS

CATS is a low cost payload onboard the ISS. Due to the ISS inclination orbit, CATS retrievals are confined in the geographical region between 51^{o}S and 51^{o}N. CATS operates at 415 km altitude. The orbit characteristics of ISS enable CATS to provide information on the vertical structure of the atmosphere at different local times each day.

The CATS lidar was designed to operate in three different modes and in four different Instantaneous Fields Of View (IFOV). Mode 1 and Mode 3 are not operational due to a failure of the electronics of laser1 and to a problem related to the optical path respectively. Mode M7.2 is limited to the 1064 nm channel. The vertically-resolved retrievals of aerosol and clouds are provided in different processing levels [4]. In this study, EARLINET is utilized for the validation and exploitation of CATS M7.2 L2 of the V1-05 version of data.

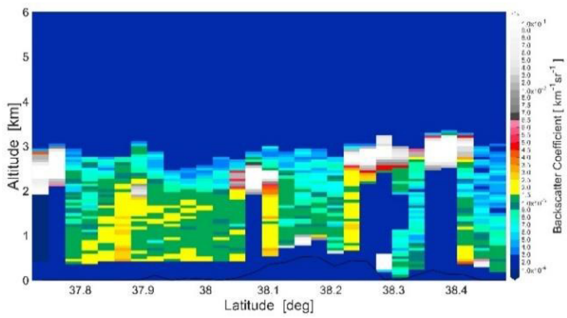

Figure 2. CATS Backscatter Coefficient 1064 nm of the overpass on the 2016-01-13, 01:16:38 UTC.

CATS L2 product provides information on aerosols and clouds along the ISS track, with 5 km horizontal and 60 m vertical resolution, for the altitudinal range between 28 and -2 km. L2 product includes the backscatter coefficient at

1064 nm, the Feature Type, Aerosol Subtype and the confidence of the classification are provided. The total backscatter coefficient at 1064 nm of the CATS overpass of the study case on the 13th of January 2016 is shown in Fig.2.

For the comparison of the correlative backscatter coefficient dataset between CATS and ground-based lidars, cases that are not contaminated by clouds are selected. Regarding the accuracy of the classification of the cloud and aerosol layers, a Cloud-Aerosol Discrimination (CAD) score is assigned to the identified atmospheric layers.

2.2 A typical EARLINET system

Fig. 3 shows an example of EARLINET lidar quicklooks, providing the range-corrected signal time-height plot at 1064nm (13th of January 2016). In the example presented here, the sky above the Athens site was contaminated by clouds during the ISS overpass. Thus the time averaging window of the lidar signal is shifted for few minutes after the satellite overpass, in order to avoid cloud presence.

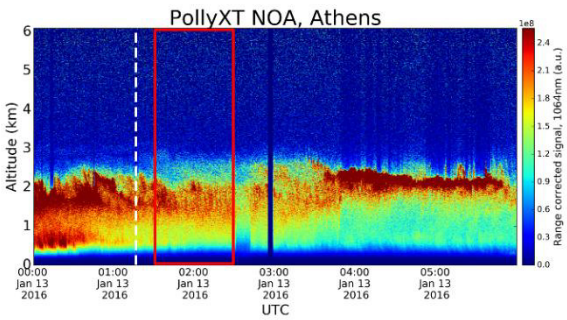

Figure 3. The range corrected signal time-series for the Polly^{XT} 1064nm channel. The red box depicts the temporal averaging of the lidar signals for the selected scene (01:30-02:28), while the white dashed line indicates the CATS overpass time.

3 RESULTS

3.1 EARLINET-CATS comparison: 2016-01-13, 01:16:38 UTC

CATS L2 backscatter profiles within a region of 50 km radius from the ground-based lidar are spatially averaged into a mean CATS profile. CAD score equal to -5 has been used for filtering out of the analysis the low confidence aerosol layers, which are possibly misclassified or contaminated by clouds. Accordingly, the mean backscatter profile is computed through the temporal averaging of the lidar signal. Fig.4 shows the comparison between the averaged Backscatter profiles of CATS and Polly^{XT} ground-based system. The CATS error-bars shown correspond to the standard deviation from spatially averaging the CATS scene. Regarding EARLINET, typical uncertainties are in the range of 5–10% for the backscatter coefficient retrieved with the Raman method.

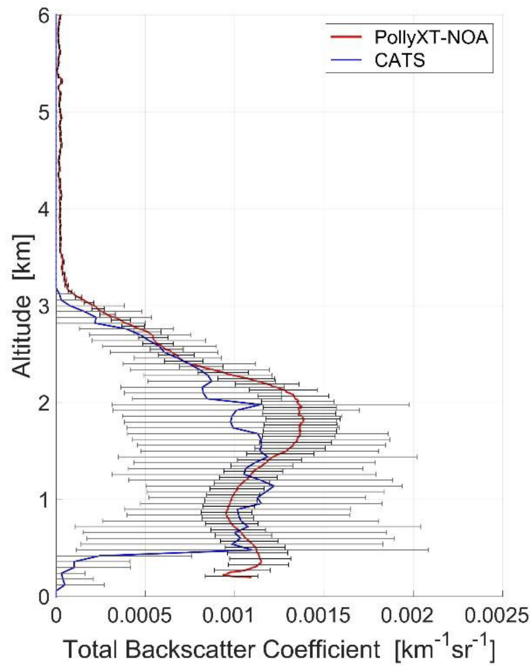

Figure 4. CATS (blue line) and EARLINET (red line) mean profiles of backscatter coefficient at 1064 nm.

From the analysis of the 13th of January 2016, it is observed that under homogeneous, relatively cloud free, nighttime conditions, the mean Backscatter Coefficient Profile at 1064 nm retrieved by CATS is in good agreement with the profile retrieved by the ground-based lidar. The comparison demonstrates a good nighttime performance of CATS. The observed disagreements to low altitudes (below 0.4 km) are most probably attributed to the effect of the orography in the spatial window used for averaging.

3.2 EARLINET-CATS comparison

The distribution of the absolute differences between CATS and the EARLINET stations of Leipzig (13 cases), Dushanbe (5 cases) and NOA

(4 cases), for nighttime ISS overpasses and for the altitudinal range between 0 and 10 km a.s.l., is shown in Fig.5. EARLINET measurements lower than the CATS minimum nighttime detectable backscatter limit (5e-05 $km^{-1}sr^{-1}$) are rejected from our analysis, for the same cases that CATS measurement provides values equal to zero as well. Based on the nighttime cases, the distribution of the absolute differences is characterized by mean value of -1.519e-04 $km^{-1}sr^{-1}$, median value of -9.94e-05 $km^{-1}sr^{-}1$ and standard deviation of 6.634e-04 $km^{-1}sr^{-1}$.

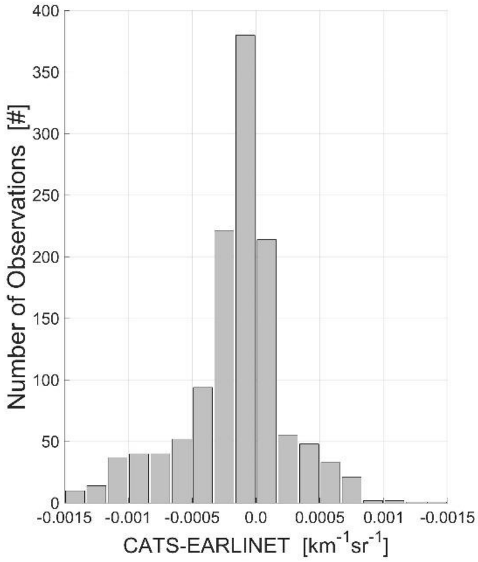

Figure 5. Distribution of the mean absolute differences between CATS and EARLINET backscatter measurements of Leipzig, Dushanbe and NOA stations and nighttime ISS overpasses.

The observed disagreements are most probably related to CATS minimum detectable backscatter, to the incomplete overlap of the ground-based lidars for lower altitudes, to the effect of the orography on CATS spatial averaging and to the horizontal distance between CATS footprint and the location of the EARLINET stations.

4 CONCLUSIONS

EARLINET is utilized for the validation study of CATS L2 backscatter profiles at 1064nm. Results demonstrate the good performance of CATS during nighttime conditions. The distribution of the absolute differences between CATS and EARLINET, for all the correlative measurements, is characterized by a mean value of -1.518e-04 $km^{-1}sr^{-1}$, a median value of -9.94e-05 $km^{-1}sr^{-}1$ and a standard deviation of 6.634e-04 $km^{-1}sr^{-1}$. Future work includes the integration of the entire EARLINET network in this study. Furthermore the study will be expanded to include the CATS-EARLINET daytime intercomparison.

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