Detection of a desert dust intrusion over Cluj-Napoca, Romania using an elastic backscatter LIDAR system

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Abstract. In this paper we present a case study regarding a desert dust intrusion over Cluj-Napoca city, observed using a LIDAR system in synergy with other instruments and models. We identified and analyzed the different dust layers present in the atmosphere at the beginning of April 2014. Besides the LIDAR system used in the identification of the dust layers we also used different models like HYSPLIT and FLEXPART in order to estimate the source of the long-range transported aerosol. We used an optical aerosol point monitor in order to measure the ground level concentration of aerosol particles. Several aerosol layers were detected at 3000 -3500 m and 4000 -4500 m. At ground level we measured the PM_{10} concentration with maximum values reaching 132 μg/m^3.

Key Words: LIDAR, aerosol, desert dust, long range transport.

Introduction. Observations of aerosols are important for improving the understanding of climate, weather, particle transport and air quality. Aerosols are the most uncertain elements in the evaluation of radiative effect, due to their temporal and spatial variation and their diversity in shape and type (Hess et al 1998; Seinfeld & Pandis 2006; IPCC 2013).

The aerosol in the atmosphere has many sources both natural, like desert dust, pollen, sea salt, biomass burning aerosols and anthropogenic, like urban and industrial pollution.

The long range transported aerosol over Romania, containing desert dust, originates almost exclusively from the Sahara desert. The intrusions may occur anytime during the year with a maximum frequency in the spring season (Ajtai et al 2013).

Airborne dust generation occurs when the wind speed surpasses a certain threshold, its value depending on the roughness of the soil surface, on the soil particle size and humidity.

At the beginning of April 2014, a large dust intrusion occurred over Romania (Nicolae et al 2014). Measurements were conducted at the Faculty of Environmental Science and Engineering in Cluj-Napoca in order to identify and analyze the aerosol layers present in the atmosphere and to observe the evolution of particulate matter (PM) concentration at ground level. These measurements represented the first observation of a desert dust intrusion over Cluj-Napoca using a LIDAR system.

Material and Method. In order to identify the aerosol layers a 532 elastic backscatter LIDAR system was used, located at the Faculty of Environmental Science and Engineering, Babes-Bolyai University of Cluj Napoca, part of the Romanian 3D Research Observatory –RADO network. The elastic lidar system uses a Nd-Yag laser emitting at three wavelengths (1064, 532 and 355 nm), capable to collect the backscattered signals for 532 nm. The dynamic range covers 1-15 km depending on the atmosphere transmission, with a 7.5 m spatial resolution.

The output parameter is the backscattered coefficient calculated using the single calculus chain (SCC) developed in the framework of the EARLINET (European Aerosol Research Lidar Network) network in order to process the LIDAR data in a similar way by all member stations (D'Amico et al 2012).

The EARLINET network is the first aerosol LIDAR network, established in 2000. It's main goal is to provide a comprehensive and statistically significant data base for the aerosol distribution over Europe. In present there are 27 LIDAR stations distributed over the entire continent. The Cluj-Napoca station is not yet a member of EARLINET, but the station has access to the Single Calculus Chain platform in order to process its measured data.

The HYSPLIT (Draxler & Rolph 2012) and FLEXPART (Stohl et al 2005) models were also used in order to determine the trajectories of air masses and to estimate the source of long-range transported aerosol.

Besides the using of synergy between LIDAR system and the different models to identify and analyze the layers of aerosol present in the atmosphere, the particulate matter concentration PM_{10} and $PM_{2.5}$ at ground level, were also measured using a DUSTTRACK DRX 8533 optical aerosol monitor (Roba et al 2014).

Results and Discussion. The measurements used in this study were taken on 4th of April, 2014. There were analyzed 3 data sets from this day starting at 10:00 UTC, 13:20 UTC and 17:00 UTC. The measurement time was approx. 2 hours for each set. A Saharan desert dust intrusion was predicted over Cluj-Napoca during this period.

According to the range corrected signal (RCS) obtained from the LIDAR measurements aerosol layers between 3 and 5 km in the atmosphere were detected, as seen in Figure 1. One may also observe the Planetary Boundary Layer up to 2 km and some cirrus clouds above 7.5 km. The main dust layers are situated between 3 and 3.5 km and between 4.2 and 4.6 km.

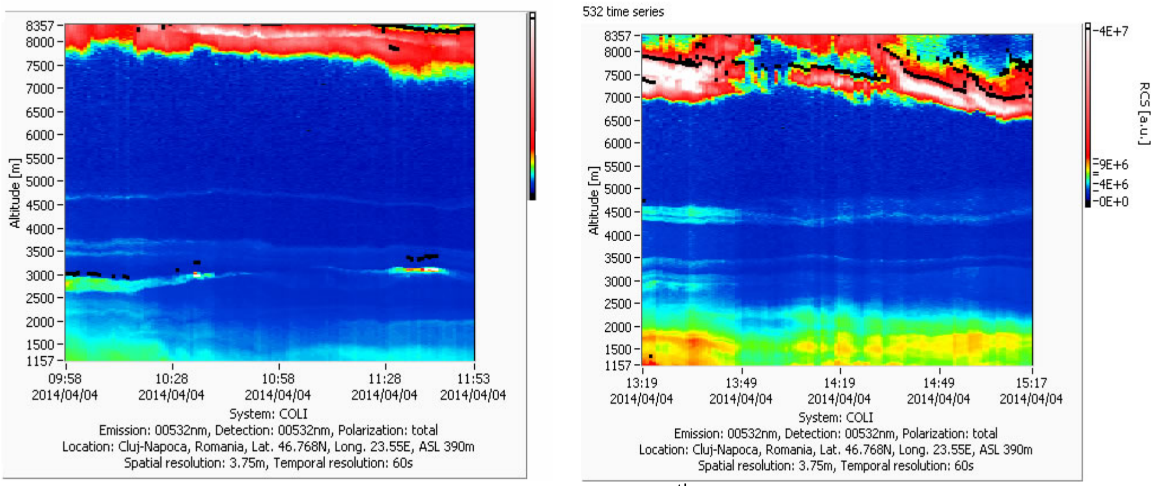

Figure 1. RCS signal for Cluj Napoca site for 4th of April 2014, 10:00 UT (left) and 13:20 UT (right).

The backscatter profiles for our measurements (Figure 2) were obtained using the Single Calculus Chain developed in the framework of EARLINET network.

In the backscatter profiles we can observe the same layers of aerosol between 3 and 5 km. Also the strong scattering of the aerosol present in the Planetary Boundary Layer may be observed under 1 km in the measurements at 10:00 UTC and under 2 km in the 13:20 UTC set.

HYSPLIT back-trajectories were computed in order to estimate the source of the long-range transported aerosol. We present the results from Cluj Napoca for 4th of April, 13:20 UTC (Figure 3) showing the Saharan origin of the aerosol layers present in the atmosphere between 3-3.5 km and 4.2-4.6 km. The back-trajectories for the other measurements showed similar results, the air masses passing above the Saharan desert at low altitudes, inside the PBL.

The FLEXPART model was used in order to obtain the emission sensitivity for different aerosol layers observed above Cluj Napoca. The emission sensitivity is proportional to the residence time of the particles over a unit area. At low altitudes (1-2.5 km) we can see the predominant influence of local continental aerosols, at upper altitudes (4.2–4.6 km) we can observe a predominant desert dust influence and between them a mixed desert dust with continental influence (Figure 4).

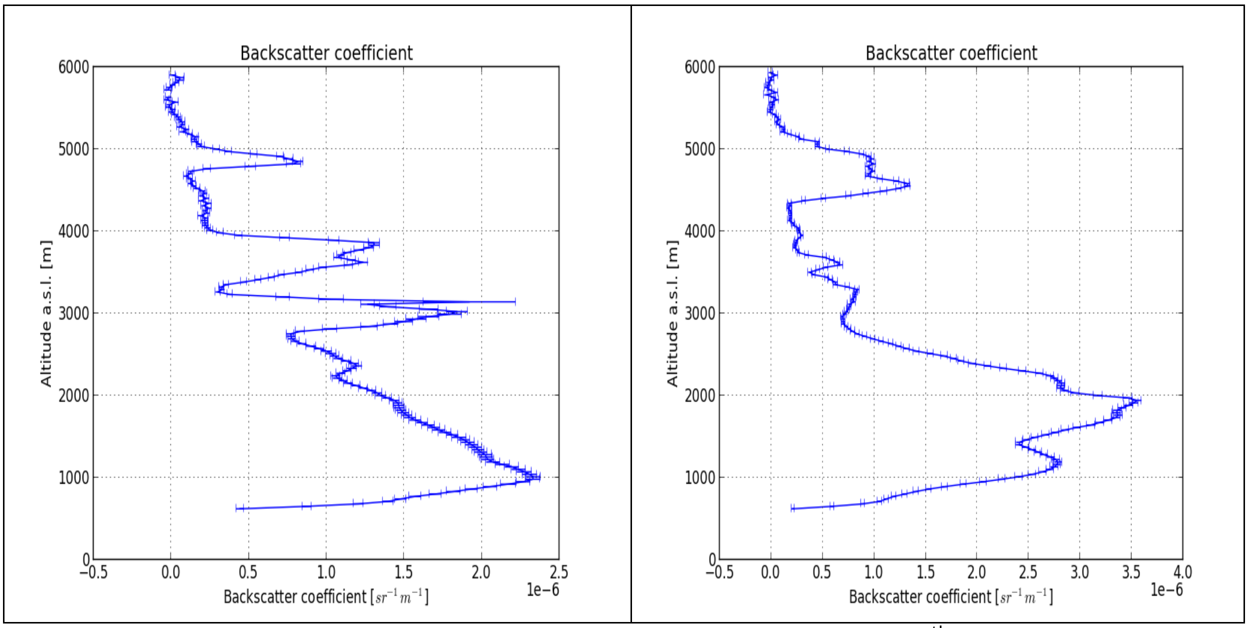

Figure 2. Backscatter profiles for Cluj station measurements on 4th of April, 10:00 UT (left) and 13:20 UT(right).

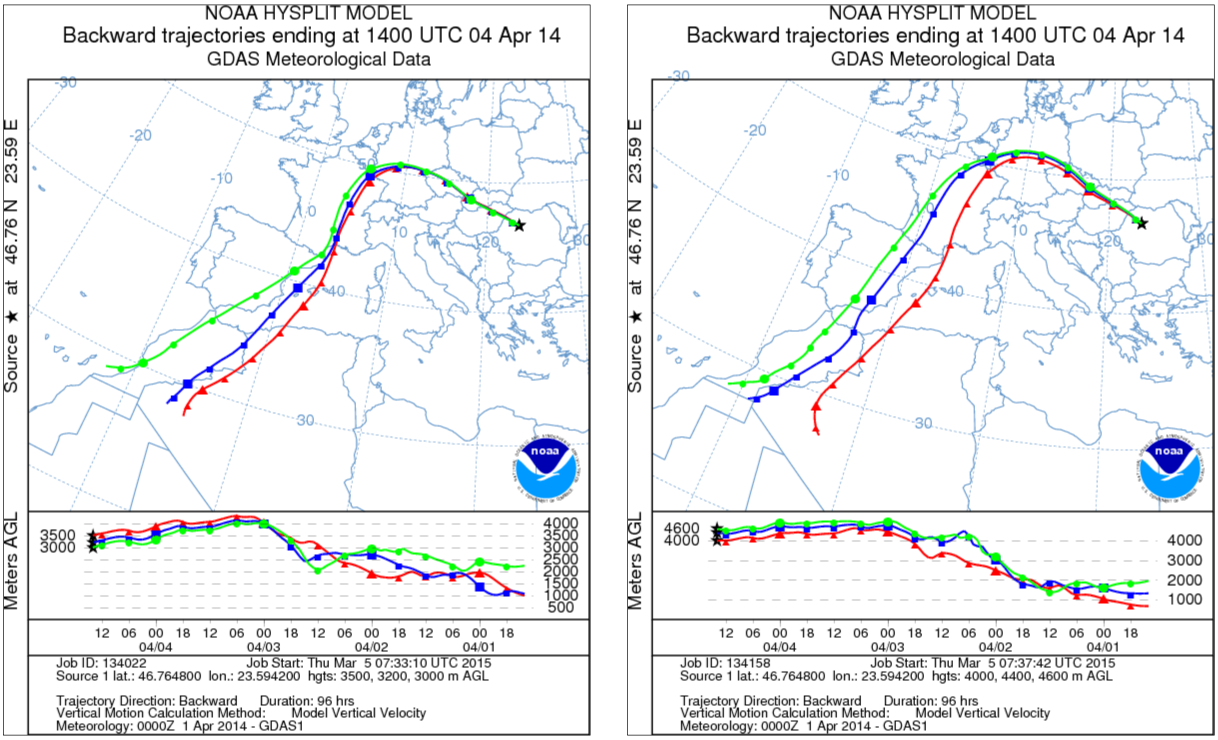

Figure 3. HYSPLIT 96 h back-trajectoriesending at Cluj station, 4th of April, 14:00 UTC.

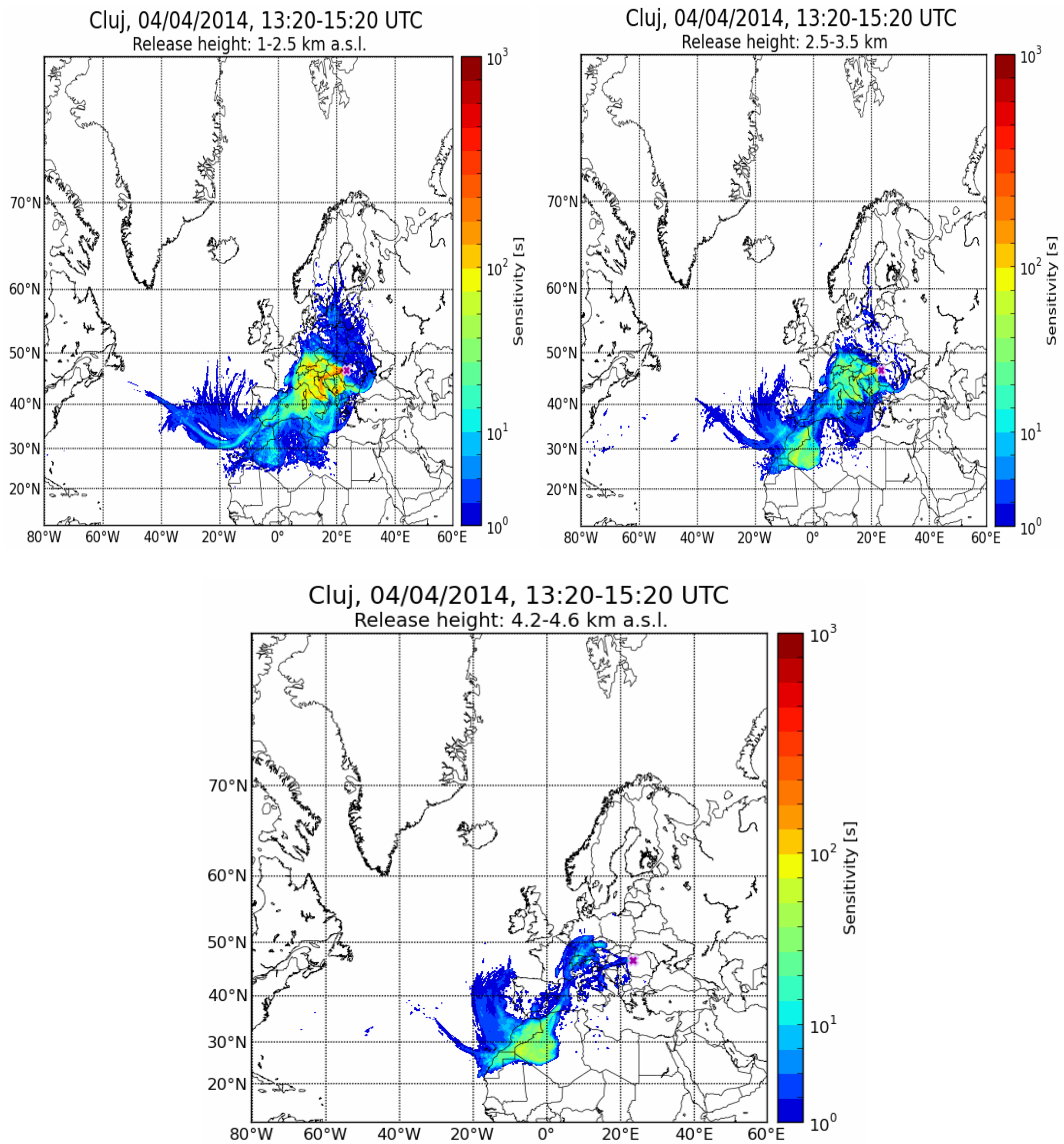

Figure 4. FLEXPART sensitivity, Cluj station, 4th of April, 13:20-15:20 UTC, for different altitudes: a) 1–2.5 km (upper left); b) 2.5–3.5 km (upper right); c) 4.2–4.6 km (down).

At the same time with the LIDAR measurements, the PM_{10} and $PM_{2.5}$ concentrations at ground level were measured (Table 1). he concentration on 7th of April 2014 after the dust intrusion was also measured. On 6th of April 2014 there were rains, thus the dust in the atmosphere was subject to wet deposition and it can be assumed that on 7th of April 2014 the measurements were free of desert dust. We can observe the high values of PM_{10} concentration, with high values during 13-15 time period. We can observe that for the specified data set even the minimun value was above the threshold for human health present in the national legislation (50 $\mu g/m^3$ – Law 104/2011 regarding the air quality). For the day without mineral dust the values are much lower, the maximum value measured being 47 $\mu g/m^3$

Table 1
PM_{10} and $PM_{2.5}$ concentrations at ground level on 4th of April 2014 and 7th of April 2014

Date and time (UT)		*04.04. 2014 10-12*	*04.04.2014 13-15*	*07.04.2014 12-14*
PM_{10} µg/m^3	MIN	23	70	29
	AVG	56	86	34
	MAX	112	132	47
$PM_{2.5}$ µg/m^3	MIN	23	68	29
	AVG	52	80	33
	MAX	85	126	45

Conclusions. This paper shows the results of the first LIDAR measurements of a desert dust intrusion over Cluj-Napoca. The dust layers in the atmosphere were analyzed using a LIDAR system in synergy with different models, in order to assess the presence of dust particles over Cluj-Napoca. There were identified dust layers in the atmosphere between 3-3.5 km and 4.2-4.6 km on 4th of April 2014. The HYSPLIT and FLEXPART models confirmed the Saharan origin of the layers detected with the LIDAR.

Ground level measurements made during the intrusion on 4th of April 2014 exhibit high concentrations of aerosols that exceed national legislation thresholds regarding air quality for PM_{10} and $PM_{2.5}$. After a rain event on 6th of April 2014 deposited the aerosol on the ground, much lower values were obtained on 7th of April 2014 for both PM_{10} and $PM_{2.5}$.

This study shows the potential impact on air quality of long rage transported particles and reveals sources of aerosols that may not be accounted for during a conventional study on air quality.

Future development of the Cluj LIDAR system with 2 Raman Channels (387nm and 607nm) and a depolarization channel (532nm) will allow a better characterization of particles present in the atmosphere and also a better estimation of their concentration.

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