

# LIDAR MEASUREMENT ON DUST TRANSPORT FROM THE SAHARAN DESERT TO THE IRAN PLATEAU

Hossein Panahifar<sup>1\*</sup>, Ruhollah Moradhaseli<sup>3</sup>, Hadi Bourzoie<sup>4</sup>, Mahdi Gholami<sup>1</sup>, Hamid Reza Khalesifard<sup>1,2</sup>

<sup>1</sup>Department of Physics, and <sup>2</sup>Research Center for Climate Change and Global Warming, Institute for Advanced Studies in Basic Sciences, 4513766731 Zanjan, Iran

<sup>3</sup> Physics Department, Faculty of Science, Zanjan Branch, Islamic Azad University, Zanjan, Iran

<sup>4</sup> Faculty of Engineering, Sabzevar University of New Technology, 9615131113 Sabzevar, Iran

\*Email: [h.panahifar@iasbs.ac.ir](mailto:h.panahifar@iasbs.ac.ir)

## ABSTRACT

Optical properties of long-range Saharan dust particles transported to the Iran Plateau have been investigated. The results were derived from the measurements of a dual-wavelength Depolarized backscatter/Raman lidar and a Cimel CE318-2 sunphotometer. Observations were performed in Zanjan, Northwest Iran. The backward trajectory analysis show that the lofted dust plumes come from the Saharan desert and travel along Mediterranean Sea and Turkey toward Iran. The lidar ratio within the lofted dust layer has been found with mean values of 50 sr at 532 nm. For the depolarization ratio, mean values of 25% have been found.

## 1. INTRODUCTION

Atmospheric mineral dust can be transported more than tens of thousands of kilometers away from its sources in the free troposphere [1-3]. Dust is an important component of the atmospheric aerosol system and sensitively influences environmental and climatic conditions on the regional and global scales especially in northern hemisphere [4, 5]. The Saharan desert as a main part of the dust belt, is the world largest mineral dust source [6, 7]. The Iran Plateau (~26°-36° N, ~45°-61° E) which lies in the middle of the global dust belt is frequently affected by local, regional and trans-regional dust storm outbreaks.

Up to now, few works have been done to characterize the atmospheric aerosol properties as well as their transport scheme over the Iran Plateau. Khalesifard et al. installed a depolarized lidar to investigate the atmosphere above Tehran, the capital of Iran. They have shown that the urban pollution and polluted dust are the dominant contributors to the atmospheric aerosol burden

most of the time, especially during the cold season. Dust particles are also the dominant atmospheric aerosol fraction during the warm season [8, 9]. Panahifar et al. have reported a long-range dust transport from Arabian Peninsula to Tehran, Iran [10]. Bayat et al. and Masoumi et al. used a sunphotometer and measured column integrated aerosol properties for the atmosphere over Zanjan. They characterized the Mesopotamian region as the most influencing dust source over the measurement site [11, 12]. Vishkaee et al. used a backscatter lidar to investigate some cases for transport of dust to Northwest of Iran during summer and winter times. They reported the Tigris and Euphrates basin and a dry region between the Aral and Caspian seas as sources for the mentioned cases [13]. There are also a few reports that are mentioning some parts of the Iran Plateau as sources for dust events. [3, 6].

This article provides a scenario of long-range dust transport from Northern Africa to Iran. In Sect. 2 the measurement site, the used lidar system, and the used auxiliary data are described. Sect. 3 gives an overview of the observations and two case studies are presented in detail. The conclusions are discussed in Sect. 4.

## 2. INSTRUMENTATION AND MEASUREMENTS

The IASBS Remote sensing Station (IRIS) in Zanjan is equipped with a Depolarized backscatter/Raman lidar and a Cimel CE318-2 sun-photometer (SPM) [11]. Both instruments are deployed at the IASBS Physics Department building (36.70° N, 48.51° E, 1800 m above mean sea level (amsl)). The lidar, has a frequency doubled pulsed Nd-YAG laser (pulse duration: 10 ns, energy per pulse: 150 mJ @ 1064 nm and 130 mJ @ 532 nm) with a linear polarized output, as its transmitter. The detection

unit after a 11" Schmidt–Cassegrain telescope can separate the parallel and cross-polarized signal components at 532 nm. Further measurement channels collect lidar return signals at 607 nm (nitrogen Raman channel) and 1064 nm (elastic backscatter). The basic temporal and spatial signal resolution, with which the raw signals are stored, is 60 s and 7.5 m, respectively. Figure 1 shows schematic diagram of the IRIS lidar setup.

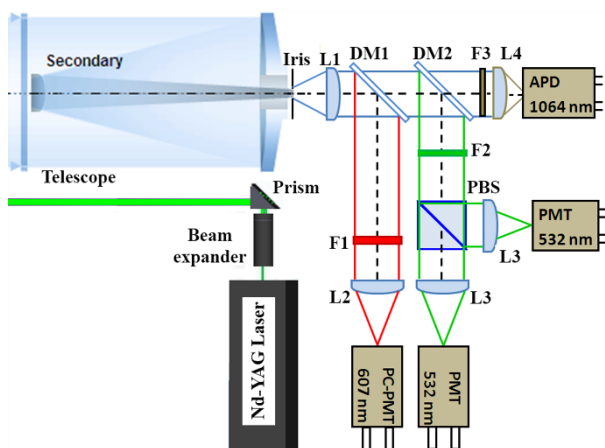


Figure 1 IRIS Polarization/Raman lidar setup

The particle backscatter coefficient at 532 nm, the particle extinction coefficient at 532 nm and the respective particle extinction-to-backscatter ratio (lidar ratio) at 532 nm are determined from the elastic and inelastic return signals in the way described by Ansmann et al. [14]. Aerosol Optical Depth (AOD) at 550 nm taken from the Moderate Resolution Imaging Spectroradiometer (MODIS) Deep Blue collection (MOD08, MYD08) available from the Giovanni Web portal (<http://disc.sci.gsfc.nasa.gov/giovanni>). The Back-trajectories are calculated with the NOAA HYSPLIT model [15].

### 3. RESULTS

In the following two cases which are representing trans-continental dust transport from the Saharan desert to Zanzan area have been presented.

#### 3. 1 Case I, 20-22 January 2019

Figure 2 shows the time-height series of volume linear depolarization ratio (VLDR) at 532 nm recorded in Zanzan from 06:40 UTC, 20 January to 06:00 UTC, 22 January 2019. Fig. 2 demonstrates that the depolarization for the boundary layer

varies between 10%-15% that can be due either to urban pollution or to temporally happening fog layers over the ground surface.

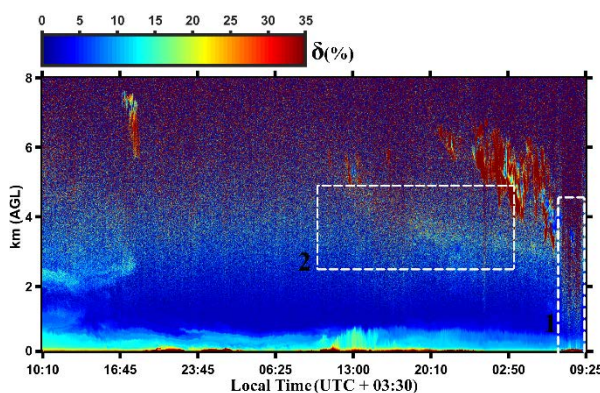


Figure 2 Time evolution of volume depolarization ratio between 06:40 UTC on 20 January 2019 and 06:00 UTC on 22 January 2019.

The Fig. 2 illustrate that at the last 2 hours of the time series (Dashed rectangle 1) the laser beam was obstructed by a dense layer of fog near the ground level and depolarization ratio increased probably due to multiple scattering (VLDR ~ 35%) [16]. A layer of lofted dust ( $20\% \leq VLDR \leq 30\%$ ) can be seen around 4 km agl (Dashed rectangle 2). The layer spans from 09:30 UTC on 21 January 2019 until the early hour of next day.

The HYSPLIT 96 hour backward trajectories in Figure 3 demonstrate that the observed lofted dust layer (Fig. 2) is transported to Zanzan from North Africa. The backward trajectories that are starting from IRIS on 21 January 2019 at altitudes of 5 and 4.5 km agl, returning back to the south of Algeria and north of Niger respectively (Fig. 3). The air parcels travel over Mediterranean Sea, pass along Turkey-Syria border and eventually reach to the IRIS.

#### 3. 2 Case II, 07-08 April 2013

Figure 4 represents the temporal development of the attenuated backscatter ratio at 1064 nm channel recorded from 09:30 UTC, 07 April to 06:30 UTC, 08 April 2013. Black area denotes periods where no measurements were performed.

The mean (Maximum) AOD variations at 440 nm, recorded on the SPM, during 07-08 April 2013 reaches to 0.25 (0.35).

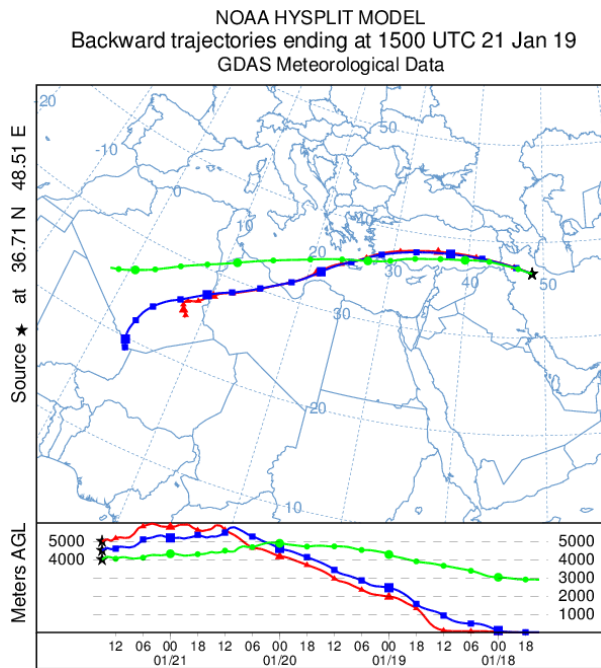


Figure 3 96 h HYSPLIT backward trajectories arriving to Zanzan on 15:00 UTC, 21 January 2019 at 5, 4.5 and 4 km heights agl.

The retrieved Ångström Exponent from the SPM data is obtained as  $0.35 \pm 0.1$  for the mentioned date which corresponds to existence of particles in coarse mode. Fig. 4 depicts a lofted layer of Saharan dust that arrives over Zanzan at ~20:00 UTC on 07 April 2013 at altitudes 3-4 km agl. At the following times, beneath this layer, a thinner dust layer is recorded at altitudes around 2 km agl (Fig. 5c). Vertical profiles of the optical properties of these dust layers are shown in Figure 5. The average (maximum) value of the particle linear depolarization ratio at 532 nm for the recorded layer at ~ 4 km is obtained as 25% (30%).

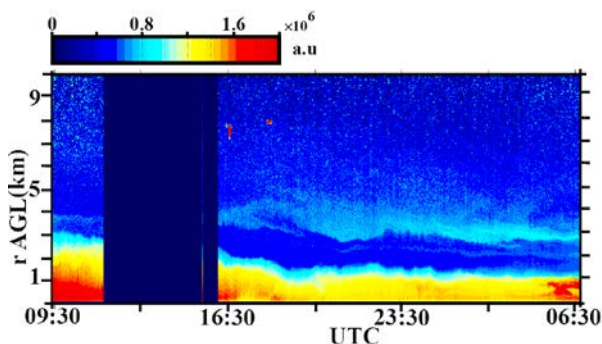


Figure 4 Time-height series of lidar attenuated backscatter profile recorded in Zanzan at 1064 nm between 09:30 UTC on 07 April 2013 and 06:30 UTC on 08 April 2013.

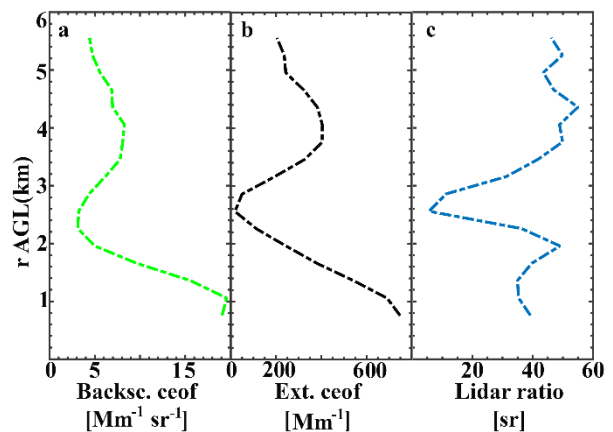


Figure 5 The averaged lidar profiles of a) Particle backscatter coefficient b) Particle extinction coefficient c) lidar ratio at 532 nm recorded during 19:40 UTC, 07 April 2013 to 01:30 UTC, 08 April 2013.

Fig. 5c depicts the mean lidar ratio values for this layer as 50.2 sr at 532 nm and its maximum reaches to 55 sr. These values are comparable with previously reported lidar ratios for transported Saharan dust to European regions [17].

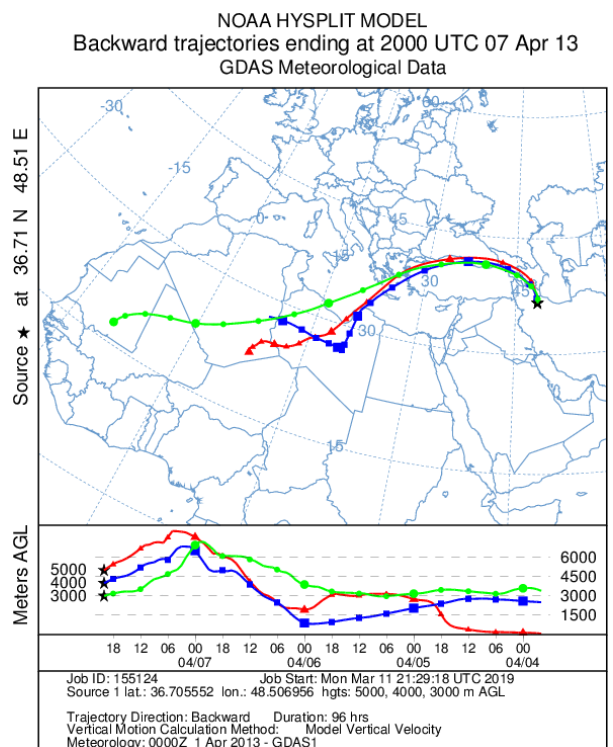


Figure 6 96 h HYSPLIT backward trajectories arriving at Zanzan on 20:00 UTC at 3, 4 and 5 km height.

Figure 6 shows the 96 hours HYSPLIT backward trajectories calculated for arrival heights of 5, 4 and 3 km agl starting from the IRIS. These heights are chosen based on the layer parameters that are

represented in Figs. 5a-5c. Fig. 7 shows that the dust plume originates from Algeria and Niger, travels along the Mediterranean Sea, passes over Turkey and finally reaches to Zanjan. This behavior is very similar to Case I.

Figure 7 demonstrates MODIS derived daily Terra AOD Deep blue on 04 April 2013. Fig. 7 is corroborated by Fig. 6 and shows that AOD increased (AOD~1) over Niger.

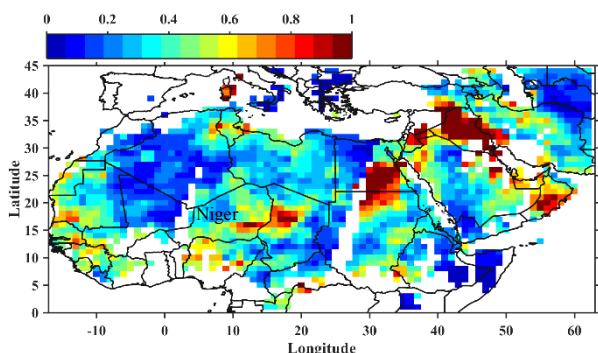


Figure 7 MODIS Terra daily AOD at 550 nm for 04 April 2013, Deep blue AOD for land surfaces.

#### 4. CONCLUSION

We presented two cases where the Saharan dust transported across the Mediterranean Sea and reached to Northwest Iran. The extinction coefficient, the lidar ratio and the particle linear depolarization ratio have been calculated. The lofted Saharan dust layers are recorded at height between 3-5 km agl for both cases. The measured depolarization ratios for both cases range between 20% to 30% at 532 nm [18, 19]. Mean values of the lidar ratio of the long-range transported Saharan dust (07 April 2013) are 50 sr at 532 nm. These lidar ratio value is comparable with typical lidar ratios of the Saharan dust (50–60 sr) and higher than lidar ratios of dust from Middle East (35–45 sr) [17-19]. According to HYSPLIT backward trajectories, for both cases, the lofted dust layer originates from the Saharan desert and travel over Mediterranean Sea and could not mix with dust from Mesopotamia and the Arabian Peninsula.

#### ACKNOWLEDGEMENTS

The authors would like to appreciate the NOAA Air Resources Laboratory (ARL) for the provision of the HYSPLIT transport model. The MODIS mission scientists and associated NASA personnel is acknowledged for the production of the data used in this research effort.

#### REFERENCES

- [1] Haarig et al., *Atmospheric Chemistry and Physics* 17, p.10767 (2017)
- [2] Mamouri, Rodanthi-Elisavet, et al. *Atmospheric Chemistry and Physics* 16.21 (2016): 13711-13724
- [3] Hofer, Julian, et al. *Atmospheric Chemistry and Physics* 17.23 (2017): 14559
- [4] Myhre, G. and Stordal, J. *Geophys. Res.*, 106, 18193–18204 (2001)
- [5] Balkanski, Y., et al. *Atmospheric Chemistry and Physics* 7.1 (2007): 81-95
- [6] Prospero, Joseph M., et al. *Reviews of geophysics* 40.1 (2002): 2-1
- [7] Liu, Xiaohong, et al. *Atmospheric Chemistry and Physics* 11.15 (2011): 7781
- [8] Khalesifard, Hamid Reza, and Hossein Panahifar, *Optics and Photonics for Energy and the Environment*. Optical Society of America, 2015
- [9] Panahifar, Hossein, and Hamid Khalesifard. *EPJ Web of Conferences*. Vol. 176. EDP Sciences, 2018
- [10] Panahifar et al. to be appear in *Central Asian Dust Conference (CADUC 2019)*, Dushanbe, Tajikistan
- [11] Bayat, Ali, et al. *Atmospheric Measurement Techniques* 6.10 (2013): 2659-2669
- [12] Masoumi, A., et al. *Atmospheric research* 120 (2013): 343-355
- [13] Abdi Vishkaee, Farhad, et al. *Journal of Geophysical Research: Atmospheres* 117.D3 (2012)
- [14] Ansmann, Albert, et al. *Appl. Opt.*, 31, 7113–7131, 1992
- [15] Stein, A. F., et al. *Bulletin of the American Meteorological Society* 96.12 (2015): 2059-2077
- [16] Weitkamp, Claus, ed. *Springer Science & Business*, 2006
- [17] Nisantzi, Argyro, et al. *Atmospheric Chemistry and Physics* 15.12 (2015): 7071-7084
- [18] Groß, S., et al. *Atmospheric Chemistry and Physics* 19 (2015): 11067-11080
- [19] Tesche, Matthias, et al. *Chemical and Physical Meteorology* 61.1 (2009): 144-164