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PRELIMINARY RESULTS FROM THE NEW MULTIWAVELENGTH AEROSOL LIDAR IN TURKEY

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The multiwavelength Mie-Raman lidar based on a tripled Nd:YAG laser becomes an important tool for profiling aerosol physical parameters in the planetary boundary layer (PBL) and troposphere. Such lidar quantifies three aerosol backscattering and two extinction coefficients and from these optical data the particle parameters such as concentration, bimodal size distribution and complex refractive index are retrieved through inversion with regularization. In this paper, the description of new multiwavelength lidar installed in TUBITAK, MRC, Materials Institute, K09 Lab., Turkey is explained, and the first results obtained from the data acquired during the summer of 2009 are presented.

1. INTRODUCTION

Atmosperic aerosols originating either naturally from sources as diverse as marine spray, desert dust, volcano eruptions, natural grassland or forest fires, or generated from anthropogenic activities like fossil fuel burning or industrial activities, affect the Earth's radiation balance by absorbing or scattering the fluxes of either solar or terrestrial radiation. This change leads to radiative forcing of the atmosphere. Scattering and absorption tend to cool the atmosphere and it is called the aerosol direct effect. Moreover, they modify the cloud properties effecting rainfall patterns and this is called the aerosol indirect effect. Since the effect on the radiative forcing isn't immediately followed by a change in the climate, there is a major uncertainty with the predictions. On the report of the Intergovernmental Panel on Climate Change (IPCC) in 2002, it was stated that aerosol indirect effect is the most important source of error in climate modeling. At the same time, the level of understanding of the influence of aerosols onto the global mean radiative forcing is poorly understandable at present time [1].

With the lidar system, aerosol optical and physical properties like the spatial and temporal distribution, morphological characterization, particle size distribution and complex refractive index can be calculated. Also, important atmospheric data like cloud height, and characteristics as well as aerosol extinction and backscattering coefficients can be obtained by the remote sensing instrumentation technology of lidars. This information has uppermost importance regarding a better understanding of the atmosphere and its constituents [2].

The aim of this paper is to demonstrate the first results of homemade lidar sounding over the industrial zone of Gebze, Kocaeli district, Turkey (Gebze is located at the shore of Marmara Sea, Gulf of Izmit, about 40 km East from Bosphorus).

2. EXPERIMENT

Lidar is a highly sophisticated instrument able to obtain in-depth important data from the troposphere. Therefore every lidar is designed precisely for the certain purpose which it will be used. Briefly the technical characteristics of the lidar designed and developed in a joint project by the TUBITAK, Marmara Research Center, Materials Institute (Turkey) and the Physics Instrumentation Center of General Physics Institute, Troitsk, Moscow region (Russia) are as follows: The transmitting unit is a QUANTEL BrilliantB *Q*-switched Nd:YAG laser emitting 855 / 400 / 240 mJ in a pulse at 1064 / 532 / 355 nm wavelengths, respectively. Laser repetition rate is 10 Hz. Laser beam is collimated by off axis parabolic mirrors with high reflecting dielectric coating at all three wavelengths. Laser beam diameter after collimation is 40 mm and divergence is below 0.2 mrad. Laser and collimator are mounted on top of the telescope allowing operation at an adjustable desired angle to the horizontal. Scattered radiation is collected by 400 mm aperture Newtonian telescope with the focal length of 1.2 m. The optical signals are separated and analyzed in 7-channel spectrum analyzer. In the process of measurements, elastic backscatters (355, 532, 1064 nm), depolarization at 355 nm, Raman signals of nitrogen (387, 608 nm) and water vapor (408 nm) are detected. The scheme of the telescope and the mounted laser is shown in figure 1.

The optical data is converted to digital signals by Hamamatsu analog-to-digital converters (ADC) inside the 7 photo-multiplier-tubes (PMT) situated on the spectrum analyzer. The digital data is acquired by the Licel transient recorder and then transferred to a computer to be pretreated and interpreted.

After the light which is backscattered by the atmospheric particles arrive the pinhole of the spectrum analyzer, it is seperated into several channels and the analog signal is converted to digital data by three different types of instruments, 2 different photomultiplying Hamamatsu analog-to-digital convertors and Avalanche convertors. This digital data is acquired by Licel software. The acquired data is pretreated by custom made analyzing program. On this step backscattering and extinction coefficients can be calculated. Next step is the retrieval of data and this is achieved by another custom made program. On this next step, aerosol microphysics is resolved by inversion with regularization to obtain the aerosol parameters. Complex refractive index, particle size distribution (PSD), Angström component, particle volume distribution and surface area concentration can be retrieved. The photo of the homemade lidar installed at the TUBITAK, MRC is presented in Fig. 2.

3. RESULTS AND DISCUSSION

In lidar measurements aerosol backscatter β and extinction α coefficients, attributed to particle size distribution *f(r)* by means of integral equation can be determined using the following formulae.

$$\beta(\lambda) = \int_{r_{\min}}^{r_{\max}} f(r) K_{\beta}(r, m, \lambda) \mathrm{d}r \qquad (1)$$

$$\alpha(\lambda) = \int_{r_{\min}}^{r_{\max}} f(r) K_{\alpha}(r, m, \lambda) \mathrm{d}r \qquad (2)$$

where *r* – particles radius, *m* – refraction index and λ - wave length. The nuclei of the aerosol particles represented with $K_{\beta,\alpha}$ for spherical particles are calculated on the grounds of Mie theory. The principle of multiwave sounding is based on measurements of β(λ) and α(λ) spectral dependences. Change of particle parameters, such as average size or mass, leads to β(λ) and α(λ) spectrum change. If $\beta_i(\lambda)$ or $\alpha_i(\lambda)$ exsecants, corresponding to different aerosol parameters, are linearly independent, the identification of these parameters becomes possible [3].

With our Multiwavelength Mie-Raman lidar α and β at multiple wavelengths are converted to microphysical properties of aerosols through mathematical inversion. The retrieved data contains parameters of size distribution, particle radius (r), volume (V), number density (N), complex refractive index (m_R-im_I). The most practical configuration (3β+2α) is based on tripled Nd:YAG laser with backscattering (β) at 355, 532, 1064 nm wavelengths and extinction (α) at 355, 532 nm wavelengths. Acceptable input errors are estimated not more than 10% and the uncertainties of retrieval: number density –40%; volume, radius –20-30%. The retrieval for the aerosol parameters is realized by Tikhonov's Inversion with Regularization method [4] and further developed by I. Veselovskii et al [3, 5]. The first successful application of regularization to Raman lidar is realized by D. Muller et.al. in 1998 [6].

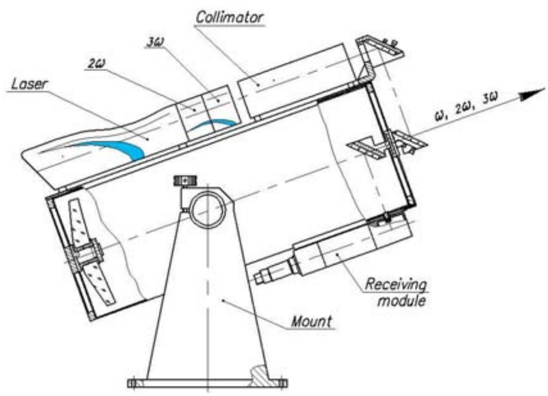

Fig.1. The scheme of the telescope and the laser on the angle adjustable mount is situated in a monostatic configuration, i.e., the transmitter (laser) and the receiver (telescope) are collocated.

Fig. 2. The picture of the lidar set-up at TUBITAK MRC, Materials Institute, K09 Laboratory during a night-time Mie and Raman scattering data acquisition. The unit on the right is the power supply and cooling unit for the transmitting unit, QUANTEL BrilliantB laser. Next is the laser mounted on top of the receiving unit, the telescope and the electronics which consist of a LICEL recorder, power supply units for the PMT's and necessary equipment for the calibration like oscilloscope and pulse generator is situated left to the telescope.

First experimental results from Gebze region were detected on the 13th of May 2009. Obtained results were presented at the 17th International Conference on Advanced Laser Technologies, Antalya, Turkey [7]. The color maps detected during a clear night sky on June 30, 2009 is shown in Fig. 3. Please note that the term “color map” is frequently used and the graphics is not in color. In the original versions of these color maps, colors extend from blue to red, including all the shades of green and yellow, however for the requirements of Azerbaijan Journal of Fizika, they are converted as a grey scale starting from white to black, using all shades of grey.

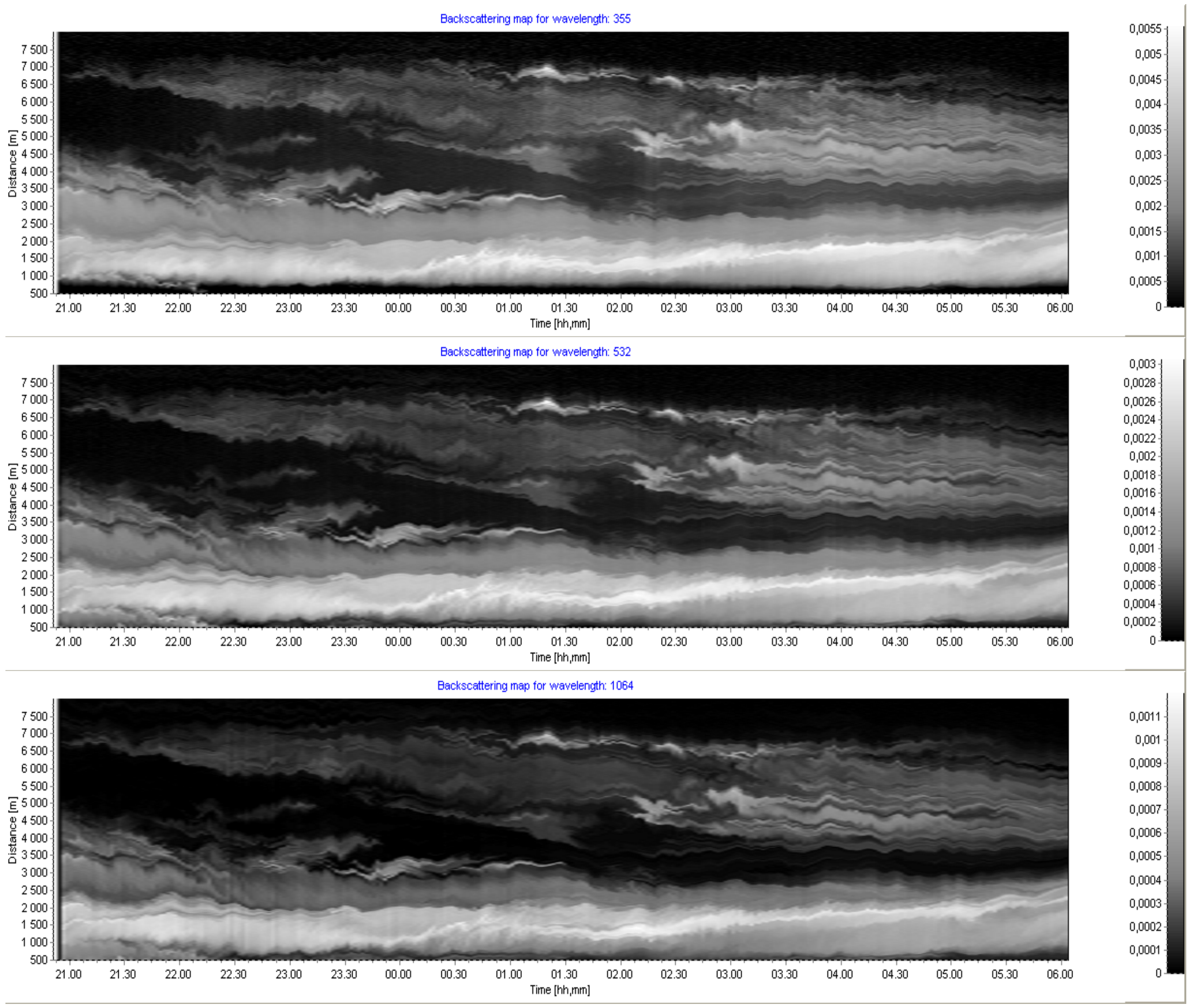

Fig. 3. The color map represents the results of lidar data obtained on June 30, 2009 during a night from 21:00 PM to 6:00 AM.

With the retrieval of data from lidar, 3 dimensional color maps can be drawn. Here, on each three parts of the figure, the vertically situated numbers on the left denotes the distance from the lidar, and since the lidar is angled 30 degrees with the horizon, to be able to calculate the real heights, the distance on the color map should be divided by 2 (Sin 30^0 is ½). On the left, vertical numbered scale is given, and the horizontal numbers on the bottom of each graph denote the time. In this backscattering to distance ratio, presented in the 3-D color map for the interval of 9 hours on the x-axis, the aerosol layer at 1000 to 1500 meters kilometres was easily detected. Also, after midnight, another weaker layer is present between 6500 and 4000 meters. The three wavelengths (355, 532 and 1064 nm’s) from the laser are transmitted simultaneously, and the color maps belong to these three wavelengths respectively.

4. CONCLUSION

Homemade multiwavelength Mie-Raman lidar provided the opportunity to obtain important data of the aerosols in the troposphere layer of Gebze. These first results serve as the beginning of a greater understanding of the atmospheric constituents and their affects on cloud formation and cloud lifetime in general, and especially in the region of Bosphorus and Marmara Sea.

The main directions of coming lidar research are the study of seasonal and diurnal variations of aerosol characteristics in Gebze and Bosphorus region; separation of atmospheric aerosols of anthropogenic and natural origin; investigation of

African dust transport; study of fuel burning aerosol distribution over the area; comparison of aerosol parameters retrieved from lidar data with data from other instruments; application of aerosol lidar data for estimation of climate forcing.

5. ACKNOWLEDGMENTS

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