The aim of this study is to demonstrate that different methods of remote sensing for evaluating air pollution over urban area (Timisoara city), by using LIDAR combined with Sun Photometer data, completed with satellite images (Modis – Moderate Resolution Imaging Spectro-radiometer), are recommended for the extended understanding of complex phenomenon in the free atmosphere, further for quality of life and particularly for the determination of aerosols. These particles play a huge role in the energetic equilibrium of the different layers. Modis has the capability to monitor the air pollution over land, especially urban areas, which is the main source of aerosol particles caused by industry and urban traffic. LIDAR measurements offer a good temporal resolution and are considered limited only by the weather conditions (rain, snow or very cloudy days) compared with Sun Photometer, which is limited to daylight hours, but has the ability to identify the exact height of the aerosol layers. The advantage of the sun photometer is that it is able to indicate the optical parameters of the aerosols in the investigated area.

Keywords: aerosol, LIDAR, Sun photometer, urban pollution

In the recent years a very particular interest has been given to the urban pollution and the chemical composition of pollutant, among which aerosols are of great importance, knowing the great impact of pollution sources upon human health. Aerosols are unevenly distributed in space and change significantly in time. In-situ measurements techniques do not allow to investigate spatial and temporal the structure of aerosol in space, the aerosols layers and properties.

The aerosol optical properties in conjunction with air mass back trajectory analysis indicate that the observed elevated aerosol layers could contain significant fraction of coarse mode particles with a mix of dust and marine aerosols [1, 2]. It is known that the boundary layer (BL) is the lowest layer of the atmosphere near ground affected by diurnal heat, moisture or momentum transfer to or from the surface.

Further analysis [1, 2] reveals that the aerosols, within atmospheric boundary layer (ABL), dominate the column aerosol loading. Seasonal variation of ABL-AOD (aerosol optical thickness) is expected. Life on Earth is critically dependent upon the continuous cycling of water between oceans, continents and the atmosphere. Precipitation is the key physical process that links aspects of climate, weather, and the global hydrological cycle. One of the factors that could contribute to precipitation modification is aerosol pollution from various sources such as urban air pollution [3, 4]. Combinations of ground, airborne and remote sensing observations can be valuable to assess the role of the free atmosphere and its impact at local, regional and global scales [2].

Worldwide, most atmospheric aerosol particles are produced by natural processes such as grinding and erosion of land surfaces resulting in dust, salt-spray formation in oceanic breaking waves, biological decay, forest fires, chemical reactions of atmospheric gases, and volcanic injection. Some particles, on the other hand, have human origins: industry, agriculture, transport (including aviation), and construction. The composition of atmospheric aerosol particles varies widely depending on their source. They may contain salts (predominantly sulfates), minerals (such as silicon), organic materials, and, in most cases, water [5].

The particles grow by absorbing water vapor and other gases. If the relative humidity is sufficiently high (usually about 80 percent or more), tiny water drops can form on some of the particles. A subset of these, called ‘cloud condensation nuclei,’ then grow into cloud drops, which eventually fall to the surface as rain or snow, depositing the particles on land or in the ocean. At higher altitudes, cloud ice particles form on some insoluble particles, such as dust.

From figure 1 it results that an important precursor gas for fine aerosol in the lower troposphere is the sulfuric acid (H₂SO₄) which is produced by oxidation of SO₂ emitted from fossil fuel combustion, active volcanoes and other sources, as well the ammonic (NH₃). Through nucleation with ultra fine aerosols (less than 0.01μm) and further condensation and coagulation within fine aerosols (0.01 – 1.00 μm) final products, that are collected by coarse aerosols attend the soil, or are contributing to the scattering and evaporating phenomena generated by the Sun and cloud presence in the free atmosphere. Coarse particles are mainly formed of sea salt, soil dust and vegetable debris into the atmosphere [6].

\[
\begin{align*}
SO₂ + OH + M & \rightarrow HSO₃ + M \\
HSO₃ + O₂ & \rightarrow SO₃ + HO₂ \\
SO₃ + H₂O + M & \rightarrow H₂SO₄ + M
\end{align*}
\]

The oxidation of the SO₂ takes place in cloud droplets and in the raindrops. The sulfuric acid also reacts with the sea salt from the ocean producing sodium sulfate [6].

\[
H₂SO₄(g) + 2NaCl \rightarrow Na₂SO₄ + 2HCl(g)
\]

The LIDAR (LIght Detection and Ranging) is an optical remote sensing technology [7]. Also sun photometry is used in this investigation [10]. It is based on a photometer conceived in such a way that it points at the sun. Sun
photometers are automated instruments incorporating a sun-tracking unit, an appropriate optical system, a spectrally filtering device, a photo detector, and a data acquisition system. The measured quantity is called direct-sun radiance.

The instruments used are located at Mechanical Faculty in Timisoara, (fig. 2). The characteristic of this location is that it is situated near the center of the city, a very crowded area with a lot of traffic. Vertical structure is evaluated by the use of LIDAR and the sun photometer offers complementary information about aerosol physical and optical properties. Remote sensing techniques play an important role in characterization of aerosol particles and thus one can find different optical and physical characteristics of the aerosol particles [8].

Light-colour aerosol particles can reflect incoming energy from the sun (heat) in cloud-free air and dark particles can absorb it. Aerosols can thus modify how much energy clouds reflect and they can change atmospheric circulation patterns. In conclusion aerosols can modify our climate [5].

From [9] it is resulting that major population centres represent the largest of growing urban agglomerations with major societal and environmental implications. In terms of air quality they are seen as localized but strong emission sources of aerosols and trace gases which in turn affect air pollution levels in the city or in downwind regions. The impact on humans, measured with a threshold exceedance of pollutant surface mixing ratios, is more dependent on population densities than on the size of the area holding a certain mixing ratio.

Experimental part

Data measurements that are used in this paper are from the mentioned four channel LIDAR [3, 10] and a 8 filter Cimel CE318 sun-photometer [11], all mounted in proximity of the ground level and scattering the BL; Cimel data that can be also observed from the AERONET network webpage [14]. AERONET [13] provides continuous cloud-screened observations of AOD precipitable water, and inversion aerosol products in diverse aerosol regimes. Inversion products are retrieved from almucantar scans of radiance as a function of scattering angle and include products such as aerosol volume size distribution, aerosol complex refractive index, optical absorption and the aerosol scattering phase function. All these products represent an average of the total aerosol column within the atmosphere [13].

For the purpose of the present analysis, two days of LIDAR measurements accomplished are used for investigation: 19.09.2012 and 24.09.2012.

Results and discussions

Figures from 3 to 6 present the RCS (Range Corrected Signal) images generated by the Timisoara Politehnica University LIDAR. At 06th UTC (Universal Coordinated Time) a very well defined layer is observed at 4.5 km and also a cirrus cloud between 9.00 and 12.00 km.

In the second part of the measurement of the same day high concentration of aerosol are depicted between 3.5 and 2 km, and also the tendency of descent of the cirrus cloud is obvious illustrated.

From figure 5 one can observe very clear a layer of aerosol at 2.5 km, layer that is raised, carried by air masses and turbulences; a similar phenomenon is experienced in the second part of the measurement (fig. 6). For this stage of information, one can conclude only in reference to the height of the layers; complementary information must be extracted from Sun Photometer measuring results and satellite images.

By analyzing figure 7 one can observe clearly high AOD values for all wavelengths, especially between 09th and
Fig. 5. RCS signal from LIDAR data generated by means of the Timisoara LIDAR, for 24.09.2012, from 10th to 14th UTC

Fig. 6. RCS signal from LIDAR data generated by means of the Timisoara LIDAR, for 24.09.2012, from 18th to 21th UTC

Fig. 7. Aerosol Optical Depth (AOD) from 19 of September 2012 [13]

Fig. 8. Angstrom Coefficient from 19 of September 2012 [13]

Fig. 9. Angstrom Coefficient from 19 of September 2012 [13]

Fig. 10. Aerosol Optical Depth (AOD) from 24 of September 2012 [13]

Fig. 11. Aerosol Optical Depth (AOD) from 24 of September 2012 [13]

16th GMT time, when the layer is present; this fact is concluding that much of the aerosol particles are of smaller size [11, 12, 15, 16]. The Angstrom Coefficient small values confirm, as well, this supposition, meaning that the aerosol is consisting of fine particles.

Although one has no information on the size distribution from 19th of September 2012, we can get an idea by analyzing the day before, (fig. 8). The radius is between 0.1-1.0 μm, namely small size particles. The AOD values over the dimension of 1.00 μm are specific for biomass burning and smoke [2, 11, 12].
Unlike the AOD from 19, in 24 of September 2012 small values between 0.1 and 0.5 μm are recorded, thus one can draw an interpretation that the aerosols are a mix of coarse and fine particles. This conclusion is sustained also by the values of the angstrom coefficient presented in figure 11, which reveals values bigger than 1.00 as well as from the size distribution recorded in figure 12.

By analyzing figure 13 one can detect clearly high concentrations of sulfate and smoke over western part of Romania, Timisoara region, validated also by the values of AOD from that day. On 24th September 2012 a continental polluted aerosol is predominant, due to local pollution that is determined as well by the mixing of course and fine particles.

Conclusions

Aerosol investigation is a very complex task that requires multiple type of information. Such information can not be obtained from a single instrument, that’s why we need additional information. This can be achieved by combining different remote sensing instruments such as LIDAR, sun photometer and also satellite images [16].

This is the first study presenting a comprehensive data set on optical properties of aerosols at the ground, BL and FT in the Timisoara region (western part of Romania). The resulted and analyzed comparative data set, along with proofs and comments, can be used to further depict aerosols behavior. The combined ground, airborne and remote sensing observations can be valuable to assess the role of environmental pollution sources and their impact at local, regional and global scales. The importance of complementary air quality analysis is revealed, and it is of major importance especially for the mentioned Timisoara region, as in the city, most of the particulate matter analysis (PM10) are over the limits, and thus latest infringement procedure versus Romania, can become critical and enter into force, if no active measures are taken, affecting all polluting sources in the area, by limiting their exhaust.
September has, in the analyzed area, still a summer climate, and is considered a representative interval of pollution episode. Further analysis for winter episodes might be further completed.

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