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LIDAR system implementation and development for novel romanian systems

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The LIDAR (LIght Detection And Ranging) technique is based on the interaction of a laser beam with atmospheric compounds (molecules, gases, clouds) via elastic-inelastic or resonant-nonresonant processes (scattering, absorption, fluorescence), relative to the radiation of the laser beam. By analyzing the detected backscattered radiation, suitable at many wavelengths, several parameters can be recovered, with relatively high space-time resolution: optical properties of the atmosphere (e.g. backscatter-extinction coefficients of aerosols and clouds), atmospheric concentrations (e.g. ozone, water vapor), and atmospheric parameters (e.g. temperature, wind). The article is focusing on the characterization of a LIDAR system and also on verifying the accuracy of information supplied. This scope is achieved by means of the information generated through the HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) model, compared with information from satellite data.

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1. Introduction

Atmospheric research nowadays is hard to consider without the use of remote-sensing techniques. Light detection and ranging (LIDAR) is one of the backbones of the research field that deals with the profiling of the atmosphere. Lidar has largely contributed to the knowledge of the Earth’s atmosphere during the past decades. It provides definitively additional information about emission rates and concentration levels of trace gases. It is also used to distinguish water droplets from ice crystals in clouds. Lidar contributes to the information of the aerosol effect on the real radiation budget [1]. Research has been achieved in the Bucharest area (Magurele), based on two novel LIDAR systems, the Timisoara (POLITEHNICA University of Timisoara) concept, that was newly developed, and the INOE (Institute of Optoelectronics), a novel, already working system.

Atmospheric aerosols play an important role in atmospheric processes, because they have appreciable influence on the Earth’s radiation facts, air quality and visibility, clouds formation, and chemical processes, both in the troposphere and stratosphere. Therefore, vertically resolved measurements of physical and optical properties regarding the particles, such as the particle surface-area concentration, their concentration by volume and mass, mean particle size, and the volume extinction coefficient, are of main interest [2].

In principle, a Lidar consists of a transmitter and a receiver. The laser generates short light pulses with lengths of a few to several hundred nanoseconds and specific spectral properties. For reducing the divergence of the beam light a beam expander is used. At the receiver’s end, a telescope collects the photons backscattered from the atmosphere. It is usually followed by an optical analyzing system which, depending on the application, selects specific wavelengths or polarization states out of the collected light. The selected radiation is further directed onto a detector, where the received optical signal is converted into an electrical signal.

2. Experimental

2.1 Technical equipments

The scheme in Fig. 1 represents the configuration of the LIDAR from the Timisoara location, as designed in order to realize analysis for the western part of Romania.

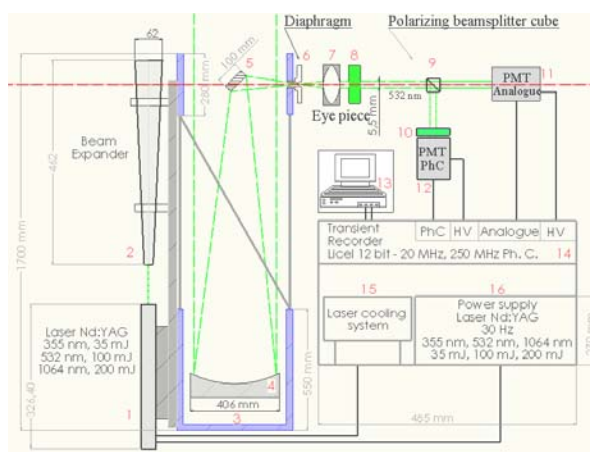

Fig. 1. Scheme of the Lidar system for the Timisoara system (in the frame of the ROLINET [7] and RADO [8] research projects).

The system that has been developed is configured by following components:

- Nd:YAG 30 Hz pulsed laser (35 mJ at 355 nm, 100 mJ at 532 nm, 200 mJ at 1064 nm);
- Newtonian telescope of 406 mm in diameter of primary mirror;
- Licel transient recorders acquisition cards;
- Analogue photo detector and Photon counting photo detector.

The acquisition for Timisoara Lidar system is based on 2 channels, 532 nm analogue and photon-counting (depolarization). The Licel transient recorder is a TR 20 model, with a 7,5 m spatial resolution. Because of the powerful 30 Hz YAG laser, the instrument is proper to be used in air scattering applications, the acquisition being triggered by the laser and it can record up to 30 profiles every second [3].

2.2 Lidar system data

The stability in time of the equipments is very important for a Lidar system, especially concerning the laser and quality of data collected with the Lidar system, but a very important part in analyzing the data by means of the preprocessing method. Preprocessing and validation of data lead to reliable results of measurements. An example of an RCS (Range Corrected Signal) is presented in the Fig 2 that is generated with the preprocessing method integrated in a LabView program created by the research team. A Saharan dust intrusion is observed by means of the Timisoara LIDAR, which was received also by the LIDAR system from INOE, at ~ 4000 m altitude.

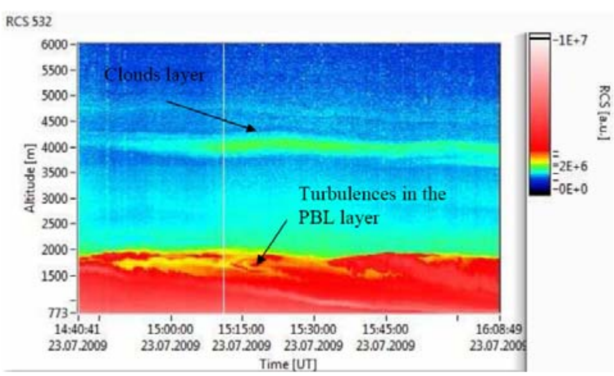

Fig. 2. RCS signal from LIDAR data generated by means of the Timisoara LIDAR, for the in 23.07.2009 episode, at Magurele location.

The detection of the Lidar converts the received light from the receiver in an electric signal, as a function of altitude. The detected light backscatter power S(λ,R) at the wavelength λ, from a distance R, is expressed by the so-called LIDAR equation [3], [4],[5]:

$$S(\lambda_D, R) = \frac{1}{R^2} C_S(\lambda_L, \lambda_D, R) T_{\rightarrow}(\lambda_L, R) T_{\leftarrow}(\lambda_D, R) \beta(\lambda_L, \lambda_D, R) \quad (1)$$

where λ_D is the wavelength at which the backscattered radiation is detected by the lidar receiver, λ_L is the wavelength of the laser, C_S is the instrument function.

RCS is the range corrected signal with the following equation [4]:

$$RCS(\lambda_D, R) = S(\lambda_D, R) \cdot R^2 \quad (2)$$

The backscatter light is proportional to the number density of diffusers (i.e. molecules and aerosols) and to the volume backscatter cross-sections of Rayleigh and Mie processes [5],[6].

In order to represent the RCS series in a comprehensive picture, from where the layers might be observed and detected, the used preprocessing software was completed by a color gradient, proportional with the signal intensity.

3. Results and discussion

3.1 Back-trajectories of the particles

Two models for backwards trajectories of the aerosol particles were used, one is the HYSPLIT model (collaboration between NOAA-National Oceanic and Atmospheric Administration and the Bureau of Meteorology from Australia) and the second is that developed by NASA-GSFC. Meteorological data are used in the models to track the trajectory of the aerosol particles.

In the HYSPLIT – Hybrid Single Particle Lagrangian Integrated Trajectory – model, a fixed number of particles are advected about the model domain, by the main wind field and a turbulent component. The back-trajectories for the particles are calculated for 7 days period, 48 hours calculation time, specified in the input of the model. In this case, by detecting where the aerosol layer is situated by means of the LIDAR measurements, it was possible to input in the model the desired altitude for calculation of the trajectories. For the accomplished case, one analyzed altitudes of 3500 m, 4000 m and 4500 m. The result of the calculation is presented by Fig. 3 [9].

According to HYSPLIT backward trajectories, the air masses that are over Magurele-Bucharest (44.35N, 26.03E) in July, 23-th, are approaching from over the ocean, at high altitude, more than 6000 m, passing several countries from Europe.

For a more concluding result a second backward trajectory model was used, meaning the NASA/GSFC model, for the same day and conditions.

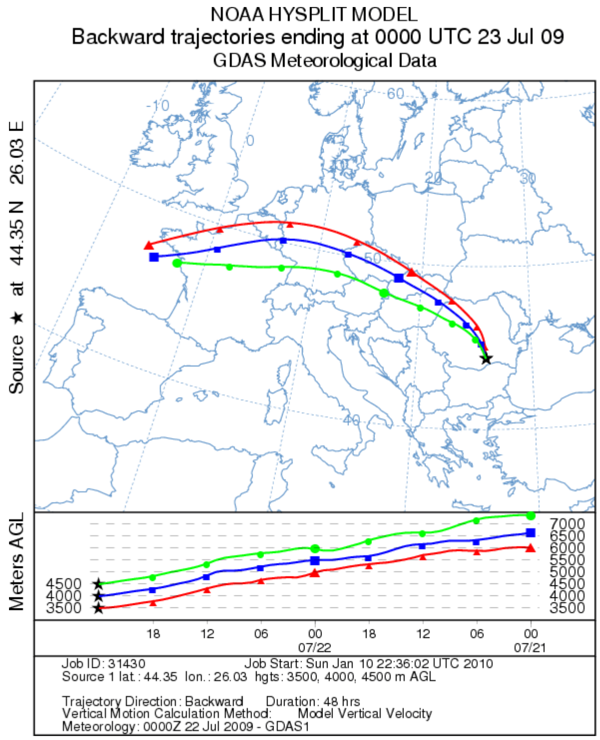

Fig. 3. Backward trajectories generated by the NOAA HYSPLIT MODEL for 23-th July 2009 episode.

The results from the NASA model are presented in Fig. 4, and it can be seen that it is similar with the result generated from HYSPLIT model. The altitude of the aerosol particles situated at the 4500 m, Bucharest (Magurele) location, in the second day is at ~7000 m, value that was pointed out also by the HYSPLIT model.

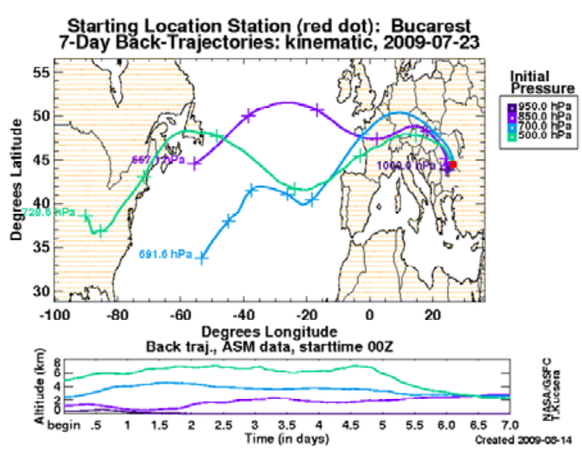

Fig. 4. 7 days backward trajectories from NASA MODEL for 23 July 2009.

3.2 Satellite data

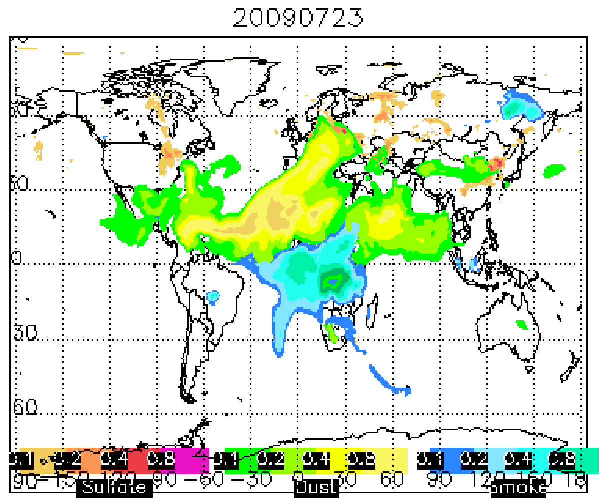

Fig. 5. NAAPS/TOMS measurements (Navy Aerosol Analysis and Prediction System) from 23 July 2009 obtained from satellite data and integrated in global model.

Satellite data is able to add synoptic information and visualization to other air quality instruments. In addition to light detection and ranging (LIDAR) systems, measuring aerosol scattering in the atmosphere as a function of altitude, a vertical dimension of air pollutant, are provided as well [11-14], [16, 17]. For this specific evaluation of the LIDAR measurements, satellite data from NASA/GSFC – TOMS, integrated in NAAPS/TOMS model, for the 23 July 2009 episode, are represented by Fig. 5.

With green – yellow (light colors) the gradient for the concentration of the dust is represented. The dust particles are coming from Central America over the Europe, crossing the ocean, exactly like in the trajectories models. If one superposes this image with the trajectory generated by the models, it results clearly that they coincide with the detected mass of dust, represented in RCS picture Fig. 2.

4. Conclusions

The satellite data and trajectories models confirmed that the results of the measurements are real and exact. From the trajectories model it can be observed that the aerosol particles over the Magurele-Bucharest location, during the 23 July 2009 episode, are arriving from high altitude, ocean direction. This fact is real and was confirmed by the satellite data.

Along with the LIDAR measurements it is useful and worth to have more information from other different air quality instrument not only for certifying the measurements but also to know better the pollution situation.

The new built up LIDAR system from Timisoara has a promising good potential and performs useful information related to aerosol distribution. It can be easily up-gradable with more channels, for example with an UV (355) channel and Raman, or NIR (1064 nm) length-wave, in order to enlarge its performances. Its simple architecture makes it easily operable, and suitable for clouds studies, aerosol distribution in the area of observation and continuous and real time atmospheric monitoring of PBL.

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References

[1] C. Weitkamp, Springer (2005).
[2] L. Kondratyev, L. Ivlev, V. Krapivin, C. Varotsos, Processes and, Springer (2006).
[3] M. M. Cazacu, P. Ristori, O. Tudose, A. Balanici, D. Nicolae, V. Ristici, D. Balin, I. Balin, ^{mESY}*LIDAR*: a new cost-effective powerful lidar configuration for tropospheric aerosols and clouds investigations, The General Assembly of the European Geosciences Union, EGU 2009, Viena, Austria, 19 – 24 aprilie (2009).
[4] S. Sabina, D. Nicolae, M. Caian, Ars Docendi (2008).
[5] A. Ansmann, D. Muller, In: Weitkamp, C. (Ed.), LIDAR—Range-resolved optical remote sensing of the atmosphere. Springer, New York, 105–141 (2005).
[6] M. I. Mishchenko, J. W. Hovenier, L. D. Travis, Light Scattering by Nonspherical Particles. Theory, Measurements, and Applications, Academic Press, San Diego, 152-157 (2000).
[7] http://inoe.inoe.ro/ROLINET
[8] http://inoe.inoe.ro/RADO
[9] R. Draxler, G. D. Rolph, HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) Model access via NOAA ARL READY Website (http://www.arl.noaa.gov/ready/hysplit4.html), NOAA Air Resources Laboratory, Silver Spring, MD (2003).
[10] http://www.nrlmry.navy.mil/aerosol/#satelliteanalyses
[11] L. Remer, Y. Kaufman, D. Tanre, S. Mattoo, D. Chu, J. Martins, R. Li, C. Ichoku, R. Levy, R. Kleidman, T. Eck, E. Vermote, B. Holben, Journal of the Atmospheric Sciences, Special Section **62**, 947–973 (2005).
[12] J. Engel-Cox, C. Holloman, B. Coutant, R. Hoff, Atmospheric Environment **38**, 2495–2509 (2004).
[13] J. Engel-Cox, R. Hoff, A. Haymet, Journal of the Air and Waste Management Association **54**, 1360–1371 (2004).
[14] J. Al-Saadi, J. Szykman, B. Pierce, C. Kittaka, D. Neil, A. Chu, L. Remer, L. Gumley, E. Prins, L. Weinstock, C. MacDonald, R. Wayland, F. Dimmick, J. Fishman, Bulletin of the American Meteorological Society **86**, 1249–1261, (2005).
[15] J. Y. Kaufman, D. Tanre, O. Boucher, Nature, **419** (2002).
[16] D. Nicolae, C. Talianu, R.-E. Mamouri, E. Carstea, A. Papayannis, G. Tsaknakis, J. Optoelectron. Adv. Mater. – Rapid Comm. **2**(6), 405 (2008).
[17] Ioana Ionel, Sabin Ionel, Doina Nicolae, J. Optoelectron. Adv. Mater. **9**(11), 3541 (2007).

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