Aerosols Classification by Lidar and ground based Measurements over Eastern European AERONET/EARLINET Site ACLIMEEA

Beata Sroka

- Introduction and motivation

Despite tremendous development of aerosols studies, there is still a lack of information about the optical, physical and chemical properties of some classes of atmospheric aerosols, especially aerosols with complex composition from biomass burning (natural or anthropogenic), smoke, dust or volcanic ash. The pollution with biomass burning aerosols can have a substantial impact on human health and a strong influence on weather and climate at local, regional and global scale through the emission of high concentrations of fine particles containing organic matter and black carbon (IPCC 2013).
A major step forward in earth observation has been made by the successful implementation of numerous ***lidar stations in Europe.*** Lidar is used to determine range-resolved vertical profiles of aerosols optical parameters (such as the backscatter and extinction coefficient) with very high spatial and temporal resolution. The altitude of layers as well as their temporal evolutions are observed and further used as inputs in air mass trajectories models. Lidars are nevertheless limited in terms of sounding wavelengths and dynamic range One weak point still under debate is the classification of aerosol types. Identification of mixed aerosols is a critical issue, since different aerosol types have different effects on climate, visibility and health. For a full characterization of the aerosol distribution, lidar data have to be complemented by in situ (more physical information content) and integrated column (more spatial information content). This increases the level of confidence in the aerosol typing decisions and/or validates the lidar retrievals.
Presently different measurement techniques such as lidar and sun-sky photometry are used complementary for retrieval of height distributions of optical and microphysical properties of fine-mode and coarse-mode particles (Wagner J et al. 2013). This is able to provide a classification of the aerosols depicted. Recently it was developed the Lidar/Radiometer Inversion Code (**LIRIC**) and it analyses the profiles of elastic-backscatter signals measured with multiwavelength lidar and spectrally-resolved column-integrated particle optical properties from photometer observations in a synergistic way (Chaikovsky A. et al. 2012). LIRIC was designed as a universal code for processing of lidar/photometer network data, applicable to many different instrumental conditions and technical approaches. Another procedure is the Polarization Lidar Photometer Networking (***POLIPHON***) method (Ansmann A. et al. 2012). The POLIPHON technique allows the separation of the contributions of spherical particles (mostly fine-mode particles) and non-spherical particles (mostly coarse-mode particles) to the measured optical effects. This method is based on directly measured linear particle depolarization ratios.

- Scientific objectives

The project aims to perform an aerosols classification based on their optical and microphysical properties using a multiwavelength Raman lidar system in synergy with ground based instruments.
In order to achieve this, first I learnt how to perform measurements with the multiwavelength Raman depolarization lidar. The next goal was to get acquainted with the methods of reading and analysis of the measured data (Nicolae D. and Belegante L. 2013). For confirmation of aerosol depicted by lidar I used sunphotometer data, available on the AERONET (Aerosol Robotic Network) site.
The final goal is to correlate aerosol type and corresponding properties, in various atmospheric conditions (air transport paths, humidity, circulations) using measurements performed during June-July 2013 at RADO station.

- Reason for choosing station

I was an exchange student within the Erasmus program during the winter semester 2012/2013 at the University of Oradea, Romania when I found that RADO station could be an option to study aerosols using lidar. During that period I was preparing to write my thesis on the study of aerosols using lidar - determination of the boundary layer from remote sensing measurements. Supervisor of this work was Professor Petelski, who recommended me to contact RADO research station that is associated with the Institute of Oceanology in Sopot.

One of the most important factors was the location of the station in southern Romania, where the influence of dust from the Sahara is often seen, along with influence of biomass burning events in Russia or Ukraine. Also, it is a good opportunity to observe the difference in aerosol types between Poland and Romania, which are affected by different weather conditions and topography.

- Method and experimental set-up
  - a multi-wavelength Raman lidar (RALI) operating in the frame of EARLINET- provides vertical profiles of aerosol optical and microphysical parameters up to 15 Km high
  - 7-channels sunphotometer operating in the frame of the AERONET; continuous measurements during day time and good weather conditions
  - a C-Tof aerosol mass spectrometer able to perform continuous monitoring of the complete mass spectrum (1-800 amu), providing real-time size resolved chemical composition analysis of particulate matter;
  - a microwave radiometer that ensure accurate temperature, humidity and cloud liquid profiling in all weather conditions;

- Preliminary results and conclusions

Measurements have been taken during June-July 2013 using all available instruments but data analysis is still undergoing. The data processing algorithm (Nemuc et al. 2013; Nicolae et al. 2013) have been used for several days when several layers have been depicted in the RCS quicklooks.

This report presents a study case related to measurements on May 20, 2013. Range corrected signal time series up to 8 km altitude are represented in Fig. 1 below. Several layers can be observed from 2 km up 5km.

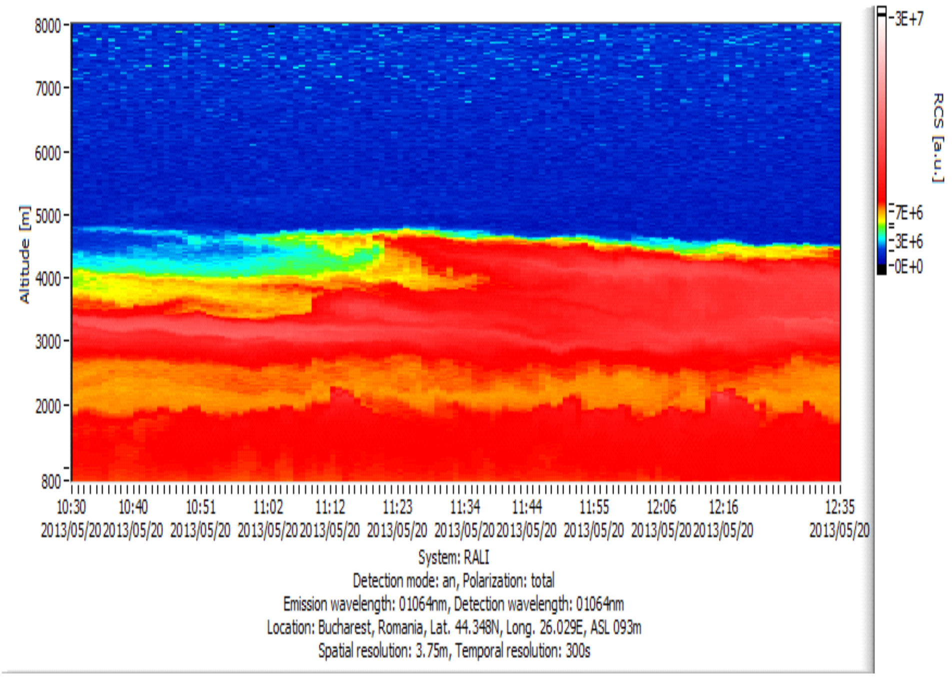
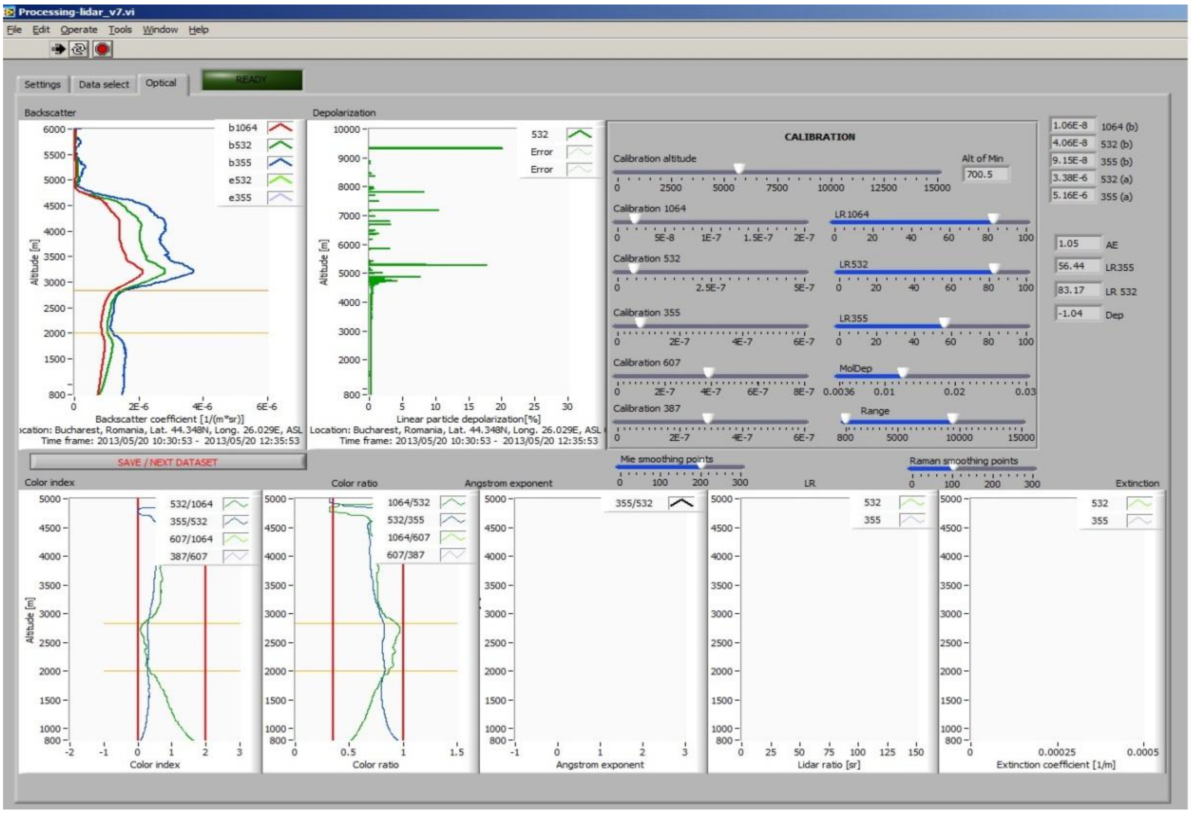


Figure 2 below shows the Labview screen of the data processing algorithm.



Mass concentration profiles for mixed aerosols have been calculated from multiwavelength depolarization Raman measurements, by considering low and high depolarizing components along with OPAC data (Hess et al. 1998). The mixture consists of two components with significantly different depolarization properties, urban/smoke and mineral dust and is described in details by Nemuc et al. 2013. Figure 3 below shows the results of this algorithm applied for measurements on May 20th 2013. It can be observed the dominance of the dust component between 3 and 4.5 km.

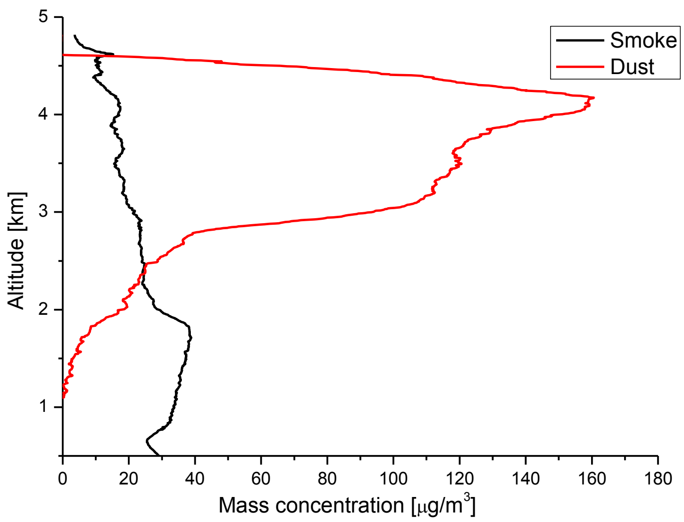


Fig. 3 Mass concentration separation on different components using lidar data and OPAC; Profiles are averaged over one hour 11:00–12:00 UTC during May20, 2013

Hysplit mass back trajectories confirmed the Saharan origin of air masses arriving above Romania at 3 and 4 km on May 20th 2013 as can be observed in the figure 4.

Data retrieved from the sunphotometer measurements on May 20, 2013 (see Figure 5 a,b,c) showed an increased value for the AOD at all wavelengths and a pronounced coarse mode in the size distribution, along with Angstrom Exponent values at about 0.4, characteristics of dust influence in the atmospheric column (Dubovik et al. 2002).

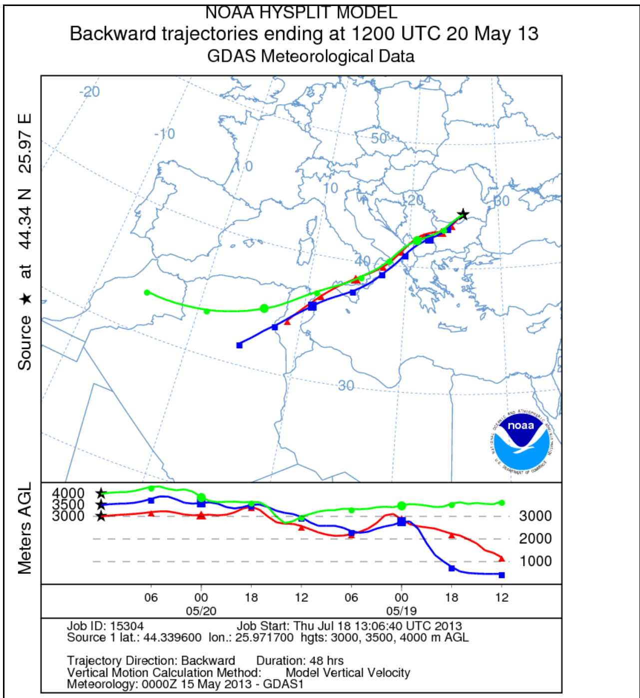


Fig.4 Air masses arriving at 3,3.5 and 4 km above RADO station on May20, 2013

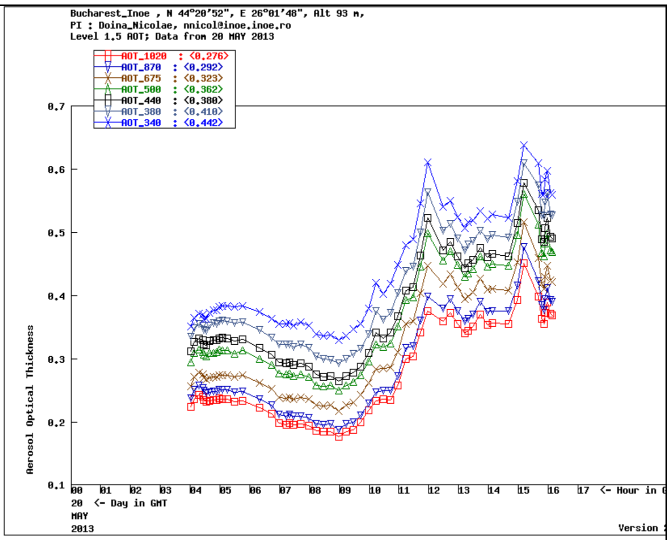


Fig.5a Sunphotometer Aerosol Optical depth(AOD) time series on May 20, 2013

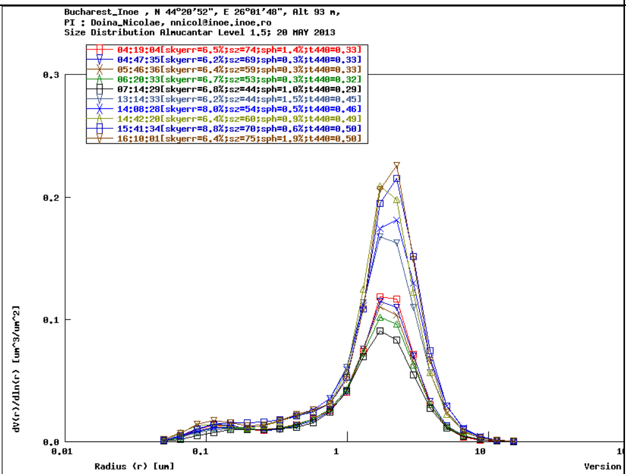


Fig 5b Column integrated size distribution as derived from sunphotometer measurements on May 20, 2013

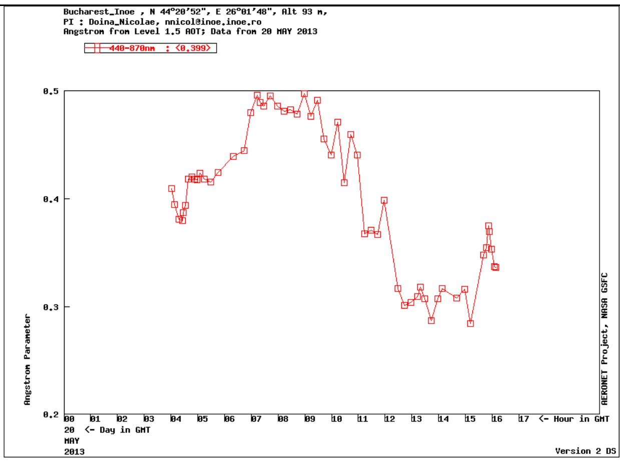


Fig.5c Angstrom exponent time series derived from sunphotometer measurements on May20, 2013

Outcome and future studies

I will continue to study the second degree, Master complementary in terms of meteorology and protection of the atmosphere at the University of Wroclaw. If possible, I would have the research practice at the Institute of Oceanology, as well as at the Institute of Meteorology and Water Management in Wroclaw during my stay in Poland, but I hope that I would be admitted to practice in the framework of the Erasmus program of which I am going to apply within the upcoming new semester. I will try to continue the work I started by applying these techniques at a research station in which they are carried out measurements related to the atmosphere and in particular aerosols. The data obtained from the measurements during the training in RADO will be analyzed in details and I'm going to use all the acquired expertise for my master thesis focusing on the analysis of the effects of atmospheric aerosols on weather conditions at various locations in Europe - taking into account the air masses trajectories.

- References

Ansmann, A., Seifert, P., Tesche, M., Wandinger, U., Profiling of fine and coarse particle mass: case studies of Saharan dust and Eyjafjallajokull/Grimsvotn volcanic plumes, Atmos.Chem. Phys., 12, 9399–9415, doi:10.5194/acp-12-9399-2012, 2012

Chaikovsky, A., Dubovik, O., Goloub, P., Tanre, D., Pappalardo, G., Wandinger, U., Chaikovskaya, L., Denisov, S., Grudo, Y., Lopatsin, A., Karol, Y., Lapyonok, T., Korol, M.,Osipenko, F., Savitski, D., Slesar, A., Apituley, A., Arboledas, L. A., Binietoglou, I., Kokkalis, P., Granados Munoz, M. J., Papayannis, A., Perrone, M. R., Pietruczuk, A., Pisani, G., Rocadenbosch, F., Sicard, M., De Tomasi, F., Wagner, J., Wang, X.: Algorithm and software for the retrieval of vertical aerosol properties using combined lidar/radiometer data: Dissemination in EARLINET, in: Proceedings of the 26th International Laser and Radar Conference/26th International Laser and Radar Conference, 1, Porto Heli, Greece, 25–29 June 2012, 399–402, 2012

Dubovik O., B.N. Holben, T.F. Eck, A. Smirnov, Y.J. Kaufman, M.D. King and I. Slutsker, Variability of absorption and optical properties of key aerosol types observed in worldwide locations, *J. Atmos. Sci.*, 59, 590–608, 2002

IPCC 2013 Working group 1, Chapter 7 Clouds and aerosols

Hess, M., Koepke, P., and Schult, I.: Optical Properties of Aerosols and Clouds: The Software 10 Package OPAC, B. Am. Meteorol. Soc., 79, 831–844, 1998.

Nemuc, A., Vasilescu, J., Talianu, C., Belegante, L., and Nicolae, D.: Assessment of aerosol's mass concentrations from measured linear particle depolarization ratio (vertically resolved) and simulations, Atmos. Meas. Tech. Discuss., 6, 5923-5957, doi:10.5194/amtd-6-5923-2013, 2013

Nicolae D., A. Nemuc, D. Müller, C. Talianu, J. Vasilescu, L. Belegante and A. Kolgotin, Characterization of fresh and aged biomass burning events using multiwavelength Raman lidar and mass spectrometry, *J. Geophys. Res. Atmos.*, 118, DOI:10.1002/jgrd.50324, 2013

Nicolae D., C. Talianu, L. Belegante 2013 Introduction to atmospheric remote sensing. Lecture notes

Seinfeld, Pandis, 1997) 3. J.H. Seinfeld, S.N. Pandis, „Atmospheric Chemistry and Physics“, Wiley, New York 1997

T. Zieliński, 2006) T. Zieliński „Fizyczne właściwości przywodnej warstwy aerozolu w brzegowym obszarze morza” Rozprawy i monografie 18/2006 Polska Akademia Nauk Instytut Oceanologii w Sopocie

http://ready.arl.noaa.gov/HYSPLIT_traj.php

Wagner, J., Ansmann, A., Wandinger, U., Seifert, P., Schwarz, A., Tesche, M., Chaikovsky, A., Dubovik, O., Evaluation of the Lidar/Radiometer Inversion Code (LIRIC) to determine microphysical properties of volcanic and desert dust, Atmos. Meas. Tech. Discuss., 6, 911-948, amtd/2013-6-911, 2013