AEROSOLS, CLOUDS AND TRACE GASSES RESEARCH INFRASTRUCTURE NETWORK (ACTRIS)

Research Infrastructure Action of the FP7 Capacities Specific Program for Integrating Activities, Grant Agreement # 262254

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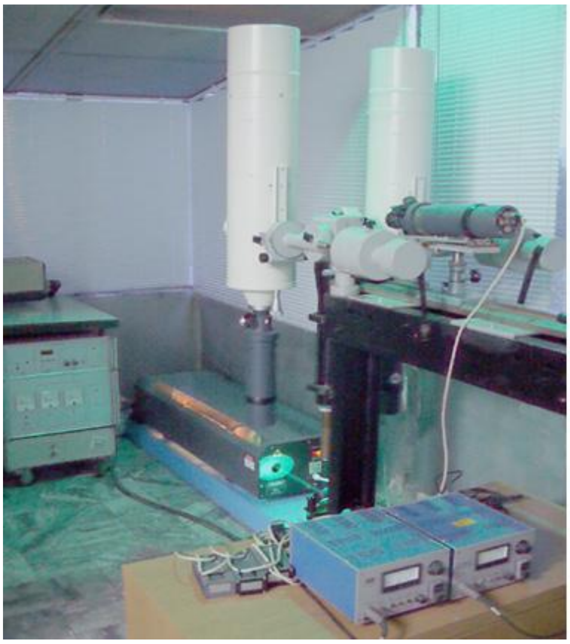
ACTRIS (Aerosols, Clouds, and Trace gasses Research InfraStructure Network) is a European Project aiming at integrating European ground-based stations equipped with advanced atmospheric probing instrumentation for aerosols, clouds, and short-lived gas-phase species. ACTRIS has an essential role in supporting the acquisition of new knowledge and in solving issues related to climate changes, air-quality, and long-range transport of pollutants. ACTRIS is building the next generation of the ground-based component of the EU observing system by integrating three existing research infrastructures EUSAAR, EARLINET, CLOUDNET, and a new trace-gas network component into a single coordinated framework. ACTRIS is funded by the European Community – Research Infrastructure Action of the FP7 Capacities Specific Program for Integrating Activities under ACTRIS Grant Agreement No. 262254. The project started on 1/4/2011 for a four-year period.

The main objectives of ACTRIS are:

- To provide long-term observational data and to substantially increase the amount of high-quality data relevant to climate and air-quality research on a regional scale produced by standardized or comparable procedures throughout the network.
- To provide a coordinated framework for transnational access to advanced European infrastructures for atmospheric research thus strengthening high-quality collaboration in and outside the EU and access to high-quality information and services for the user communities (research, environmental protection agencies, etc.).
- To develop new integration tools to fully exploit the use of multiple atmospheric techniques at ground-based stations, in particular for the calibration/validation/integration of satellite sensors and for the improvement of the parameterizations used in global and regional scale climate and air-quality models. ACTRIS aims at providing time series of climate and air-quality related variables not directly measured, which are presently not available through the existing data centers.
- To enhance the training of new scientists and new users, in particular students, young scientists and scientists from East European and non-EU developing countries in the field of atmospheric observation.
- To promote the development of new technologies for atmospheric observation of aerosols, clouds and trace-gasses through close partnership with EU companies. ACTRIS aims at contributing to more than four new operating standards for atmospheric monitoring by the end of the project.

The ACTRIS Consortium is formed by 28 contractors, representing 19 countries across Europe, as Italy, France, Germany, Spain, Bulgaria, Greece, The Netherlands, Romania, Poland, Switzerland, Norway, United Kingdom, Belgium, Hungary, etc.



(a)

(b)

Figure 1. Photographs of the CuBr-vapor (a) and Nd:YAG (b) laser-based aerosol lidars at the Laser Radar Laboratory (IE-BAS) involved in the European Lidar Network measurement programs.

Lidar remote sensing of the atmosphere in the framework of the European Lidar Network (EARLINET)

The lidar station in Bulgaria is positioned in the Laser Radar Laboratory of the Institute of Electronics of the Bulgarian Academy of Sciences (IE-BAS). The Institute is located in the urban area of the capital city of Sofia (42^{o}39’14”North, 23^{o}23’14”East), at about 550 m above sea level (ASL). Sofia lidar station is a member of the European Lidar Network (EARLINET) and has two functional lidars [1]. The first one is based on a CuBr-vapor laser, and the other one, on a Nd:YAG laser (see figure 1). Both lidars are performing tasks of the work packages (WP) of ACTRIS, in which the European Lidar Network is included. Those are:

- WP2: Remote sensing of the vertical aerosol distribution;
- WP20: Lidar and sun-photometer – improved instruments, integrated observation strategies and algorithms for the retrieval of advanced aerosol microphysical products;
- WP22: A framework for cloud-aerosol interaction studies.

The investigations at Sofia Lidar Station covered four categories of measurements, as follows:

1. Regular lidar measurements with the objective to establish a common database of atmospheric aerosol backscatter coefficient profiles [1-3];
2. Measurements in the framework of cooperation with satellite missions with the objective of a detailed comparison of ground-based and space-borne lidar data sets over Europe. These measurements are related to the *Quid pro Quo* (QPQ) validation measurements of the project Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations CALIPSO (http://calipsovalidation.hamptonu. edu/QPQ_plan062206.htm). CALIPSO is a free-flying space lidar providing data on atmospheric clouds and aerosols needed for climate studies. The ground EARLINET stations were deemed to be an optimal tool for validating CALIPSO lidar data and

providing the necessary information to fully exploit the information from this mission [1,4];
3. Observation of special phenomena, such as unusually high concentrations of aerosols in the troposphere. Their appearance may be due to transportation of dust from Sahara over the Mediterranean Sea to Europe, volcanic eruptions, formation of smoke layers as a result of forest or industrial fires, intense photochemical smog, etc. [1,3,5,6];
4. Lidar measurements combined with simultaneous sun-photometer and ceilometer measurements with the aim of improving the lidar's daytime capabilities, and developing and applying integrated lidar and sun-photometer observation strategies for for the best use of complementary information on atmospheric aerosols gained from active and passive remote-sensing instruments and for retrieving advanced information on the aerosol microphysics from multi-spectral columnar sun-photometer and height-resolved multi-wavelength lidar observations [7-9].

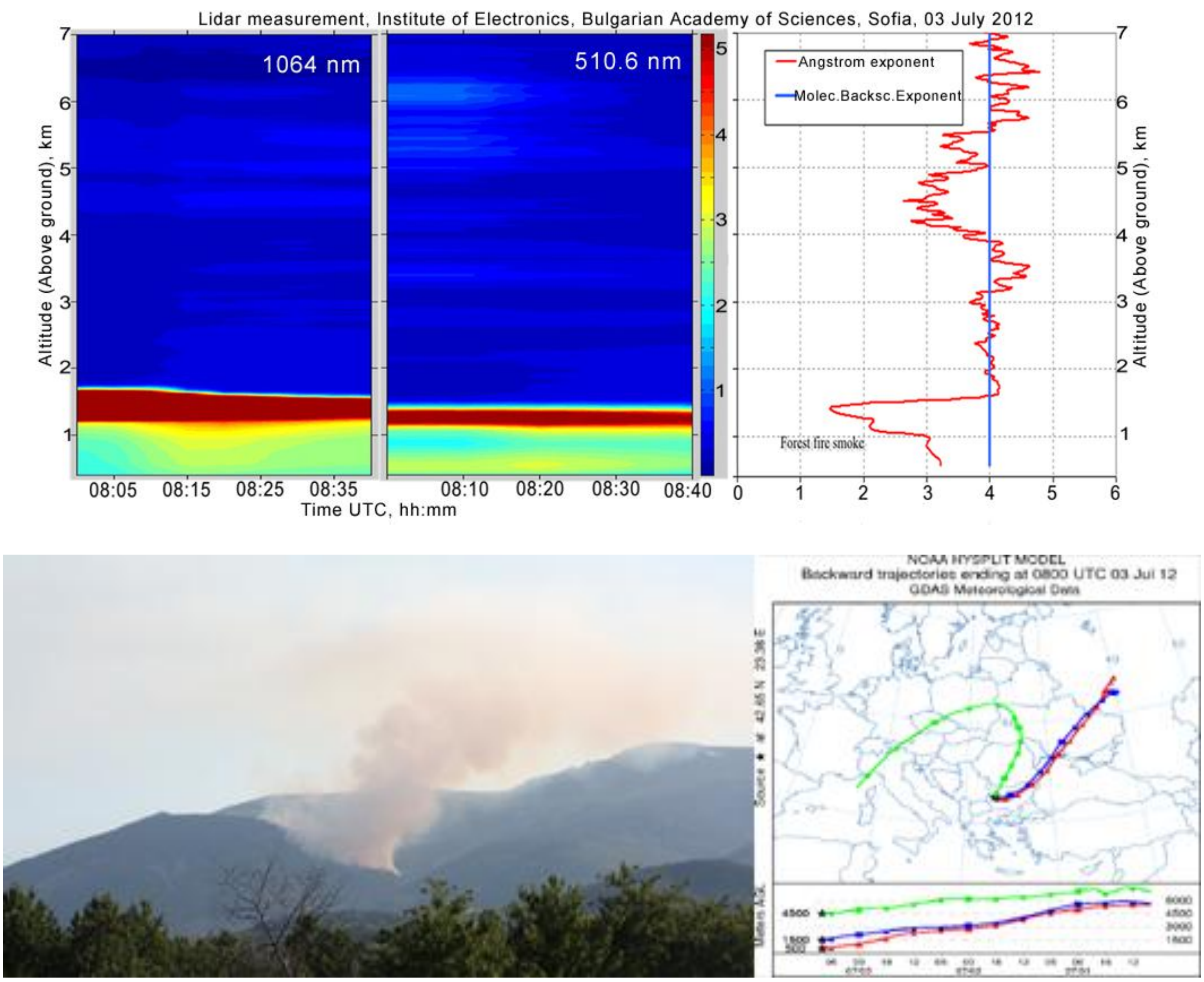


Figure 2. Lidar observations of a smoke layer spreading from a Vitosha forest fire in the atmosphere over Sofia (July 2012).

We present below some illustrative results of lidar measurements conducted in IE-BAS in 2012 during events of polluting aerosol loadings. The multi-panel figure 2 shows results of lidar observations of a wild forest fire on July 3, 2012, in the Vitosha Mountain near Sofia.

The measurements were carried out by using the two lidars mentioned above. The lidar wavelengths used were 510.6 nm by the CuBr-vapor laser and 1064 nm by the Nd:YAG laser. The photograph shows an episode of the smoke plume rising over the fire site and spreading along the mountain crest. The largest part of the aerosol field remained invisible because of the low concentration of smoke particulates in the air far from the source. The signals backscattered by the aerosol, however, were reliably detected by the highly sensitive lidar receivers, resulting in the intense red layers seen on the height-time color map diagrams displayed above the photograph.

A vertical profile of the so-called Ångström exponent is shown in the left upper panel of the figure. At the altitudes where the densest smoke layer appears (1 – 1.5 km), the Ångström exponent assumes values of about 1.5, indicating the presence of coarse particles (soot) associated with the near fire source. At altitudes > 2 km, well above the smoke layer, the atmosphere is clear as seen from the color maps and, correspondingly, the Ångström exponent maintains nearly constant typical values of about 4.

The results obtained show that the smoke aerosols ejected into the atmosphere by the fire in Vitosha Mountain on 3 July 2012 have spread predominantly westward. This is supported by the air-mass transport model (NOAA ARL HYSPLIT). The smoke layer has also expanded over the whole territory of the city of Sofia at altitudes of 1.5 km. Because of the absence of highly dynamic atmospheric processes, the smoke layer has remained at a nearly constant altitude, without extending considerably down to the surface while gradually moving away from the urban zone.

Two-wavelength (1064/532 nm) elastic-scatter lidar observations were also performed on the spatial distribution, composition, and temporal evolution over Sofia of atmospheric aerosols produced by burning biomass. The two upper panels in figure 3 present height-time coordinate color maps of range-corrected lidar data at 532 nm and 1064 nm related to lidar observation of a forest fire in Vitosha Mountain on October 9, 2012. The temporal evolution of the otherwise invisible smoke aerosol components spreading down close to the surface of the city area is clearly seen [2].

Another case of biomass-burning aerosol intrusion into the atmosphere above Sofia was detected and characterized by means of the Nd:YAG-based lidar on August 6, 2012. By using air-transport modeling data, the aerosols observed were identified as being more than 10-day-aged organic smoke originating from wild forest fires raging in the USA in July 2012, and subjected to trans-Atlantic long-range transport driven by the Northern Hemisphere Polar Jet Stream. A backscatter-related Ångström exponents (BAE)-occurrence frequency distribution analysis of the BMB aerosols considered was conducted and used as an indirect approach to a qualitative characterization of the aerosol particle-size distribution. The lower left panel of figure 3 shows BAE distributions of the fire smoke layer (case B) and of other aerosols observed. Processes of coagulation and aggregation of the finest particle size modes were thus found to have taken place during the long aging time between the smoke emission and the lidar observation. The results can contribute to the better understanding of the composition and size evolution of biomass aerosols subject to long-range transport.

Lidar observations of close-to-the-surface atmospheric domains located over a heterogeneous terrain, including adjacent city, plain, and mountain zones, were carried out by using the two aerosol channels of the Nd:YAG-based lidar. The measurements revealed a strong and specific influence of the underlying area orography on the optical parameters and dynamical behavior of the atmospheric aerosols, resulting in an unusually distinct zonal sectioning of these characteristics along the probing laser beam. The use of

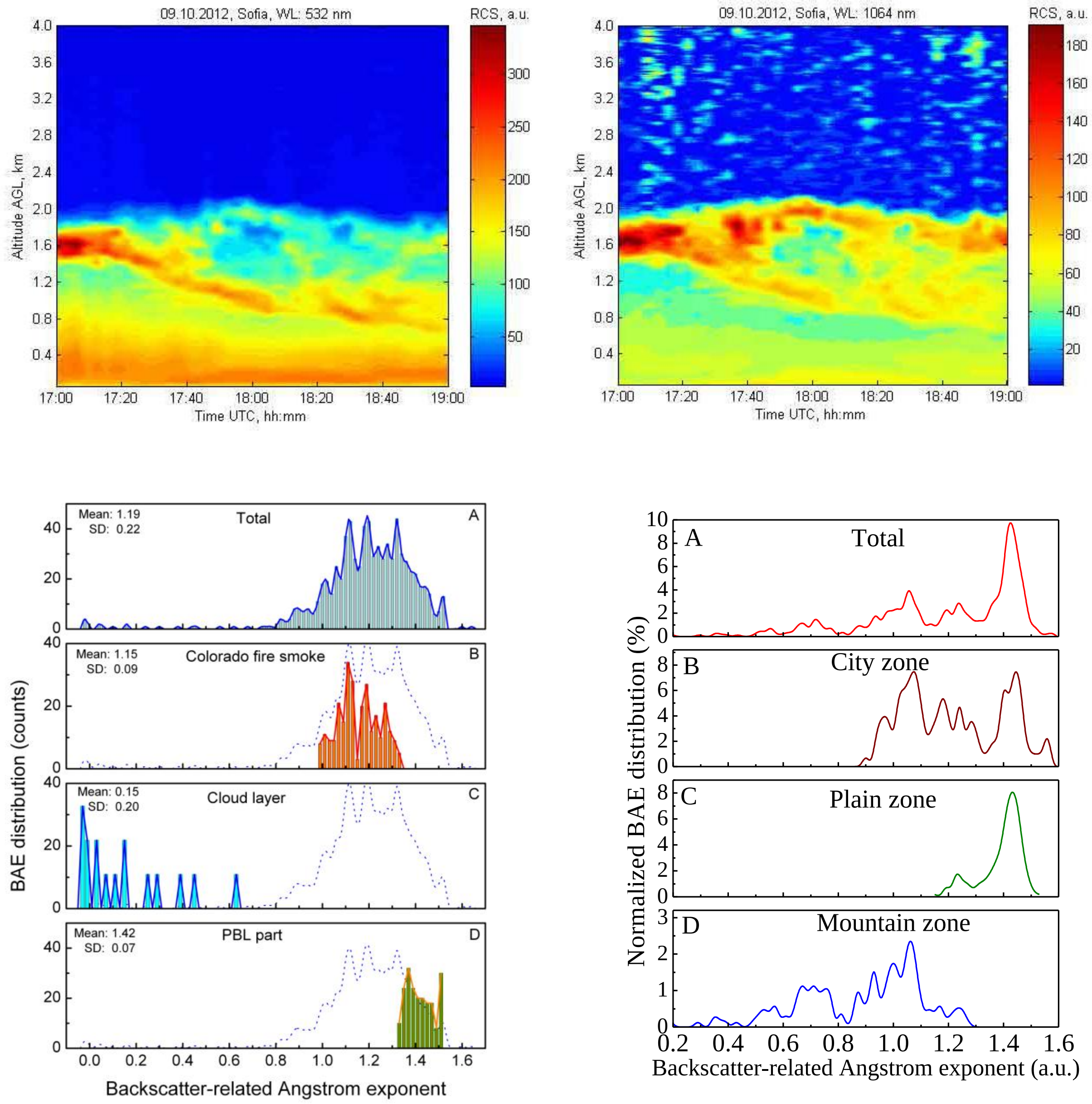


Figure 3. Range-time diagrams of the range-corrected lidar signals (RCS) corresponding to 532 nm (upper left) and 1064 nm (upper right), illustrating smoke plume evolution resulting from the forest fire in Vitosha Mountain on 09.10.2012. Retrieved partial, zonal, and total distribution profiles of the backscatter-related Ångström exponent from a fire smoke layer transported over the Atlantic and detected over Sofia on 06.08.2012 (lower left) and a quasi-horizontal lidar study of close-to-the-surface aerosol layers over a heterogeneous orographic region (lower right).

two considerably separated lidar wavelengths, 532 nm and 1064 nm, allowed the fine and coarse aerosol fractions to be distinguished and characterized. A study of the aerosol particle mode composition was performed by range-resolved profiling of the BAE and their frequency-count analysis. The distributions obtained are shown in the lower right panel of figure 3, revealing the qualitative aerosol particle size distributions in terms of BAE for the differentiated orographic zones, as well as the overall one.

The results presented above show that two-wavelength lidar observations offer good opportunities for range- and time-resolved characterization of the spatial distribution and temporal dynamics of both the fine and coarse mode aerosol fractions over large areas, based mainly on lidar data. In combination with frequency-count analysis of BAE, air-mass transport modeling data, and minor meteorological data, the two-wavelength lidar approach allows one to make valid assumptions concerning the type, origin, and approximate size distribution of the aerosol particles, as well as to identify the aerosol/pollution sources as a part of the air-quality monitoring.

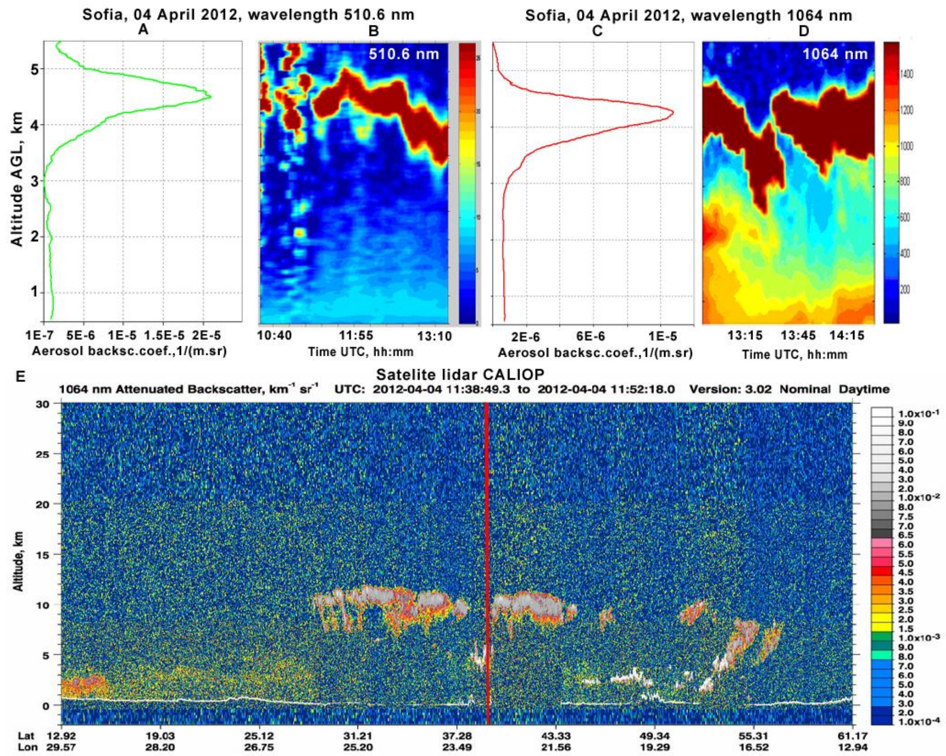


Figure 4. Lidar observation on April 4, 2012: A) retrieved backscatter coefficient profile and B) range-corrected lidar signal at wavelength 510.6 nm; C) and D) – the same, respectively, at wavelength 1064 nm; E) backscatter coefficient as calculated from data of the CALIPSO satellite lidar. The vertical red line marks the closest position to Sofia Lidar Station of the satellite's trajectory projection.

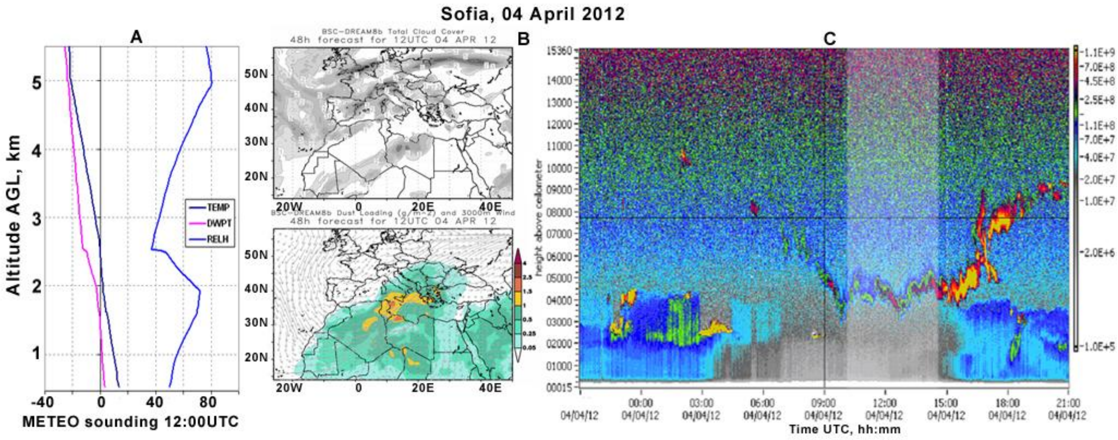


Figure 5. METEO sounding at 12:00 h UTC on April 4, 2012 A), forecast maps of cloud cover and Sahara dust load B), and ceilometer time-height diagram C) with blank bands indicating intervals of simultaneous lidar measurements.

Saharan dust transport

Lidar observations of special phenomena, such as unusually high concentrations of aerosols in the troposphere, were carried out upon notification by the program coordinator for upcoming dust events above the territory of Europe. The notification is based on satellite observations and weather forecasts provided by the Atmospheric Modeling and Weather Forecasting Group of the National Technical University of Athens (http://forecast.uoa.gr/) and the Forecast System of Barcelona Supercomputing Center (http://www.bsc.es/projects/earthscience/DREAM).

Following such a notification, we performed a series of lidar measurements from April 2 to 7, 2012, presented below [3].

The backward trajectories for April 4, 2012, show a well-expressed transport of air mass from North Africa to Europe. Unfortunately, we observed again a dense cloud cover during our lidar measurements presented on figure 4. On April 4, the CALIPSO satellite overflew the Balkans and at 11:40 h UTC the projection of its trajectory passed close to Sofia. The graph of the lidar atmospheric backscatter coefficient, measured by CALIPSO and provided by NASA, is presented in figure 4 E. As it is clearly seen, the satellite lidar provided data for the atmospheric backscatter coefficient from altitudes of 30 km above see level (ASL) to the thick cloud cover over the Balkans at 10 km and 5 km ASL. Data on the atmospheric stratification from the ground to the bottom of the same thick cloud were provided by our ground-based lidar station during the lidar observation on April 4. Both lidars registered a cloud layer, very probably a wet Sahara dust layer, at altitudes ~4 – 5 km AGL. This corresponded well to the lower aerosol layers at 5 km ASL observed by the satellite lidar from above when the cloud cover at 10 km disappeared.

Figure 5 presents the meteorological situation during th lidar observation on April 4. The close positions of the plots of the atmospheric temperature and the dew point, and the highest value of ~80 % of the atmospheric humidity, point to the altitude of 5 km being critical for water vapor condensation. We, therefore, concluded to have registered the forecast dust transport on April 4 (figure 5B) as a wet aerosol layer at an altitude of ~4 – 5 km AGL, which was also confirmed by the time-height diagram of ceilometer data (figure 5 C).

Conclusions

The new ACTRIS project implemented under the FP-7 EU Program and some of the experimental results of the ACTRIS team at IE-BAS were briefly presented. The high effectiveness was demonstrated of the lidar measurements performed by the two lidars of Sofia Lidar Station certified in EARLINET. We detected and analyzed different atmospheric processes (Saharan dust, volcanic ash, fires, etc., above Bulgarian territory originating from three continents (Europe, Africa and Northern America). Moreover, we performed a large number of lidar measurements on the local distribution of the aerosol pollution due to fires in Vitosha Mountain in July 2012. We showed that because of the absence of highly dynamic atmospheric processes during this period, the smoke layers from the Vitosha fires remained at a nearly constant altitude without considerable spread down to the surface and gradually moved away from the urban zone. Thus, Sofia (IE-BAS) Lidar Station was used for the purposes of both the ACTRIS measurements within the European Lidar Network and local atmospheric monoring.

Acknowledgements

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