Autoreferat
Curriculum Vitae

1. Name and Surname.

   Aleksander Pietruczuk

2. Diplomas, scientific / art degrees - with the name, place and year, the thesis title.

   Ph.D. graduate in Physical Sciences, specialization: experimental physics, optics, Warsaw 2005, thesis title: Investigation of electron – excited atoms collisions.

3. Information on previous employment in scientific / artistic centers.

Since June 2005	adjunct in Institute of Geophysics PAS (since 2008 head of Central Geophysical Observatory IGF PAS)
VI 2011 – VI 2013	adjunct in Institute of Geophysics UW (part time job for ACTRIS project)
2007 - 2011	development of physics course and giving a lecture „Physics" for students of Wyższa Szkołya Informatyki, Zarządzania i Administracji w Warszawie, employment as a civil law agreement
2004 - 2005	intern physicist at the Institute of High Pressure PAS

4. Indication of achievement arising from Art. 16 sec. 2 of the Act from 14 March 2003 on the academic degrees and the academic title as well as on the degrees and the title within the scope of art D. U. No. 65, pos. 595, as amended

5.

   a) Title of scientific/artistic achievement,

      „Origin and properties of aerosols in Central Poland."

   b) (autor/autors, title/titles of publications, year of issue, editor),

      Pietruczuk A. (2013); Short term variability of aerosol optical thickness at Belsk for the period 2002–2010, Atmospheric Environment 79, pp. 744-750.

      Pietruczuk A., J. Jarosławski (2013); Analysis of particulate matter concentrations in mazovia region, central poland, based on 2007–2010 data, Acta Geophysica 61 (2), pp. 445 – 462.

      Pietruczuk A., A. Chaikovsky (2012); Variability of Aerosol Properties during the 2007-2010 Spring Seasons over Central Europe, Acta Geophysica vol. 60 (5), 2012, pp. 1338-1358.

      Pietruczuk A., Krzyscin JW, Jaroslawski J, Podgorski J, Sobolewski P, Wink J., (2010); Eyjafjallajokull volcano ash observed over Belsk (52 degrees N, 21 degrees E), Poland, in April 2010, INTERNATIONAL JOURNAL OF REMOTE SENSING 31 (15): 3981-3986.

Jarosławski J., **A. Pietruczuk**, (2010); On the origin of seasonal variation of aerosol optical thickness in UV range over Belsk, Poland, Acta Geophysica 58 (6): 1134 – 1146.

Pietruczuk A., Podgorski J, (2009); The lidar ratio derived from sun-photometer measurements at Belsk Geophysical Observatory, Acta Geophysica 57 (2), pp 476-493.

Pietruczuk A., J. Jarosławskia (2008), An alternative method for aerosol optical thickness retrieval in the UV range, Journal of Atmospheric and Solar-Terrestrial Physics 70 (7), pp 973-979.

c) discussion of the scientific / artistic works and results with a discussion of their possible use.

Atmospheric aerosols are some of the less recognized climate relevant atmospheric constituents. They influences Earth radiation budget reducing solar radiation reaching Earth surface. Aerosol direct effect is related to scattering and absorption of solar radiation, especially in biologically active UV part of the spectrum. Indirect climate effect is due to aerosols role in cloud formation and dissipation. While the impact of aerosols on climate can be considered as a beneficial (cooling effect) their influence on human life is negative. Exposure to elevated concentrations of aerosol is associated with increased number if cardiovascular and respiratory diseases. That is way aerosols concentration are monitored by states agencies and there are limits of particulate matter concentrations established by law.

Satellite measurements and model estimations show that Central Europe and especially Poland is a hot spot of increased aerosol optical thickness. It is probably related to structure of power production in Poland which bases on coal combustion. Due to lack of literature data regarding aerosol properties in Central Poland it was decided to examine aerosol optical properties and PM10 concentrations depending on the direction of airmass advection. It allowed to estimate aerosols' source regions. Short term variability of aerosol optical properties as well as studies of modification of them was also performed. Analysis of aerosol optical thickness in UV range required prior development of the new method of estimation of aerosols' optical properties in UV. Moreover, spring episodes of elevated aerosols concentration were analyzed by means of different measurement techniques. This investigation shows how different types of aerosols are transported in troposphere and how they influenced PM10 concentrations and aerosol optical thickness.

Paper (Pietruczuk and Jaroslawski, 2008) describes the new method for aerosol optical thickness retrieval in UV range. The method bases on microphysical parameters taken from Sun-photometric measurements of aerosols and Mie calculations. Calculated optical thicknesses in UV were compared to that measured by Brewer spectrophotometer.

Sun-photometer performs direct Sun and scattered radiation measurements. Aerosol optical thicknesses are estimated from direct Sun measurements whilst scattered radiation is used to estimate aerosol microphysical properties, like aerosol size distribution and refractive index at 440, 675, 870 and 1020 nm. Knowledge about aerosol size distribution and refractive index allows to calculate aerosol optical properties. However, proper calculation required prior extrapolation of refractive index into UV range. Aerosol optical thicknesses were calculated for wavelengths from visible and UV part of spectrum. Optical

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thicknesses from visible part of the spectrum were used to validate the method. Optical thicknesses from UV range were compared to direct measurements by Brewer spectrophotometer. Calculated values were 8% larger than direct Brewer measurements. It is much better than classical estimation with Angstrom exponent which gives 24% larger values than direct measurements.

Application of this method to AERONET photometers could extend area of aerosol measurements in UV range because AERONET is a worldwide network covering whole continents and selected isolated islands.

I estimate my contribution to this paper as 60%, including, among others:

- Development of the method and Mie calculations,
- participation in CIMEL Sun-photometer measurements,
- analysis of obtained results,
- preparation of the manuscript.

Direct Sun measurements of aerosol optical thickness in UV and visible range are analyzed in the paper (Jarosławski and Pietruczuk, 2010). Direct CIMEL and Brewer measurements were compared with values calculated by means of method described by Pietruczuk and Jaroslawski (2008). Statistical analysis of optical thicknesses estimated with both methods shows good agreement between them. In this study series of measurements taken in the period 2002 – 2007 was used. This timeseries was used to study seasonal variability of aerosol optical thickness. Annual distribution of AOT in Belsk has two peaks in April an August, whilst climatological data for Western Europe have only one maximum in August.

Belsk observatory is located in rural area which is not affected by local aerosol sources. In this work potential aerosol source areas were appointed by means of statistical analysis of airmass backward trajectories. Cluster analysis was applied to backward trajectories to find main direction of airmass advection and then statistical parameter of AOT for each direction were calculated. The largest values of AOT were obtained for east direction during spring season. It is caused by advection of biomass burning products from Eastern Europe during seasonal episodes of fires related to agricultural activity. Such a thesis was confirmed by analysis of individual episodes and analysis of fire distribution measured by satellite based instruments.

I estimate my contribution to this paper as 40%, including, among others:

- measurements of aerosol optical properties by means of CIMEL photometer, analysis of data,
- Mie calculations and analysis of results,
- calculation of airmass backward trajectories and cluster analysis,
- preparation of the manuscript.

Similarly to analysis of AOT in UV range lidar ratio (LR) related to airmass history was analyzed in paper (Pietruczuk and Podgórski, 2009). Lidar ratio is the ratio of aerosol extinction to aerosol backscattering coefficient. It is crucial

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parameter in estimation of aerosol backscattering coefficient from lidar measurements. Lidar ratio depends on aerosol type and considering airmass as a homogenous one (on aerosol type) sun-photometric technique was used to estimate LR values in this study. LR values were calculated using Mie theory and aerosol microphysical parameters measured by Prede POM 01L Sun-photometer.

Frequency count distributions for each season and direction of airmass advection were analyzed in this work. Bimodal distributions were observed which suggests presence at least two types of aerosol over Belsk. Comparing obtained values to the literature continental and absorbing aerosols types were recognized. Absorbing aerosol could originate from urban/industrial sources or from biomass burning. Absorbing aerosol was more frequent during winter season. The largest LR values were observed for winder season and west direction. Small value of lidar ratio values typical for continental aerosol were observed during summer. During winter season the smallest values of LR were registered for north direction. It is probably related to lack of active during winter aerosol sources north of Central Poland.

Results obtained in this work allowed to characterize aerosol over Central Poland. Moreover these values are used in elaboration of LIDARr measurements taken at Belsk.

I estimate my contribution to this paper as 75%, including, among others:

- sun-photometric measurements,
- Mie calculations of lidar ratio,
- Calculation of backward trajectories and cluster analysis,
- Analysis of obtained results
- Preparation of the manuscript.

Seasonal spring episodes of aerosol transport from Eastern Europe were analyzed in paper (Pietruczuk i Chaikovsky, 2012). In this paper measurements of aerosol optical properties taken at Belsk and Minsk, Belarus as well as measurements of particulate matter concentrations taken at Belsk and Berezinski Natural Reserve at Belarus were used. Moreover analysis of measurements data was supported by airmass backward trajectory analysis and analysis of NAAPS model results.

A surprising coincidence of elevated PM10 concentrations registered at background stations at Belsk and Berezinsky Natural Reserve was found. In most cases NAAPS model predicted some aerosol over Poland and Belarus in this time. Large values of aerosol optical thickness were observed together with large values of PM10 concentrations. In case of Belarusian station such increase was 50% at 1020 nm and 66% at 440 nm. However, in case of Belsk such increase was 18 and 33 % respectively. There was no significant deviation from the mean in case of Angstrom exponent. Good correlation between aerosol optical thickness and PM10 concentration was also found during episodes of aerosol transport. Such correlation was much slower during summer time when aerosol transport was not observed. It is worth to note that anti-correlation between monthly values of PM10 concentration and aerosol optical thickness was found in work of Zawadzka et al. (2013). This negative correlation is quite obvious when one takes into account annual variation of parameters, maximum of PM10 during winter and maximum of aerosol optical thickness during summer. It is caused by specific meteorological conditions and aerosol emissions. Especially during wintertime presence of inversions and low boundary layer coincides with increased aerosol emissions. It causes accumulation of aerosols in thin atmospheric layer, high PM10 concentrations and low values of AOT due to relatively thin atmospheric layer. While in the spring and summer inversions are not observed so frequent as well as accumulation of aerosol next to Earths' surface does not take place. It causes good correlation between these values during spring and summer.

In addition to statistical analysis case studies were performed. These studies were supported by analysis of LIDAR measurements, analysis of airmass backward trajectories and predictions of NAAPS model. It was found that during observation of elevated PM10 concentrations LIDAR measurements shown larger amount of aerosol in planetary boundary layer or just over it. Sun-photometric measurements indicated increased AOT values during this time. Analysis of models results allowed to identify aerosols as smoke aerosol originating from eastern Belarus and Ukraine. Transport of biomass burning products was accompanied by episodes of Saharan dust transport. Saharan dust was transported in free troposphere and according to backward trajectory analysis originated from north Africa. In case of transport of Saharan dust only elevated concentrations of PM10 were not observed.

I estimate my contribution to this paper as 75%, including, among others:

- Sun-photometric and LIDAR measurements at Belsk,
- Calculation of backward trajectories,
- Analysis of results,
- Preparation of the manuscript.

Paper of Pietruczuk and Jaroslawski (2013) analyzes PM10 concentrations at four stations at Mazovia region. Potential source regions of PM were also appointed in this work.

Four station were chosen for future analysis:

- Warsaw Kerb station (Warszawa Komunikacyjna) – station affected by traffic,
- Warszawa Ursynow – urban area without industry (urban background),
- Radom – urban area,
- Belsk – rural station (regional background).

Statistical analysis of frequency count distributions indicated that PM10 concentrations are the same at Belsk and Ursynow station, however larger then observed at other similar stations in Europe. Estimated background concentration was also higher then reported in literature for Europe. The largest concentrations of PM10 were observed at Kerb station and were 30% higher then those registered at other stations. Slight increase of annual mean concentration was observed as well as increase of number of exceedances of limit concentration. The larger number of exceedances was observed at Kerb station and decreased with population density and traffic. Similarity between

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Belsk and Ursynow stations shows that PM10 concentrations are similar on large area and only traffic can increase them. It is probably caused by structure of heat production and distribution of main aerosol sources in Poland. Centralized heat making by combustion of fossil fuels is a main source of particulate matter in Mazovia. That is indicated for example by annual variability of PM10 concentration with maximum during winter. This maxima is due to favorable meteorological conditions like high pressure systems and inversions which causes accumulation of particulate matter making smog episodes. Power plants dominate in Warsaw and Radom and domestic heating dominates only suburban area. Centralized heat production makes that PM10 concentration depends on traffic and are less dependent on population density. Performed analysis of airmass trajectories shoes that larger concentrations of PM10 are associated with slow moving airmasses from south direction whilst lower concentrations are registered during advection of fast moving airmass originating form north Atlantic. This indicates that aerosol has mainly local source placed south of Warsaw and it is source active mainly during winter.

Annual variability indicates additional spring maximum in PM10 concentrations which is connected to episodes of long range transport of aerosols. These episodes are responsible for 18% exceedances at background stations.

I estimate my contribution to this paper as 60%, including, among others:

- Statistical analysis of PM10 concentrations,
- Calculation of backward trajectories and statistical analysis of them,
- Data analysis and preparation of the manuscript.

Specific type of aerosol present very rarely over Poland is a volcanic ash. This kind of aerosol beside it its very rarely presence makes large perturbation in social and economical life. Paper (Pietruczuk et al. 2010) contains very early analysis of lidar and sun-photometric measurements performed when volcanic ash cloud was moved over Europe. Presented measurements shown that smaller than mean values of AOT were observed in April 2010. A little larger values of AOT were observed during the days when ash cloud was moving over Poland. This kind of aerosol was dominated by fine coarse mode. Analysis of lidar measurements shown that volcanic ash was observed at around 5 km over ground that means lower than altitude of typical air traffic.

I estimate my contribution to this paper as 60%, including, among others:

- lidar and Sun-photometric measurements,
- data analysis,
- participation in preparation of the manuscript.

Climatology of aerosol optical properties registered at is presented in paper (Pietruczuk; 2013). Short term variability of aerosol optical properties as well as modification of aerosol optical properties during airmass advection over Poland are studied in this work.

Temporal variability was studied by investigation of differences between aerosol optical properties measured in subsequent days. This study was also supported by analysis of direction of airmass advection. It was shown that temporal variability of aerosol optical properties is very little, small mean differences were registered less depended on time lag between measurements. Moreover, standard deviation is decreasing in case of taking into account direction of airmass advection, especially in case of western direction. It gives an opportunity to predict next day value of AOT, which is crucial for next day prognosis of UV index or for comparing measurements taken by different techniques during the day and night time.

In addition modification of optical properties during airmass advection over Poland was studied. Sun-photometer data from AERONET network as well satellite data were used to study differences between AOT measured at Belsk and at chosen stations. Two modes in frequency count distribution was observed for all directions. One concentrated around zero and slightly shifted into positive values and second associated with accumulation of aerosol in airmass during movement of airmass over industrial or urban regions. The second mod is clearly seen in case of airmass advection from south and west direction. It allows to conclude that main aerosol sources for Central Poland are urban/industrial regions located at south and western direction from Belsk.

I estimate my contribution to this paper as 100%, including, among others:

- Sun-photometric measurements at Belsk,
- data analysis,
- preparation of the manuscript.

6. Discussion of the other scientific (artistic) achievements.

   a) Work experience prior to obtaining a doctoral degree

I was interested in optical methods for aerosol remote sensing during studies at Faculty of Physics, Warsaw University. An MA thesis on the determination of aerosol particle size distribution by means of lidar technique I wrote under supervision of prof. Tadeusz Stacwicz. I continued working in LIDAR group during my Ph.D. studies. I took part in measurements campaign and developed methods for data analysis. I also took part in the experiment applying spectroscopy in resonance cavity (CRDS) for environmental studies.

It resulted i five papers from JCR list, three papers published in other journals and numerous conference reports..

Publications from JCR list:

Stacewicz T., Chudzynski S., Czyzewski A., Ernst K., Karasinski G., **Pietruczuk A.,** Skubiszak W., Stelmaszczyk K., (2003) Studies of physical processes in the Earth's atmosphere, Radiation Physics And Chemistry 68 (1-2), pp 57 – 63,

Chudzynski S., Czyzewski A., Ernst K., Karasinski G., Kolacz K., **Pietruczuk A.**, Skubiszak W., Stacewicz T., Stelmaszczyk K., Szymanski A., (2002) Multiwavelength lidar for measurements of atmospheric aerosol, Optics And Lasers In Engineering 37 (2-3), pp 91 – 99,

Czyzewski A., Chudzynski S., Ernst K., Karasinski G., Kilianek L., **Pietruczuk A.**, Skubiszak W., Stacewicz T., Stelmaszczyk K., Koch B., Rairoux P., (2001)

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Cavity ring-down spectrography, Optics Communications 191 (3-6), pp 271 – 275,

Chudzynski S., Czyzewski A., Ernst K., **Pietruczuk A.**, Skubiszak W., Stacewicz T., Stelmaszczyk K., Szymanski A., Sowka I., Zwozdziak A., Zwozdziak J., (2001) Observation of ozone concentration during the solar eclipse, Atmospheric Research 57 (1), pp 43 – 49,
Stelmaszczyk K., Czyzewski A., Szymanski A., **Pietruczuk A.**, Chudzynski S., Ernst K., Stacewicz T., (2000) New method of elaboration of the lidar signal, Applied Physics B-Lasers And Optics 70 (2), pp 295 – 299,

b) Ph.D. thesis

The aim of my Ph.D. thesis was to determine efficiency of transitions between levels of alkali atoms excited by electron – excited atom collisions. I designed and made experimental setup in which measurements of excited lithium, potassium, and cesium atoms were made. In this setup low temperature plasma was made by resonant laser pulse in saturated sodium vapour, then second laser pulse excited investigated atoms. Excited atoms colliding with electrons reached higher energetic levels. Efficiency of transitions induced by collisions were estimated by analysis of intensity of light resulting from transition to basic state.

During preparation of my Ph.D. thesis five papers were published in journals from JCR list and numerous conference reports.

Publications from JCR list:

Pietruczuk A., Stacewicz T., Wilska M., (2006) Investigation of collisions between electrons and excited atoms of potassium, rubidium and caesium, Optica Applicata 36 (4), pp 489 – 497,

Pietruczuk A., Stacewicz T., Wilska M., Wnuk P., (2005) Method for monitoring of excited atom populations, Measurement Science & Technology 16 (2), pp 535 – 539,

Pietruczuk A., Kruk P., Stacewicz T., (2003) Investigation of electron impact-induced transitions in laser excited lithium and potassium, Radiation Physics And Chemistry 68 (1-2), pp 245 – 250,

Pietruczuk A., Stacewicz T., Investigation of collisions between Li(2P) atoms and electrons: Excitation of 4l levels, Acta Physica Polonica A 103 (5), pp 423 – 432,

Gorbunov N.A., Grochola A., Kruk P., **Pietruczuk A.**, Stacewicz T., (2002) Studies of electron energy distribution in plasma produced by a resonant laser pulse, Plasma Sources Science & Technology 11 (4), pp 492 – 497,

c) Work experience after obtaining the doctoral degree

After PH.D. studies at Warsaw University I completed short internship at Institute of High Pressure PAS, and then began to work at Institute of Geophysics PAS. I started investigations of aerosol optical properties in 2005. In subsequent years, my research interests widened in the aerosol properties measured in-situ, particulate matter concentration and aerosol size distribution as well as aerosol source appointment.

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Sun-photometric and LIDAR techniques are mainly used in my aerosol optical properties investigations. Sun-photometry allows to estimate aerosol optical thickness (AOT) and microphysical properties like size distribution and refractive index. LIDAR technique allow to determinate profiles of aerosol backscatter coefficient. Both instruments, LIDAR and Sun-photometers, are involved into international networks. This ensures the high quality of the measurements and give the opportunity to investigate aerosol properties in continental scale. Coordinated LIDAR measurements were used to validate satellite measurements (Pappalardo et al., 2010) and to investigate volcanic ash (Pappalardo et al., 2013) and Saharan dust properties (Papayannis et al., 2008). Volcanic ash and its modification over Europe was also investigated by means of Sun-photometric technique (Campanelli et al., 2012). Synergy of LIAR and Sun-Photometric techniques was applied to investigate propagation of volcanic ash cloud over Poland (Markowicz et al, 2012)

Furthermore, measurements of aerosol optical properties at Belsk are used for validation of atmospheric models (Meier et al., 2012), estimation of influence of Warsaw city on aerosol properties (Zawadzka et al., 2013) and aerosol source appointment (Chaikovsky et al., 2007).

In addition to above studies measurements of aerosol properties at Belsk and airmass trajectory analysis were used to estimation of aerosol properties in Central Poland and aerosol source appointment which is academic achievement underlying the request for habilitation procedure..

Publications from JCR list, that are not icluded into scientific achievement:

G. Pappalardo, L. Mona, G. D'Amico, U. Wandinger, M. Adam, A. Amodeo, A. Ansmann, A. Apituley, L. Alados Arboledas, D. Balis, A. Boselli, J. A. Bravo-Aranda, A. Chaikovsky, A. Comeron, J. Cuesta, F. De Tomasi, V. Freudenthaler, M. Gausa, E. Giannakaki, H. Giehl, A. Giunta, I. Grigorov, S. Groß, M. Haeffelin, A. Hiebsch, M. Iarlori, D. Lange, H. Linné, F. Madonna, I. Mattis, R.-E. Mamouri, M. A. P. McAuliffe, V. Mitev, F. Molero, F. Navas-Guzman, D. Nicolae, A. Papayannis, M. R. Perrone, C. Pietras, **A. Pietruczuk**, G. Pisani, J. Preißler, M. Pujadas, V. Rizi, A. A. Ruth, J. Schmidt, F. Schnell, P. Seifert, I. Serikov, M. Sicard, V. Simeonov, N. Spinelli, K. Stebel, M. Tesche, T. Trickl, X. Wang, F. Wagner, M. Wiegner, and K. M. Wilson (2013), Four-dimensional distribution of the 2010 Eyjafjallajökull volcanic cloud over Europe observed by EARLINET, Atmospheric Chemistry and Physics 13, pp 4429-4450

Zawadzka O., K. Markowicz, **A. Pietruczuk**, T. Zielinski, J. Jarosławski (2013), Impact of urban pollution emitted in Warsaw on aerosol properties, Atmospheric Environment 69, pp 15-28 .

Meier J., Tegen I., Mattis I., Wolke R., Alados Arboledas L., Apituley A., Balis D., Barnaba F., Chaikovsky A., Sicard M., Pappalardo G., **Pietruczuk A.**, Stoyanov D., Ravetta F., Rizi V., (2012) A regional model of European aerosol transport: Evaluation with sun photometer, lidar and air quality data, Atmospheric Environment 47, pp 519 – 532,

Markowicz K.M., T. Zielinski, **A. Pietruczuk**, M. Posyniak, O. Zawadzka, P. Makuch, I.S. Stachlewska, A.K. Jagodnicka, T. Petelski, W. Kumala, P. Sobolewski, T. Stecewicz (2012); Remote sensing measurements of the volcanic ash plume over Poland in April 2010, Atmospheric Environment 48, pp 66-75

Campanelli M., Estelles V., Smyth T., Tomasi C., Martinez-Lozano M. P., Claxton B., Muller P., Pappalardo G., **Pietruczuk A**., Shanklin J., Colwell S., Wrench C., Lupi A., Mazzola M., Lanconelli C., Vitale V., Congeduti F., Dionisi D., Cardillo F., Cacciani M., Casasanta G., Nakajima T., (2012) Monitoring of Eyjafjallajokull volcanic aerosol by the new European Skynet Radiometers (ESR) network, Atmospheric Environment 48, pp 33 – 45,

Pappalardo G., Wandinger U., Mona L., Hiebsch A., Mattis I., Amodeo A., Ansmann A., Seifert P., Linne H., Apituley A., Alados Arboledas L., Balis D., Chaikovsky A., D'Amico G., De Tomasi F., Freudenthaler Vo., Giannakaki E., Giunta A., Grigorov I., Iarlori M., Madonna F., Mamouri R.E., Nasti L., Papayannis A., **Pietruczuk A.**, Pujadas M., Rizi V., Rocadenbosch F., Russo F., Schnell F., Spinelli N., Wang X., Wiegner M., (2010) EARLINET correlative measurements for CALIPSO: First intercomparison results, Journal of Geophysical Research-Atmospheres 115, p. D00H19,

Papayannis A., Amiridis V., Mona L., Tsaknakis G., Balis D., Boesenberg J., Chaikovski A., De Tomasi F., Grigorov I., Mattis I., Mitev V., Mueller D., Nickovic S., Perez C. **Pietruczuk A.**, Pisani G., Ravetta F., Rizi V., Sicard M., Trickl T., Wiegner M., Gerding M., Mamouri R. E., D'Amico G., Pappalardo G., (2008) Systematic lidar observations of Saharan dust over Europe in the frame of EARLINET (2000-2002), Journal of Geophysical Research-Atmospheres 113 (D10), D10204,