Geophysical Research Abstracts, Vol. 7, 04016, 2005
SRef-ID: 1607-7962/gra/EGU05-A-04016

First systematic observations of Saharan dust over Europe (2000-2003): Statistical analysis and results

A. Papayannis (1), V. Amiridis (2), J. Bösenberg (3), A. Chaikovski (4), F. De Tomasi (5), V. Freudenthaler (6), I. Grigorov (7), I. Mattis (8), V. Mitev (9), C. Munoz (10), G. Pappalardo (11), S. Nickovic (12), G. Pisani (13), S. Puchalski (14), V. Rizi (15), T. Trickl (16), and G. Vaughan (17)

(1) National Technical University of Athens-NTUA, Physics Dept., Athens, Greece (apdlidar@central.ntua.gr / Phone: +30 210 7722992 / Fax: +30 210 7722928)

(2) Laboratory of Atmospheric Physics, Univ. of Thessaloniki, Thessaloniki, Greece

(3) Max-Planck-Institut für Meteorologie, Hamburg, Germany

(4) Institute of Physics, National Academy of Sciences of Belarus, Minsk, Belarus

(5) University of Lecce, Physics Department, Lecce, Italy

(6) Meteorologisches Institut der Universität München, Munich, Germany

(7) Institute of Electronics, Bulgarian Academy of Sciences, Sofia, Bulgaria

(8) Leibniz Institute for Tropospheric Research, Leipzig, Germany

(9) Observatory of Neuchâtel, Neuchâtel, Switzerland

(10) Universitat Politecnica de Catalunya, Barcelona, Spain

(11) Istituto di Metodologie per l'Analisi Ambientale-CNR, Potenza, Italy

(12) Euro-Mediterranean Centre on Insular Coastal Dynamics, Univ. of Malta, Valletta, Malta

(13) INFM and Dipart. di Scienze Fisiche-Università di Napoli Federico II, Napoli, Italy

(14) Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland

(15) Dipartimento di Fisica, Università Degli Studi - L'Aquila, L'Aquila, Italy

(16) Forschungszentrum Karlsruhe, IMK-IFU, Garmisch-Partenkirchen, Germany

(17) Institute of Mathematical and Physical Sciences, Univ. of Manchester, U.K.

During a three-year period (2000-2003) 90 Saharan dust outbreaks over Europe were monitored by a coordinated aerosol lidar Network in the frame of the EARLINET project. Multiple aerosol layers of variable thickness (200-2500 m) were systematically observed in the altitude region 1.5-8 km height asl., while traces of dust particles reached heights of 8-10 km, after a 2-5 days transport from the source region. Aerosol optical depths, linear depolarization ratios and extinction-to-backscatter ratios (lidar ratios) of aerosols ranged from 0.3-0.8 (at 355 nm or 351 nm), 10 to 25 % and 35 to 80 sr, respectively, within the lofted dust plumes. Air mass back-trajectory analysis and model calculations from the DREAM dust model, in conjunction with satellite data analysis (MODIS, TOMS, SeaWiFS), related the measurements during these dust events to the Saharan region. The vertical and horizontal extent of these outbreaks is discussed and their seasonal distribution is given. A 3-year climatology of long-range dust transport to the EARLINET sites was developed using 3-dimensional 4-day air mass back-trajectories. A cluster analysis was used to classify the air mass trajectories into distinct dust transport patterns from Africa to Europe.

Introduction

Atmospheric particles and mainly the mineral dust particles, play an important role in the earth's radiation balance and climate by scattering and absorbing both incoming and outgoing radiation (Seinfeld and Pandis, 1998). Every year very large (million of tons) quantities of desert dust from the Sahara and surrounding regions are exported to the North Atlantic Ocean and the Mediterranean Sea (Prospero et al., 1981). Before the EARLINET project the Saharan dust transportation over Europe was studied only over the water surface of the Mediterranean region by satellite observations (Dulac et al., 1992). Since 2000, the EARLINET project provided systematic observations of vertical profiles of Saharan dust aerosols over the European continent [Ansmann et al., 2003; Papayannis et al., 2004], on a coherent network basis. Dust model simulations using the DREAM dust model were found to be consistent with the lidar network observations (Nickovic et al., 2001).

Methodology

Over Europe 21 stations were deployed using elastic backscatter and Raman lidar systems to measure the vertical profiles of the aerosol backscatter and extinction coefficients at various wavelengths between 351 and 1064 nm (Bösenberg et al., 2003). In the frame of the EARLINET the lidar systems were quality assured by performing direct intercomparisons, both at hardware and software levels (Böckmann et al., 2004; Matthias et al., 2004; Pappalardo et al., 2004). The NTUA lidar group coordinated these measurements to provide an early warning of Saharan dust outbreaks over the EARLINET monitoring sites using forecast model data provided by the DREAM model (Nickovic et al., 2001). Ancillary observations included ground-based aerosol optical depth, spectral radiance (sun photometers, UVB radiometers) and satellite (AVHRR, METEOSAT, TOMS, MODIS, SeaWiFS) measurements for mutual validation with the lidar aerosol data. 96-hours air mass back-trajectory analysis confirmed the Saharan region to be the source region of the high aerosol loadings observed over Europe during these Saharan dust outbreaks.

Statistical analysis of Saharan dust outbreaks over Europe-Conclusions

A total of 90 significant events of free tropospheric Saharan dust layers were observed over the EARLINET sites in Europe, between the years 2000-2003. Multiple aerosol layers of variable thickness (0.2-2.5 km) were systematically observed in the altitudes between 1.5-10 km height asl. Most episodes were recorded during the spring and summer months, while fewest were observed during the winter period. In the majority of cases the episodes lasted from 1 to 5 days, while a few of them lasted up to 10-14 days. The mean number of dust episodes observed per season is much higher in the southern and southeastern European regions, due to the prevailing meteorological conditions (direction of wind flow) in conjunction with their vicinity to the Sahara desert. However, our observations have shown that Saharan dust aerosols can penetrate deeply into central and eastern Europe, where they may still co-exist with clouds (Ansmann et al., 2003). The mean lidar ratio values over Europe ranged from 35 to 80 sr within lofted dust plumes. In some cases enhanced lidar ratios ranging from 50 to 90 sr at 355 nm and from 40 to 80 sr at 532 nm, were found over Germany (Ansmann et al., 2003), which were similar to the ones found for Asian dust. The corresponding linear depolarization ratios of aerosols within the dust plume ranged from 10% to 25%. During intense Saharan dust outbreaks the TOMS aerosol index values ranged between 3-3.5 in the Mediterranean region and between 1-2.5 over central Europe. In this study, a 3-year climatology of long-range dust transport to the EARLINET sites was established using 3-dimensional 4-day air mass back-trajectories. A cluster analysis was used (Moody and Galloway, 1988) to classify the air mass trajectories into distinct dust transport patterns from Africa to Europe. The analysis of the data collected during the three-years of operation of the EARLINET Network during dust events made it possible, for the first time, to estimate simultaneously the horizontal and vertical extent of free tropospheric Saharan dust layers over Europe. This information can be used as an important input into radiative transfer models (RTM) and atmospheric chemistry transport models (ACTM) over Europe.

1 Acknowledgements

This work was supported by the Environment Program of the European Union, under contract EVR1-CT1999-40003. Air-mass trajectory analysis was provided by the German Weather Service (DWD) and NOAA-CMDL.

2 References

Ansmann A., et al., Long-range transport of Saharan dust to northern Europe: The 11-16 October 2001 outbreak observed with EARLINET, *J. Geophys. Res.*, 18(D24), 4783, doi:10.1029/2003/2003JD003757, 2003.

Böckmann, C., et al., Aerosol lidar intercomparison in the framework of the EARLINET project. 2. Aerosol backscatter algorithms, *Appl. Opt.*, 43, 977-989, 2004.

Bösenberg, J. et al., A European aerosol research lidar network to establish an aerosol climatology, *MPI-Report* 317, Max-Planck Inst. fuer Meteorology, Hamburg, Germany, 2003.

Dulac F., et al., Assessment of the African airborne dust mass over the Western Mediterranean Sea using Meteosat data, *J. Geophys. Res.*, 97, 2489, 1992.

Matthias, V., et al., Vertical aerosol distribution over Europe: Statistical analysis of Raman lidar data from 10 European Aerosol Research Lidar Network (EARLINET) stations, *J. Geophys. Res.*, 109, D18201, doi:10.1029/2004JD004638, 2004.

Moody, J.L. and Galloway, J.N., Quantifying the the relationship between atmospheric transport and and the chemical composition of precipitation in Bermuda, *Tellus*, 40B, 463-479, 1988.

Nickovic S., et al., A model for prediction of desert dust cycle in the atmosphere, *J. Geophys.l Res.* 106, 18113-18129, 2001.

Papayannis, A., et al., Saharan dust outbreaks towards Europe: 3 years of systematic observations by the European lidar network in the frame of the EARLINET project (2000-2003), *Proceedings of the 22nd Intern. Laser Radar Conf., ESA- SP-561*, Matera, Italy, 845-852, 2004.

Pappalardo, G., et al., Aerosol lidar intercomparison in the framework of the EARLINET project. 3. Raman lidar algorithm for aerosol extinction, backscatter and lidar ration, *Appl. Opt.*, 43, 5370-5385, 2004.

Prospero J.M., et al., Atmospheric transport of soil dust from Africa to South America, *Nature*, 289, 570-572, 1981.

Seinfeld J.H. and Pandis S.N., *Atmospheric Chemistry and Physics: From Air Pollution to Climate Change*, J. Wiley and Sons Inc., NewYork, USA, 1998.