AEROSOL PROPERTIES FOR A DUST EVENT OBSERVED OVER CYPRUS

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ABSTRACT

Saharan dust aerosols influence Cyprus due to the cyclone activity all around the Mediterranean. Routine measurements have been performed by the backscatter/depolarization lidar system of the Cyprus University of Technology (CUT) for the last two years. A case study of Saharan dust aerosols transferred over Eastern Mediterranean, on May 2010 has been selected by the authors for the purpose of this paper. Ground based and satellite passive and active remote sensing observations were used complimentary for the representative evaluation of the dust event. Specifically, CALIOP level-2 data with coincidence ground-based measurements performed by the lidar station at Lemesos, Cyprus were used for the case of 14th of May 2010. The daily backscatter coefficient at 532nm and 1064nm has been compared with the satellite derived CALIPSO data in conjunction with AERONET retrievals, for the first time in Cyprus. It has been found that the aerosol optical properties profiles of the ground-based CUT's lidar and the CALIOP were in a good agreement, especially within the aerosol dust layers.

1. INTRODUCTION

The Mediterranean area is strongly affected by the presence of desert dust due to its proximity to North Africa. Long range transport of desert dust mainly takes place in the free troposphere [1, 2]. Thus sun photometers, delivering spectrally resolved column-integrated data in combination with aerosol lidar instruments providing information on the vertical structure, are appropriate tools for a detailed description of a dust event in means of the optical parameters of mineral dust aerosols.

The Aerosol RObotic NETwork (AERONET) program is a federated remote sensing network of well-calibrated sun photometers and radiometers located at over 200 sites covering all major tropospheric aerosol regimes around the world [3]. AERONET stations provide columnar aerosol optical parameter information (aerosol optical depth, size distribution, single scattering albedo, etc.) through direct measurements and inversion techniques.

Lidar is the only technique that provides high resolution vertical profiling of aerosols. The European Aerosol Research Lidar NETwork (EARLINET) was established in 2000 to characterize the horizontal, vertical, and temporal distribution of aerosols on a European scale [4].

Lidar techniques play an increasing role in future Earth observation strategies. CALIOP (Cloud-Aerosol LIdar with Orthogonal Polarization) onboard the NASA/CNRS CALIPSO satellite provides a first opportunity to study in detail the performance and the scientific value of a space-borne aerosol lidar during a long term mission. CALIOP lidar onboard CALIPSO, provides information on the vertical distribution of aerosols and clouds as well as on their optical properties over the globe with unprecedented spatial resolution [5]. However, CALIPSO observations provide global, but snapshot-like view of aerosol vertical distributions. Only combined studies with ground-based lidars together with transport modeling techniques will allow a full exploitation of these data for a detailed description of the temporal and spatial aerosol distribution and evolution on a global scale. Active and passive remote sensing satellite data synergy on the other hand can improve aerosol characterization and specification. CALIPSO active remote sensing data can be used in conjunction with the MODerate resolution Imaging Spectroradiometer (MODIS) to better indentify and characterize aerosol distributions and properties [6].

In this study, the spatial and temporal evolution, optical properties and vertical structure of the Saharan dust plume that affected Eastern Mediterrenean on May 2010 is presented.

2. DATA

2.1 Lidar measurements

A backscatter and depolarization lidar system for atmospheric aerosol studies has been located at the premises of CUT, in Lemesos, Cyprus (34.675ºN, 33.043ºE, 10m above sea level) since 2010. This location is crucial because is in the Eastern part of Mediterranean. The lidar records daily measurements between 08:00 UTC and 09:00 UTC in order to be consistent with the MODIS overpass and to perform continuous measurements for the retrieval of the aerosol optical properties over Lemesos, Cyprus inside the Planetary Boundary Layer (PBL) and the lower free troposphere.

The Lidar transmits laser pulses at 532 and 1064 nm simultaneously and collinear with a repetition rate of 20

Hz. This system is based on a small, rugged, flashlamp-pumped Nd-YAG laser with pulse energies around 25 and 56 mJ at 1064 and 532 nm, respectively. An achromatic beam expander reduces the divergence to less than 0.15 mrad. Elastically backscatter signals at two wavelengths (532nm, 1064nm) are collected with a Newtonean telescope with primary mirror diameter of 200 mm and an overall focal length of 1000 mm. The field of view (FOV) of the telescope is 2 mrad. A plain cover plate is protecting the mirrors. The mirror and cover plate coatings are optimized for the wavelength range from 532 nm to 1064 nm. Behind the field stop two plano-convex with a focal length of 80 mm, outputs parallel rays. The, lidar covers the whole range starting at the full overlap of the lidar (170 m) up to tropopause level. So far, three channels are detected, one for the wavelength 1064 nm and two for 532 nm. The two polarization components at 532nm are separated in the receiver by means of polarizing beamsplitter cubes (PBC). A special optomechanical designs allows the manual ±45°-rotation of the whole depolarization detector module with respect to the laser polarization for evaluating the depolirization calibration constant of the system. The CUT depolarization lidar operates at 532nm and it is possible to rotate the detection box including the polarization beamsplitter cube in order to calibrate the instrument [7]. Firstly, we record the backscattered lidar signals (P and S) as usual, using the normal orientation of the lidar detection box and for the two other steps we rotate by ±45^o the lidar detection box respectively and we record as before the P and S signals. The operation principal of this method is based on the fact that same amount of energy is sent to P and S channels, at “opposite” directions. Photomultiplier tubes (PMTs) are used as detectors at all wavelengths except for the signals at 1064 nm (avalanche photodiode, APD). A transient recorder that combines a powerful A/D converter (12 Bit at 20 MHz) with a 250 MHz fast photon counting system (Licel, Berlin) is used for the detection of 532 radiation, while only analog detection is used 1064nm. The raw signal spatial resolution is down to 7.5 meters.

2.2 AERONET

The sun-photometer observations reported in this paper were performed by a CIMEL sun-sky radiometer, which is part of the AERONET Global Network (http://aeronet.gsfc.nasa.gov). The CIMEL is an automatic Sun-sky scanning filter radiometer allowing the measurements of the direct solar irradiance and sky radiance at wavelengths; 340, 380, 440, 500, 670, 870, 1020 and 1640 nm and the technical specifications of the instrument are given in [3].

The instrument is located on the roof of the building of the Department of Civil Engineering and Geomatics of Cyprus University of Technology (CUT) (34^{o}N, 33^o E, elevation: 20 m). The CUT_TEPAK AERONET station is located in the old town of Lemesos, 500 m from the sea. The sunphotometric station is operated since April 2010 by the Laboratory of Remote Sensing.

2.3 Satellite Measurements

The Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) mission (http://smsc.cnes.fr/ CALIPSO/), is an Earth Science observation mission that was launched on 28 April 2006 and flies in nominal orbital altitude of 705 km and an inclination of 98 degrees as part of a constellation of Earth-observing satellites known as the “Atrain” [8]. The CALIPSO mission provides crucial lidar and passive sensors to obtain unique data on aerosol and cloud vertical structure and optical properties. CALIOP is an elastic backscatter lidar operating at 532 and 1064 nm, equipped with a depolarization channel at 532 nm that provides high-resolution vertical profiles of aerosols and clouds [5]. The Level 2 V3.01 aerosol profiles products are used in this paper.

Finally, the Moderate Resolution Imaging Spectro-Radiometer (MODIS) aerosol 5-min level-2 swaths (collection 5) were obtained through NASA’s Earth Observing System Data Gateway. AOD values at 550 nm were extracted with an uncertainty of ±0.05±0.15*AOD over land relative to the AOD measured in coincident observations from the ground-based AERONET sun-photometer network [6].

Summarizing, we have used a synergy of different remote sensing instruments and techniques to derive a variety of dust aerosol optical properties. From ground-based measurements we have retrieved AOD, Angstrom parameters, aerosol size distribution and also lidar backscatter and depolarization profiles at visible wavelengths.

3. RESULTS

3.1 Dust Event: May 2010

A long-lasting Saharan dust event affected Eastern Mediterranean on May 2010. Such events are common during spring time for the particular area. During May 2010 (figure 1), three dust events are occurred according the SKIRON forecast model: 8-9 May 2010, 13-14 May 2010 and 26-28 May 2010. Beyond these, only for 14 May 2010 all the passive and active ground based and satellite remote sensing instruments were available. Thus for the first time, such an event could be captured by all instruments used for Lemesos area.

To characterize the dust properties over Lemesos for May 2010, ground-based sun photometric and combined backscatter lidar measurements are used in this study. From the direct CIMEL sunphotometric measurements over Lemesos, the AOD at selected spectral channels is derived, following the well-known Beer-Bouguer-Langley law. The Ångström exponent is derived according to the Ångström power law, using the 440, 670 and 870 nm channels [9]. In Figure 1 the temporal evaluation of the AOD and the Ångström exponent over the Lemesos AERONET site, is given for the period of 8 - 31 May 2010.

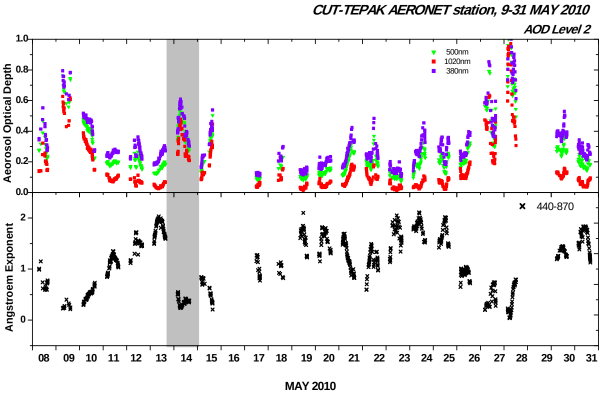

Figure 1. AOD and Ångström exponent from CUT-TEPAK AERONET sunphotometer for May 2010. Grey line highlights the under study day of 14 May 2010.

Figure 1 clearly shows the inverse behavior between two parameters which is an index of dust aerosols at Lemesos station (the AOD increases significantly from 12th of May to 14th of May 2010). The highest AOD is registered on 14th May with a value of 0.5 (500 nm). The desert dust plume is also visible on 15 May, while the following days show a clear weakening of the event as the desert plume moved away, as shown by the AOD, which dropped back to background levels. Finally, a major dust event occurred at the late of May when the AOD reached the maximum values of 0.8 (500nm).

In Figure 1 we can also observe the time series of the Ånsgtröm exponent showing very low values (from zero to 0.5) for 14th and 15th of May, in inverse correspondence with the high AOD values. One of the characteristics of the desert dust episodes is the high variability shown by both parameters during each day, as well as the low Ångström exponent values which indicate the presence of rather large particles. For the period between 8th and 31st of May, the mean daily Volume Size Distribution (not shown here) clearly shows the evolution of the desert dust in the coarse mode fraction.

3.2 Case study: 14 May 2010

On 14 May 2010 measurements from different techniques and platforms were available. In Figure 2 the 7-days backward trajectories are given for 14th of May, as calculated by the HYSPLIT model provided by NOAA. Figure 3 shows the spatial variability of the AOD at 550nm as derived from the MODIS sensor. The AOD on that day for the Eastern Mediterranean site, around Cyprus take values around 0.6 in visible.

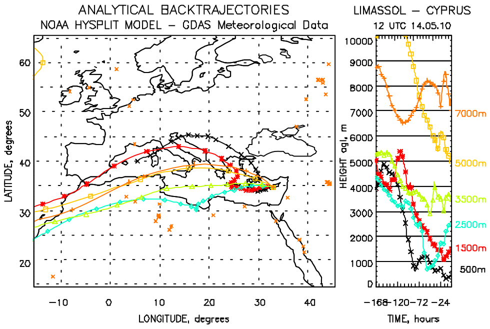

Figure 2. 7-days airmass back trajectories for Lemessos site, on 14 May 2010, 12:00UTC.

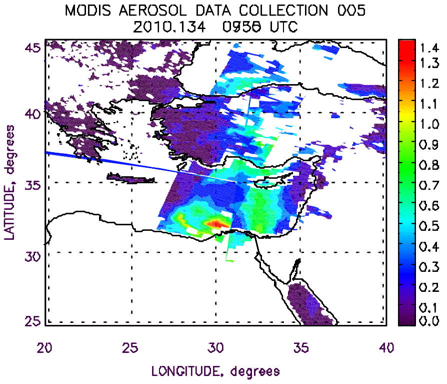

Figure 3. Terra MODIS AOD at 500nm during the dust event on 14 May 2010.

On the some day, CALIPSO's closest overpass from CUT lidar station was around 85 km at the East. From the almost simultaneously ground based and satellite lidar measurements performed during daytime at Visible and Infrared wavelengths, aerosol layers around 3.5-4.5km (Fig. 4) and 2-3km (Fig. 5) have been observed by the CUT and CALIOP lidar systems respectively. Despite the different height of the aerosol layer retrieved from satellite and ground lidar which can explained if we take into account the horizontal distance between the ground track and the CUT station, the aerosol optical properties fluctuate around the same values within the layer. Specifically, the agreement between the two instruments for the backscatter coefficient mainly at the visible wavelength is good, both at vertical structure and absolute, excluding the vertical shift. Additionally, the Ångström exponent in the plume of dust retains a value around to 0.3 for both instruments and the particle depolarization is at 33% (Fig.2, 3). Finally, the aerosols located in the layers between 1.3 and 3km was characterized by the CALIPSO vertical feature mask algorithm as dust particles (fig.2). The retrieved depolarization values for the dust aerosols over Cyprus are in a good agreement with the depolarization values found during SAMUM campaign [10, 11].

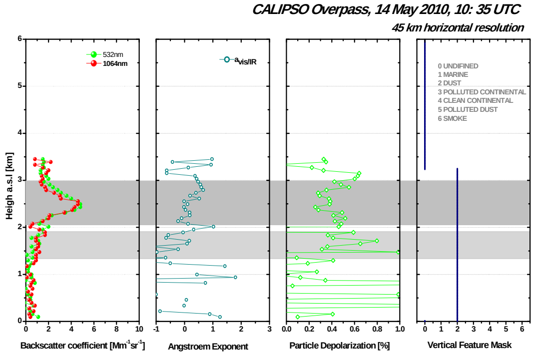

Figure 4. Vertical profile of the backscatter coefficients (532nm, 1064nm), Ångström exponent, particle depolarization and vertical feature mask from satellite lidar measurements on 14 May 2010.

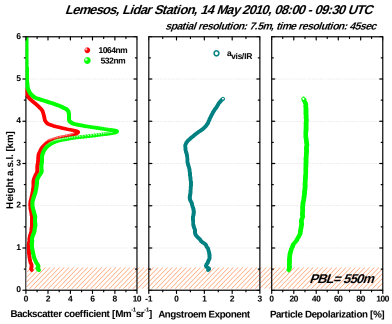

Figure 5. Vertical profiles of backscatter coefficient, Ångström exponent and particle depolarization from ground-based lidar measurements on 14 May 2010.

4. CONCLUSIONS

The aerosol properties retrieved from lidar techniques with both satellite and ground-based available instruments in the Lemesos area during a dust event on 14th of May 2010, have been presented. During the spring months, Cyprus is under the influence of Saharan dust particles. Large AOD and backscattering values in accordance with low Ångström values characterize the desert dust activity during May 2010. The dust layer observed both by CUT's and CALIOP lidar systems and the temporal variability of the dust event was recorded by the passive remote sensing sensors as MODIS and AERONET sun-photometer. The results concerning the vertical optical properties as backscatter coefficient, particle depolarization and Ångström exponent within the aerosol layers proved to be in a good agreement between the different instruments.

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