P1.8 SAWA EXPERIMENT – EVALUATION OF DUST PARTICLES PROPERTIES BY MEANS OF LIDAR AND SUN-PHOTOMETER SYNERGIC MEASUREMENTS

Aleksandra E. Kardas[*1], Krzysztof Markowicz[1], Kamil Stelamaszczyk[2], Grzegorz Karasinski[1], Szymon P. Malinowski[1], Tadeusz Stacewicz[1]

[1]Warsaw University, Poland
[2]Freie Universitat Berlin, Germany

1. INTRODUCTION

It is now commonly known, that aerosols' role in the global climate and it's change is important and complexed (Houghton, 2001; Satheesh and Krishna Moorthy, 2004). In case of many aerosol types it is not yet established, whether their net contribution to the Earth surface heat balance is positive or negative (Shine and de F. Forster, 1999). One of them is mineral dust (Sokolik and Toon, 1996). Evaluating the climatic effect of the aerosol together with constructing it's efficient and reliable numerical model requires a large bank of observational data.

In this paper we investigate optical properties of mineral dust transported in the middle troposphere from Sahara and Arabian deserts to central Europe. We perform synergic measurements with the use of multi-wavelength depolarisation lidar and a sun-photometer. A method of retrieving basic information on the investigated aerosol from such measurements is proposed.

The idea of the method is to use information on the aerosol optical depth obtained from passive photometer in order to reduce the number of usual assumptions necessary to invert the lidar signal. Then, with an additional assumption that the particles may be represented by ensembles of randomly oriented, identical spheroids necessary to adopt the Transition matrix (T-matrix) algorithm by Mishenko and Travis (1998), the size and aspect ratio of the the observed aerosol particles is estimated.

The method was first used during SAWA measurement campaign in Warsaw, held during spring 2005 at emerging aerosol/radiative transfer laboratory of Warsaw University. The goal was to characterise particles of Saharan dust, drifting over Poland with a southern wind. Such episodes are common in Central Europe during spring time. In this study we analyse case of 12-15 April, 2005.

2. EXPERIMENT, METHODS, RESULTS

2.1 *Experimental setup*

SAWA experiment took place in April and May 2005, in Warsaw. It's main goal was to examine the aerosols typical for Central Europe and Sahara desert dust episodes, usually appearing in springtime in Poland. Among many radiometric instruments used during the campaign were the sun-photometer (*Microtops)* and the aerosol lidar (*Terramobile Profiler* from Freie Universitat Berlin).

Microtops measures direct solar radiation in five channels between 380 and 870nm. It's built-in algorithm produces total aerosol optical depths (AOD).

Terramobile instrument is a multi-wavelength pulsed lidar, operating at 355nm, 532nm, 1064nm wavelengths. In case of the 532nm wave, two separated signal components polarised in parallel and perpendicularly to the emitted beam are recorded.

During the campaign one major dust episode appeared, between 12th and 19th of April. Synergic lidar and sun-photometer measurements were made on 13th and 14th. Unfortunately, as it was noticed later, the UV channel of *Terramobile* was not operating correctly and it's records were not accounted in the analysis.

2.2 *Lidar signal inversion method*

The classic approach to the inversion of the lidar returns was formulated by Klett (1981) and Fernald (1984). It requires knowledge on the aerosol backscatter to extinction ratio (R_A), which considered constant with height. The value of R_A is often guessed or assumed (Landulfo et al., 2003; Iwasaka et al., 2003).

In the modified approach (Welton et al., 2000), R_A is calculated with the use of the total aerosol optical thickness as an additional bond. In the first step $R_A = 1$ is assumed. Then, after calculating the whole backscatter profile, R_A is redefined as:

$$R_A = \frac{1}{\tau_{SP}} \int \beta_A(z)\,dz\ . \qquad (1)$$

Here τ_{SP} is the total AOD measured with the sun-photometer, z – the vertical co-ordinate and $\beta_A(z)$ – the aerosol backscatter coefficient.

The procedure is repeated until the differences between R_A's calculated in subsequent steps are sufficiently small.

Another improvement of the procedure comes from the following observation. When several aerosol layers are present in the atmosphere, it is advisable to allow for R_A to differ between layers. Therefore we divide the atmosphere into appropriate layers determined on the basis of the lidar backscatter signal.

* Aleksandra E. Kardas, Warsaw University, (048 022) 55 46 877, aekardas@igf.fuw.edu.pl

First we calculate the extinction coefficient profiles for the whole atmosphere. Integrating them within chosen height ranges produces optical depth values to be used instead τ_{SP} while running the algorithm for each layer separately.

2.3 *Measured AODs and aerosol extinction profiles*

AODs measured during the dust episode were noticeably higher than those observed in other days. For example on the 14th of April (Fig.1.) the optical depth in 500nm wavelength reached $0{,}67m^{-1}$ in contrast to typical values of $0{,}05\text{-}0{,}25m^{-1}$.

In order to estimate AODs in the lidar wavelengths the *Microtops* measurements were recalculated with the use o the Angstrom power law (Angstrom 1964).

Atmosphere was divided into three layers: boundary layer, desert dust and “clear” air. Estimations based on the lidar returns show, that the optical thickness of dust was comparable to that of the boundary layer aerosol (Fig.2).

From the lidar signals at 532nm and 1064nm the extinction coefficients profiles were derived (Fig.3.), following the procedure described in section 2.2.

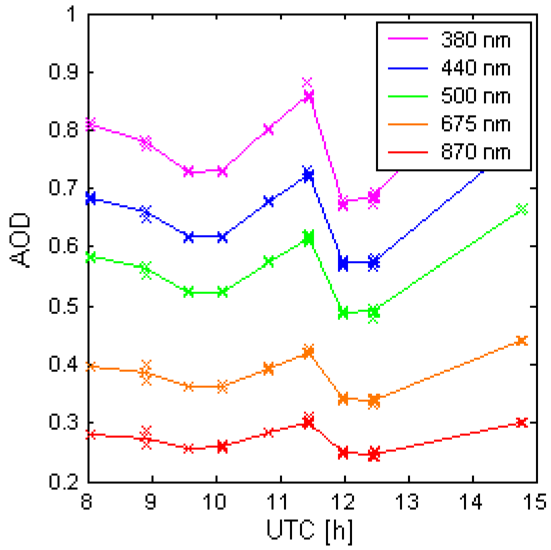

Fig. 1: Microtops observations of AOD, Warsaw 14.04.2005.

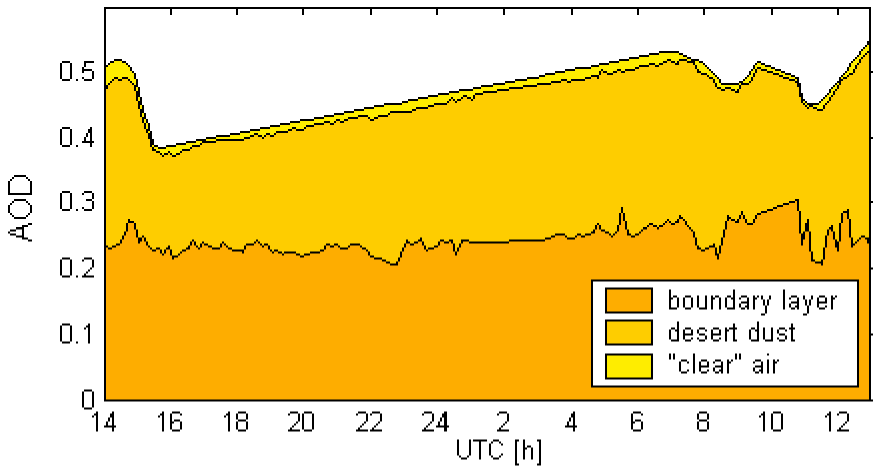

Fig. 2: Estimated AOD's of atmospheric layers over Warsaw, 13-14.04.2005 (532nm channel).

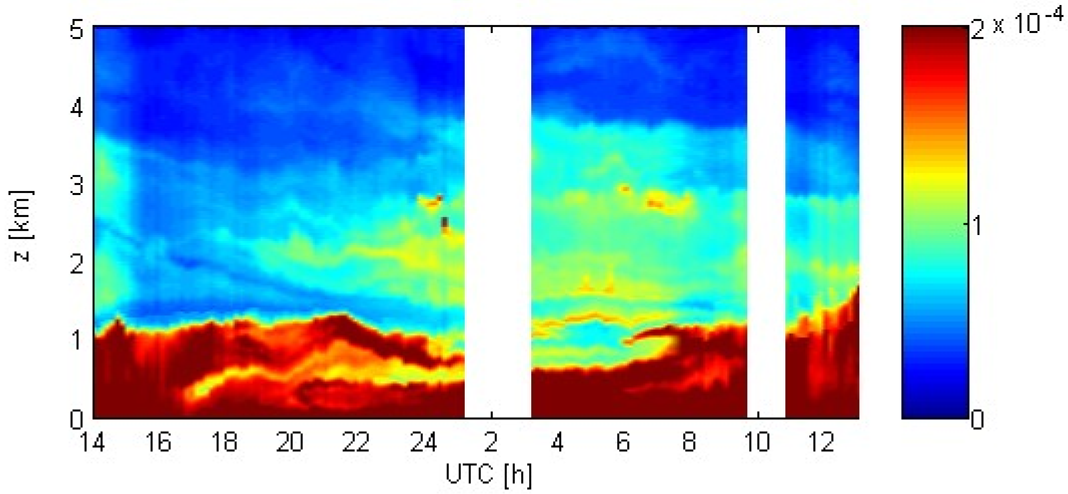

Fig. 3: Vertical profiles of aerosol extinction coefficient [m^{-1}], Warsaw 13-14.04.2005 (532nm channel).

2.4 *Determination of particles' size*

One of the goals of the SAWA campaign was to find a mathematical representation of the dust particles, suitable for a radiative transfer model. We assumed that the observed dust particles can be represented by an ensemble of randomly oriented spheroids with a log-normal size distribution and fixed aspect ratios.

We decided to estimate the mean size of the appropriate spheroids, using the values of the Angstrom exponent (α), retrieved from the extinction coefficients profiles (Fig.5.).

The Mishchenko's T-matrix code (Mishchenko and Travis, 1998) was used to perform numeric simulations of the light transfer through a mentioned ensemble for the 532nm wavelength and the refractive index of sand, equal to 1,53 + 0,008i. Results (Fig.4.) show, that at least within a limited particle radius range (0,1 – 0,6 μm), the relationship between α and the mean radius is monotonic and shape-independent. This allows us to use the Angstrom exponent values of the observed aerosol (Fig. 5.) together with Fig.4. in order to estimate the modal radius of the spheroids representative for the dust particles α values observed during SAWA indicate that the proper radii range is between 0,15 and 0,3 μm.

2.5 *Determination of particles' shape*

A parameter which is highly sensible to particles' shape is the depolarisation of the returning signal defined as:

$$\delta = P_R / P_L \tag{2}$$

where P_R and P_L are the values of lidar returns with polarisation perpendicular and parallel to the original beam (Stephens, 1994).

T-matrix simulations performed for different modal radii of aerosol particles (Fig.6.) show, that δ can be used in estimating the aspect ratio of aerosol particles, as it always equals zero for spheres and is decidedly higher for spheroids.

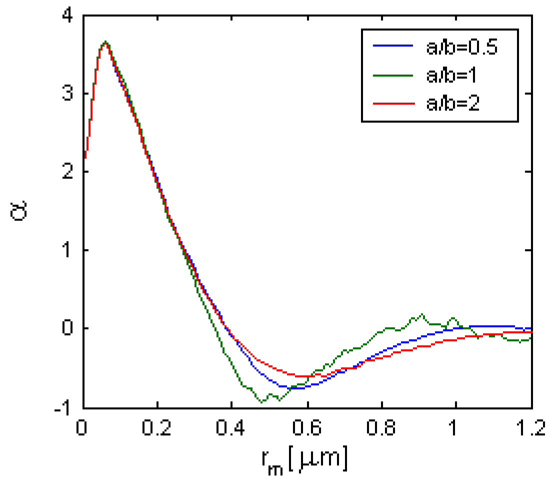

Fig. 4: Angstrom coefficient (α) dependency on modal radius (r_m) of randomly oriented spheroid particles, calculated for a log-normal size distribution and the refractive index of sand.

Fig.7. presents the depolarisation profiles calculated for the 532nm. Depolarisation values in the dust layer are 0,1 – 0,17, while in the boundary layer, they are decidedly lower. Due to T-matrix calculations, aspect ratios of the spheroids which are representative for the dust particles of modal radii as estimated in section 2.4 should be lower than 0,7 or larger than 1,7.

3. SUMMARY

During SAWA campaign one large dust episode was observed. Synergic measurements by the means of lidar and sun-photometer together with numeric calculations performed with a T-matrix code allowed to estimate the size and aspect ratio of the observed mineral dust particles. Their estimated modal radii was in the range of 0,15 – 0,3 μm and their aspect ratios were smaller than 0,7 or larger than 1,7.

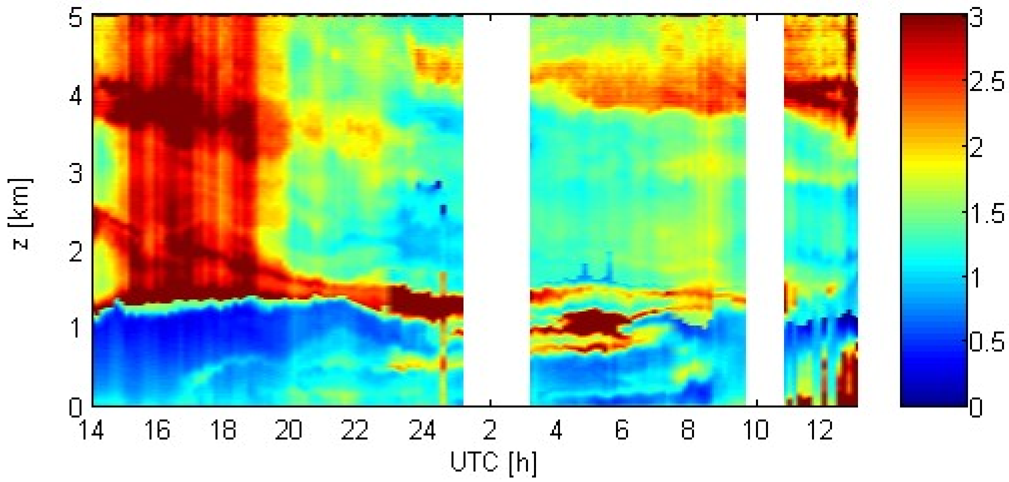

Fig. 5: Angstrom exponent's vertical profiles over Warsaw, 13-14.04.2005.

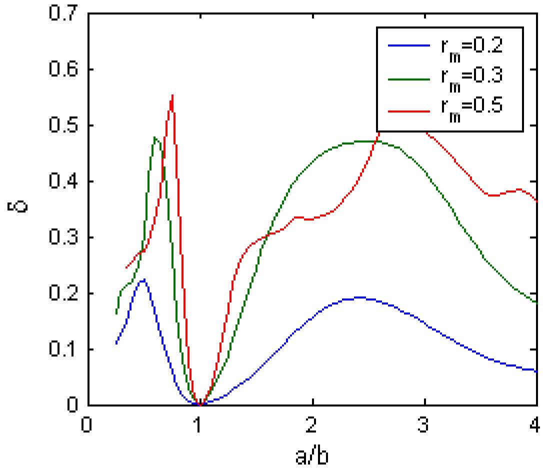

Fig. 6: Depolarisation (δ) dependency on aspect ratios (a/b) of randomly oriented spheroid particles, calculated for the log-normal size distribution, the refractive index of sand, and different modal radii r_m [μm].

4. REFFERENCES

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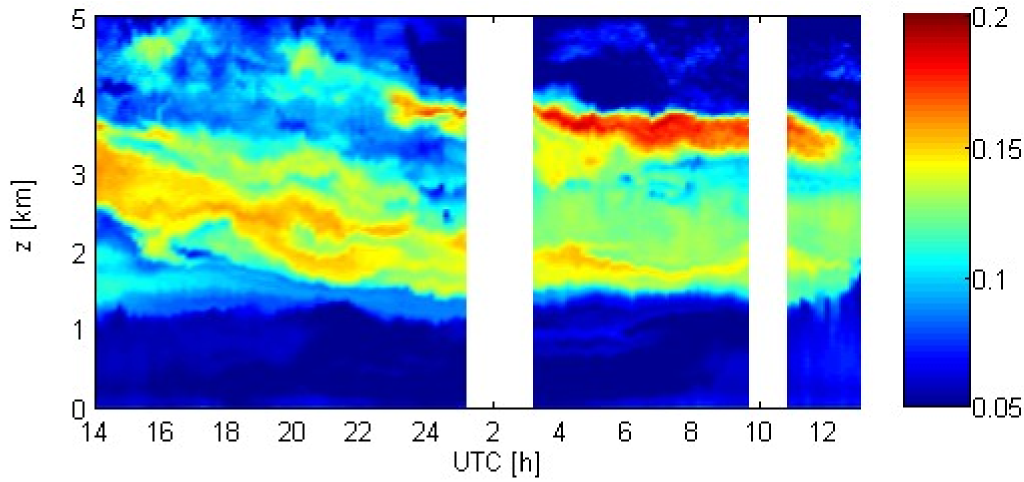

Fig. 7: Depolarisation's vertical profiles over Warsaw, 13-14.04.2005 (532nm channel).