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Interactive Comment

Interactive comment on "Optical characteristics of biomass burning aerosols over Southeastern Europe determined from UV-Raman lidar measurements" *by* V. Amiridis et al.

V. Amiridis et al.

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On behalf of the authors, I would like to thank anonymous referees 1 and 2 for their constructive and helpful comments and suggestions on our paper. The answers to the reviewers’ comments are presented below.

Reviewer 1:

(1) Units regarding Equation 1 were added in the text: A is in m2, B is in kg/m2, alpha is a fraction without units, and beta is also unitless (mass/mass) but can be, e.g., in g/kg.

(2) In Table 2, the mean value for the lidar ratio is given for each day along with the

standard deviation. These values were calculated by vertical averaging the profile of the lidar ratio. This information was added in the text and the caption of Table 1 so the reader will not confuse standard deviation from vertical averaging with statistical errors from lidar ratio calculation. The standard deviations for the lidar ratio indicate the vertical variability of this parameter within the smoke layers. For example, and since lidar ratio is an indicator of the aerosol type, low values of its standard deviation indicate no vertical variability and thus, the same aerosol type in the averaging height range.

(3) Max value is the maximum value in the plot and is probably not so important information regarding our study. More detailed explanations regarding the hot spot definition are given in: http://zardoz.nilu.no/˜andreas/publications/web_based_tool.pdf. The Internet site that provides the relative information as long as relative references [e.g. Stohl et al., 2007] are also given in the text.

(4) Figures 6 and 7 were not referenced in the correct order in the text. This is corrected in the new version of the paper.

Reviewer 2:

According to reviewer’s suggestion, authors emphasized through the text the possible impact of our paper on the lidar community for reducing uncertainty in the aerosol backscatter coefficient determination starting from a simply elastic backscatter lidar as the first satellite-borne lidar actually operational (CALIPSO) (Abstract and Conclusions sections).

Answer to the main comment:

The aerosol backscatter coefficient at 532 nm is determined from the elastic backscatter lidar signal profile using the well-known Klett inversion method [Klett 1981]. This method requires a critical input parameter, the range-independent value of the lidar ratio. In this study, we are estimating a column-averaged value of the lidar ratio at

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532 nm using a combination of the backscatter measurements and coincidental sunphotometric aerosol optical depth measurements (taken by CIMEL, MFR or Brewer measurements). Specifically, we are performing Klett inversions at 532 nm for different values of lidar ratio (in the range between the mean value of already calculated LR@355 minus 30 sr to mean value of LR@355 plus 30 sr with a step of 5 sr) and then, we choose that lidar ratio value for which the lidar calculated optical depth agrees with the optical depth retrieval from our collocated sunphotometers. This approach was presented in Balis et al., [2003].

There are three sources of uncertainties on this methodology: (i) The lidar ratio can be variable with height and a mean value for the entire columnar profile is not representative. The method is applied only in cases where the vertical variability of the calculated lidar ratio at 355 nm is not large. This behavior for the lidar ratio indicates the same aerosol type for the height range under study, and one can assume the same behavior at 532 nm. In cases where lofted aerosol plumes are present, the lidar ratio at 355nm is expected to have large vertical variability and the method cannot be applied. However, for smoke cases within this study, the lidar ratio at 355 nm shows no significant vertical variability within the smoke layers.

(ii) Since a sunphotometer measures during daytime, the agreement of the optical depth retrieved with Brewer spectroradiometer in the UV region during afternoon hours with the optical depth retrieved by Raman lidar at 355 nm during nighttime could be different. Again, we are first examining the consistency between daytime and nighttime optical depth values and then we apply the method. Again, a good agreement was found for the 10 cases under study.

(iii) The assumptions are critical, especially in regard to the incomplete overlap region of our lidar measurements (complete overlap at ˜ 1 - 1.5 km depending on alignment) where we are usually assuming well mixed aerosol conditions and a uniform nocturnal boundary layer for the calculation of the optical depth with Raman lidar. To account for this assumption, and only when the (i) and (ii) are fulfilled, we constrain our calculations only in the complete overlap height region. To do that, we first calculate the percentage contribution of the lidar calculated optical depth at 355 nm in the complete overlap region (e.g. from 1-5 km to the aerosol free region) to the total optical depth measured by the sunphotometer. The input parameters for the Klett method at 532 nm are then chosen in such a way that the integrated backscatter coefficient at 532nm for the same height region (e.g. 1-5 km to the aerosol free region), when multiplied with the appropriate lidar ratio (found after iterations), would give the same percentage of the optical depth value determined for the respective wavelength (500 nm) with the sunphotometer. The above method was applied and presented in a biomass burning case studied in detail in Balis et al., [2003].

For the 10 cases of the present study, the vertical variability of the lidar ratio was not significant for the height ranges of smoke presence (see Figure 5). Additionally, the daytime sunphotometric measurements were in good agreement with lidar derived optical depths at 355 nm assuming a uniform boundary layer for the incomplete overlap region. Possible reason for this agreement is that smoke advection from wildfires at the Northern-Eastern of Thessaloniki is always accompanied with stagnant meteorological conditions. As a result, during these episodes smoke remains in the free troposphere over Thessaloniki for a number of days, resulting in no significant daily aerosol variability.

After careful lidar data analysis and being consistent with collocated sunphotometric measurements, the above presented approach was applied to the 10 cases under study. A more detailed error analysis is beyond of the scope of this paper, although we agree with the reviewer that the uncertainty on backscatter at 532 nm is affecting significantly the uncertainty on the backscatter related Angstrom exponent derived by the lidar. However, the variability of this parameter, which provides an indication on the size of the particles, follows the variability of the extinction related Angstrom exponent calculated by the collocated sunphotometric measurements, showing a range of aerosol sizes measured with our instruments. Backscatter related Angstrom exponent (355.532nm) from the Lidar measurements and extinction related exponent (350.400nm) taken from the sun photometric measurements showed a correlation coefficient of 0.94 for the 10 studied cases. This information was added in the new version of our paper. It has to be noticed that when the backscatter-related Angstrom Exponent equals the extinction-related Angstrom Exponent of the corresponding wavelengths, then the lidar ratios at the 2 wavelengths have to be equal. The authors believe that the backscatter-related Angstrom Exponent values calculated following the approach presented in Balis et al., [2003], are trustworthy. However, authors agree with the reviewer that in case of the lidar ratio measurements, the error is only statistical and much lower than the total error affecting the backscatter-related Angstrom exponent values. Therefore, the authors emphasize in the new version of the paper on the relationship of the lidar ratio measured values at 355 nm against the model estimated age of the smoke particles. However, we have to mention that CALIOP lidar instrument on board of CALIPSO satellite aims to provide backscatter-related Angstrom Exponent values in a global scale operating with 2 backscatter channels. Authors, following this fact, and estimating ground-based backscatter-related Angstrom Exponent values carefully, tried in the previous version of the paper to present a methodology that could provide Lidar Ratios for the space-borne lidar, based on its own measurements/estimations. This methodology is demonstrated in Figure 7 of the new version of the paper, where we present the relationship between the lidar ratio and the age of the smoke particles with the estimated backscatter-related Angstrom exponent. The uncertainties on the estimation of this parameter are properly emphasized in the new version following reviewer’s suggestions.

Finally, and following the reviewer’s suggestion, the authors clearly state in the new version of the paper that the results presented are not valid for all agricultural fires and the whole globe. This was already stated in Page 15 of the old version, however we gave more emphasis by mentioning it also in Conclusions.

Minor comments:

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Page 5, line 6: The EARLINET was replaced with EARLINET

Page 6, toward the end: The error estimations are referring to Thessaloniki’s algorithms. The text has been corrected according to reviewer’s comment and the errors are now distinguished on the base of aerosol content, following also the results reported in Pappalardo et al., 2004.

Page 8: The number of the equation has been right aligned. (A) in (A)ATSR is an abbreviation to clarify that we use a combination of fire data from ATSR and AATSR Along Track Scanning Radiometers onboard the ERS-2 (2000-2002) and ENVISAT (2003-2005) respectively. The (A)ATSR was replaced with ATSR and AATSR

Page 11, line 3: Stohl et al., [2007] found that 180 ha of burned area per hotspot is a representative value for MODIS hotspot detection. ATSR detects fewer fires, so we used a larger area burned/hot spot (600 ha) (no reference for this assumption). This assumption is not calibrated as the MODIS relationship, so it's even more uncertain. The tracer values presented in this study must be seen as qualitative and this is mentioned in the text. However, and beyond the absolute values, since the relationship used is linear, our assumption doesn’t affect the variability of the tracer values presented.

Page 12-13: The following text has been added, following reviewer’s suggestions:

It has to be emphasized here, that backscatter-related Ångström Exponent values presented in this paper are not directly retrieved by measurements, since the backscatter profile at 532 nm used for the calculations is retrieved after the assumption of an unknown vertically constant lidar ratio. However, even if affected by a large uncertainty due to lidar ratio assumption, backscatter-related Ångström Exponent can still provide an indication about the size of the particles.

Page 15, line7: The lidar ratio can be calculated also by High Spectral Resolution

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Lidars (HSRL). This was mentioned in the text and a relative reference has been added [Fiocco et al., 1971].

Table 1: According to hot spot data from ATSR World Fire Atlas (http://dup.esrin.esa.int/ionia/wfa/index.asp), fewer fires were occurred during 2003 and 2004 comparing with wild fires occurred in 2001, 2002 and 2005 in biomass burning regions examined in this study (latitudinal belt between 45N – 55N). This is the main reason that no smoke data are available for 2003 and 2004.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 18267, 2008.

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