Aerosols are particles in the solid or liquid phase that are suspended in the atmosphere and play a very important role in the Earth-atmosphere energy budget, since they modify it through various atmospheric processes. Such processes are: The direct effect by scattering and absorption of the solar and Earth’s radiation (Coakley et al., 1968; Charlson et al., 1992), the semi-direct effect by changing atmospheric thermodynamics and cloud formation (Ackerman et al., 2000; Koren et al., 2004), and finally the indirect effect by changing cloud microphysics (Twomey, 1977; Rosenfeld and Lavecchia, 1996). The influence of aerosols on ultraviolet (UV) radiation has received a lot of attention in research, since the impact of UV radiation on human health, the biosphere and atmospheric chemistry strongly depends on the characteristics and quantity of aerosols in the atmosphere. Therefore, long-term and accurate data sets of aerosol optical properties are critical for a better understanding of the role of aerosols on the energy balance of the planet (Wilm, 2009) and thus to estimate future climate scenarios.

The aerosol optical depth (AOD) is used to quantify the amount and variability of aerosol loading in the atmospheric column over a certain area. In the past few years, several algorithms have been proposed in order to retrieve the AOD in the UV region using ground-based observations. The AOD can be determined by estimating the attenuation of the direct solar beam throughout the atmosphere compared to the extraterrestrial irradiance (Langley, 1903).

Over polluted environments, measurements of the AOD using the Langley extrapolation method are highly uncertain. Kazadzis et al. (1992) proposed and validated methods for the estimations of the AOD in the UV region which is more proper for such environments. The main purpose of this study is to evaluate this methodology and investigate a variety of parameters that have an impact on the AOD retrieval. In order to assess the quality of our results, the derived AOD values are compared with quasi-simultaneous measurements (13min), obtained by a co-located Cimel sunphotometer. Both instruments are located at the facilities of the Laboratory of Atmospheric Physics (altitude 40.634°N, longitude 22.956°E, altitude 60 m above sea level), Thessaloniki, Greece.

**Introduction**

Aerosol particles are small objects that are suspended in the air and can have a significant impact on the Earth's radiation budget. They scatter and absorb sunlight, affecting the temperature and climate. The aerosol optical depth (AOD) is a measure of the amount of aerosol loading in the atmospheric column over a certain area. In recent years, various algorithms have been proposed to estimate the AOD in the ultraviolet (UV) region using ground-based observations. The AOD can be determined by estimating the attenuation of the direct solar beam throughout the atmosphere compared to the extraterrestrial irradiance (Langley, 1903). Over polluted environments, measurements of the AOD using the Langley extrapolation method are highly uncertain. Kazadzis et al. (1992) proposed and validated methods for the estimations of the AOD in the UV region which is more proper for such environments. The main purpose of this study is to evaluate this methodology and investigate a variety of parameters that have an impact on the AOD retrieval. In order to assess the quality of our results, the derived AOD values are compared with quasi-simultaneous measurements (13min), obtained by a co-located Cimel sunphotometer. Both instruments are located at the facilities of the Laboratory of Atmospheric Physics (altitude 40.634°N, longitude 22.956°E, altitude 60 m above sea level), Thessaloniki, Greece.

**Effect of circumsolar light and polarization on the calibration**

While direct-sun observations the Brewer is meant to measure only the direct component of the solar radiation, a certain fraction of diffuse circumsolar light (circumsolar light) gets in the instrument’s field of view and increases the uncertainty of the measurements. The calibration should be performed when the AOD increases minimal since the circumsolar light becomes more significant as they increase. Fig. 2 shows the difference in % between the calculated response at different SZA relative to the response at SZA = 47.9°, as well as the effect of circumsolar light for each case. For Sza lower than 55° the differences in the calculated response are small (<1%). For higher values, the differences become larger as the SZA increases. Although the effect of circumsolar light increases with SZA, it seems that its effect is not the main driver of the differences.

In most similar research activities the effect of NO2 is assumed to be small and can be ignored. In this study, we estimated the effect of NO2 absorption by running the Brewer retrieval algorithm with and without taking into account NO2 absorption. For this purpose we used monthly mean values of the NO2 concentration for the period 2012 – 2016 measured by the co-located MAX-DOAS Phaethon systems (Drosov et al., 2017). Fig. 6 shows the comparison between the AOD at 340 nm retrieved by BBS and Cimel for the two case scenarios mentioned above. As shown in Table 1, the agreement is slightly better when the effect of NO2 is taken into account.

**Effect of NO2**

Table 1. The results of the statistical analysis of the comparison between the AOD retrieved by BBS and Cimel for the two case scenarios mentioned above. As shown in Table 1, the agreement is slightly better when the effect of NO2 is taken into account.

**Results and discussion**

**Effect of temperature and polarization on the AOD retrieval**

Fig. 4 shows the difference in AOD measured with the Brewer spectrophotometer and the Cimel sunphotometer when the polarization correction is not applied relative to SZA. The polarization correction leads to smaller differences between the two instruments for all SZA. Yet, even after the polarization correction is applied, there are still differences for higher SZA, which however are not greater than the standard deviation of the measurements.

**Variability of the AOD**

Fig. 8 shows the monthly mean values of AOD and their differences for 340 nm as measured by the BBS Brewer spectrophotometer and the Cimel sunphotometer for the period 2015 – 2017. Simultaneous measurements from both instruments reveal a clear seasonal pattern with a distinct maximum of AOD in the summer months (between 0.4 and 0.5), while in the winter the AOD is generally of the order of 0.2. The observed AOD seasonality can be attributed to various processes: Enhanced photoxidation and high temperatures in the summer increase the turbidity in the boundary layer due to convection with stagnant weather systems over the area in the help in the build up of the aerosols. The summer peak in the AOD is also supported by the absence of significant wet removal of aerosols and by the tem-pré-boundary transport of particles from eastern directions. During the winter months, there is significant wet deposition of aerosols, which together with the northern winds that are dominant in the area, result in clearing of the atmosphere and thus to lower AOD values (Kazadzis et al., 2005).

The differences in AOD are relatively small (<1%) when the measurements of the two instruments are quasi-simultaneous. The fact that the differences become significant, especially in the winter, when the monthly mean values are derived from the whole dataset of BBS is possibly due to imperfect cloud screening.

**Conclusions**

- The effects of the polarization and the circumsolar light on the Brewer’s calibration process are relatively small (<1%) for lower SZA.
- Applying a correction for the Brewer’s internal temperature and polarization reduces the differences between the AOD values derived by the Brewer and the Cimel sunphotometer. Yet, non-negligible differences remain for higher SZA and lower temperatures.
- A high resolution solar extraterrestrial spectrum should be used in order to minimise the uncertainties of the derived AOD.
- A reasonable estimate (preferably based on meteorological data) should be considered for NO2 absorption.
- The seasonal and variability of the AOD derived by the Brewer spectrophotometer, is consistent with other studies that show higher AOD values during spring/summer and lower values in autumn/winter.