Aerosol Optical Depth retrieval in the UV spectral range by means of Brewer spectrophotometry and an application at Roma and Lampedusa measurement stations

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1. Introduction

Atmospheric aerosols can affect the radiative transfer in Earth's atmosphere by means of scattering and absorption of solar and terrestrial radiation (d'Almeida, 1991). In addition they can interact with cloud formation, lifetime, and optical properties. Owing to the large uncertainties in aerosols' space-time characterization, the global aerosol effect is one of the major unknowns issues of the Earth's climate system (IPCC, 2001).

Aerosol optical properties are relatively well known in the visible spectral range. Little information is known on the optical properties of atmospheric aerosol in the ultraviolet spectral region. Recently, it has been observed that desert dust and aerosols from biomass burning can significantly reduce surface UV levels (WMO, 2002); moreover, Krzyscin and Puchalski (1998) showed that, in highly polluted areas, absorption of solar UV radiation by urban anthropogenic aerosols produces a reduction of surface UV irradiance; this reduction may mask the surface UV irradiance increase associated with low total ozone episodes. For these reasons precise observations of UV aerosol optical properties with global coverage and over long time periods are crucial; furthermore this would be of great aid in satellite data calibration and validation. Only few long time series of aerosol optical properties measurements in the UV are available and there is no satisfactory worldwide spatial coverage. It would be of great aid adding measurement techniques with alternative instruments to the existing ones; from this point of view Brewer spectrophotometer data re-analysis is a good chance. In fact the Brewer is expressly designed to perform measurements of UV radiances and irradiances and there exists a network of Brewer spectrophotometers (ca. 140 instruments) worldwide distributed, mainly for ozone monitoring.

In my thesis' work I have developed and validated an improved Langley Plot-based AOD(UV) retrieval and re-analysis methodology which, if applied to Brewer data, can provide decade-long time series of AOD at the Brewer operative wavelengths (6 wavelengths from ca. 300 nm to ca. 320 nm). The methodology has been applied at radiance data from the Brewer stations #067 and #123 operating respectively at Roma-La Sapienza University and Lampedusa (Ag), allowing trend analyses over near-10-years series of aerosol optical depth data in the UV at these interesting Mediterranean locations.

2. Methodology

A modified Langley Plot method has been implemented to retrieve aerosol optical depth from direct sun Brewer measurements. The Langley plot is the linear regression of the logarithm of the measured radiance versus the airmass in clear sky mornings and afternoons. The extraterrestrial instrumental constant is determined from the plot as the extrapolated radiance at zero airmass. In the Langley method the reference radiation source is the Sun itself, and a relative radiometric calibration, i.e. in instrumental units, is obtained. The method uses measurements obtained with two different neutral density filters (by computing the relative transmissivity of one filter with respect to the other using a dedicated routine) over a relatively wide range of atmospheric airmasses, and accounts for short-term variations of total ozone, derived from the same direct sun observations. The efficiency of the improved algorithm has been tested comparing the number of determinations of the extraterrestrial constant against those obtained with a standard Langley plot procedure. The improved method produces a larger number of reliable Langley plots (applying the same selection criteria), allowing for a better statistical characterization of the extraterrestrial constants and a better study of its temporal variability. For details on the standard Langley plot methodology for AOD retrieval from Brewer direct sun measurements see e.g. Marenco et al. (2002).

3. Results

The improved algorithm has been applied to data collected with a single monochromator Brewer Mk IV, operational at Roma, and with a double monochromator Brewer Mk III, operational at Lampedusa, in the Mediterranean. I have obtained the time series of AOD at the Brewer operating wavelengths for the period 1995-2004 for Roma station and 1998-2004 for Lampedusa station. From the monthly mean AOD (only using data in clear-sky conditions) at each UV wavelength a marked seasonal trend emerges with a maximum in summer months (0.41±0.16 in August at Lampedusa and 0.49±0.18 in July at Roma, both at 320.1 nm) and a minimum in winter months (0.12±0.07 in January at Lampedusa and 0.28±0.13 in December at Roma, both at 320.1 nm). This trend is in agreement with the globally observed AOD variation through the year, reported in the VIS and IR ranges (see e.g. Husar, 1997). In addition phenomena involved with Saharan dust intrusions in the Mediterranean area or transport of biomass burning particles (e.g. in Summer 2003) have been observed, showing so the capabilities of the methodology.

4. Validation

The values of aerosol optical depths calculated at Roma and Lampedusa compare well with simultaneous determinations in the 415-440 nm interval derived from a MultiFilter Rotating Shadowband Radiometer (operating side by side with Brewer #123) and two NASA-AERONET CIMEL (operating at Lampedusa station and at Roma-Tor Vergata station) measurements. It emerges a quite similar temporal behaviour of the time series of daily mean AOD from Brewer, Cimel and MFRSR at the same locations while AODs at 320.1 nm, as expected for the Ångström relation, are constantly greater than AODs in the interval 415-440 nm. The correlation coefficients of the comparisons of coincident daily mean values of AOD were: R^2=0.94 for data from Brewer (at 320.1 nm) and Cimel (at 440 nm) at Roma in the period 2001-2004 (148 pair of data) and R^2=0.93 for data from Brewer (at 320.1 nm) and MFRSR (at 415 nm) at Lampedusa in the period 1999-2004 (254 pairs of data), showing the reliability of the methodology.

5. Conclusions

In my thesis' work I developed an improved Langley Plot-based retrieval methodology for AOD(UV) by means of Brewer spectrophotometer direct sun radiance data.

By applying this methodology at data from Brewer #067 (Roma) and #123 (Lampedusa) I have obtained near-decade-long time series of AODs at Brewer UV operative wavelengths, allowing the study of seasonal trends and geophysical phenomena involved in Saharan dust intrusions, biomass burning and anthropogenic aerosols' production. This methodology leads, in principle, at a higher accuracy retrieval than a standard Langley Plot methodology. In fact, calibration factors can be calculated with a better statistical sample, by using data from two neutral density filters instead of only one and Langley Plot are made avoiding ozone perturbations at the constancy of the linear regression function angular coefficient.

The methodology has been successfully validated (high correlation coefficients) by comparing the retrieved AOD (320.1 nm) with AOD data by NASA-AERONET CIMEL (at 440 nm) and MFRSR (at 415 nm).

6.Bibliography

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