Sun-Pointing-Error Correction for Sea Deployment of the MICROTOPS II Handheld Sun Photometer

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ABSTRACT

Handheld sun photometers, such as the MICROTOPS II (manufactured by Solar Light, Inc.), provide a simple and inexpensive way to measure in situ aerosol optical thickness (AOT), ozone content, and water vapor. Handheld sun photometers require that the user manually point the instrument at the sun. Unstable platforms, such as a ship at sea, can make this difficult. A poorly pointed instrument mistakenly records less than the full direct solar radiance, so the computed AOT is much higher than reality. The NASA Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies (SIMBIOS) Project has been collecting maritime AOT data since 1997. As the dataset grew, a bias of the MICROTOPS II data with respect to other instrument data was noticed. This bias was attributed to the MICROTOPS II measurement protocol, which is intended for land-based measurements and does not remove pointing errors when used at sea. Based upon suggestions in previous literature, two steps were taken to reduce pointing errors. First, the measurement protocol was changed to keep the maximum (rather than average) voltage of a sequence of measurements. Once on shore, a second screening algorithm was utilized to iteratively reject outliers that represent sun-pointing errors. Several versions of this method were tested on a recent California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruise, and were compared to concurrent measurements using the manufacturer-supplied protocol. Finally, a separate postprocessing algorithm was created for data previously gathered with the manufacturer-supplied protocol, based on statistics calculated by the instrument at the time of capture.

1. Introduction

This note is an extension and validation of the recommendations made in Porter et al. (2001) with regard to problems associated with proper sun pointing using a MICROTOPS II (Solar Light, Inc.) sun photometer. Porter et al. (2001) showed that rough sea conditions can cause a bias in aerosol optical thickness (AOT) measurements with the MICROTOPS II sun photometer when using the manufacturer-supplied default measurement protocol, because this protocol is not sufficient to remove erroneous data points caused by improper pointing at the sun. Porter et al. discussed making changes with respect to sun-pointing problems. While the instrument is deployed at sea, only the highest voltage from a sequence of 25 measurements, rather than the average of the top 4 voltages of a sequence of 32 measurements, is to be saved in the instrument's memory. Once on land, an iterative process, based upon the variability of each set of measurements, is used to reject measurements contaminated by sun-pointing errors. We compared measurements made with these changes to the manufacturer-supplied default measurement protocol while at sea, and refined the iterative rejection routine to reflect the uncertainty analysis of Pietras et al. (2002) and the statistical analysis of maritime aerosols by Smirnov et al. (2002). We also demonstrate a method to remove erroneous measurements from data previously collected by the manufacturer-supplied default MICROTOPS II measurement protocol.

Figure 1 shows the MICROTOPS II sun photometer in use. The operator points the instrument at the sun, and presses the ''Enter'' button. The voltage is stored for each of the five detector bands (typically centered at 440, 500, 675, 870, and 936 nm), along with the

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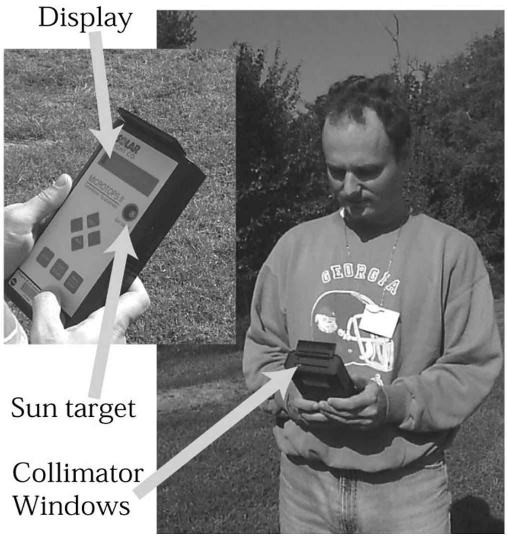

FIG. 1. MICROTOPS II sun photometer in use.

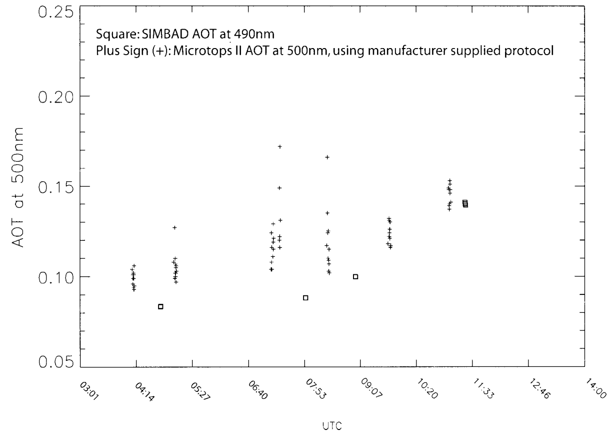

FIG. 2. AOT values measured by two sun photometers during the Indian Ocean Experiment (INDOEX) cruise off southern India on 10 Mar 1999. Note the large range of values associated with each set of MICROTOPS II measurements. This range is due, in part, to sun-pointing errors.

ambient pressure, and latitude and longitude coordinates. Aerosol optical thickness [AOT, or $\tau(\lambda)$] values are calculated for each band (except the 936-nm band, which is used to determine water vapor content) from instrument voltages using the following relationship (Frouin et al. 2001; Volz 1959):

$$V(\lambda) = V_o(\lambda)\left(\frac{d_o}{d}\right)^2 e^{-M\tau(\lambda)} t_g(\lambda), \qquad (1)$$

where λ is the center wavelength of the detector band; $V(\lambda)$ is the measured detector voltage in the band with a center wavelength of λ; $V_o(\lambda)$ is the voltage expected at the top of the atmosphere, and expresses the calibration for the band with a center wavelength of λ; d_o/d accounts for the earth–sun distance as it varies with the day of the year; M is the air mass, based on the solar zenith angle; $\tau(\lambda)$ is the total optical thickness; and $t_g(\lambda)$ is the transmission of absorbing gases.

Figure 2 shows AOT values from two instruments. The range of the MICROTOPS II values is well beyond the uncertainty of the instrument (0.015; Pietras et al. 2002). Note the bias associated with MICROTOPS measurements with respect to data from the Simbad radiometer (designed by Laboratoire d'Optique Atmosphérique). (Fougnie et al. 1999; Deschamps et al. 2002, manuscript submitted to *Appl. Opt.*, hereafter DFFLV). The lowest AOTs for each set of MICROTOPS II points represent actual physical values, as erroneous measurements collected with poor pointing will produce unrealistically high AOTs. Like the MICROTOPS II, the Simbad is pointed directly at the sun; however, it avoids pointing problems by using a higher measurement rate (10 Hz) and by keeping only the lowest AOT value of a set of 10. (Fougnie et al. 1999; DFFLV).

4. Conclusions

The SIMBIOS Project has been collecting aerosol data from the MICROTOPS II for several years. As comparisons with other instruments became available, it became apparent that this particular instrument was collecting data with variability, in a short time span, much higher than the calculated instrument uncertainty. Also, Porter et al. (2001) wrote that high variability is often due to problems pointing the instrument accurately at the sun while on a moving platform such as a boat at sea. Porter et al. recommended reducing the number of measurements averaged into each data point and iteratively removing outliers from the results. We did this, then collected data to test both measurement protocols. Although a sizeable dataset with this new protocol has yet to be captured, comparisons between both protocol types and with data from other instruments show that this is a viable method to reduce or remove the sun-pointing-error problem. This protocol and postprocessing algorithm has been incorporated into the operational SIMBIOS deployment strategy for all future MICROTOPS II use.