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Microtops II Handheld Sun Photometer Sun Pointing Error Correction for Sea Deployment

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Abstract

Handheld sun photometers, such as the Microtops II (manufactured by Solar Light, Inc..), provide simple and inexpensive means to measure in situ aerosol optical thickness (AOT). Handheld sun photometers require that the user manually points the instrument at the sun. Unstable platforms, such as a ship at sea, can make this difficult, causing pointing errors. A poorly pointed instrument mistakenly records less than the full direct solar radiance, so the computed AOT is much higher than reality, and can be mistaken as cloud contamination or used incorrectly for validation with satellite derived AOT measurements.

The National Aeronautics and Space Administration's (NASA) Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies (SIMBIOS) Projects have been collecting maritime AOT data since 1997. As the data set grew, a bias of the Microtops II data with respect to other instrument data was noticed. This bias was attributed to the failure of the Microtops II measurement protocol, intended for land based measurements, to remove pointing errors when used at sea (Porter et al. 2001).

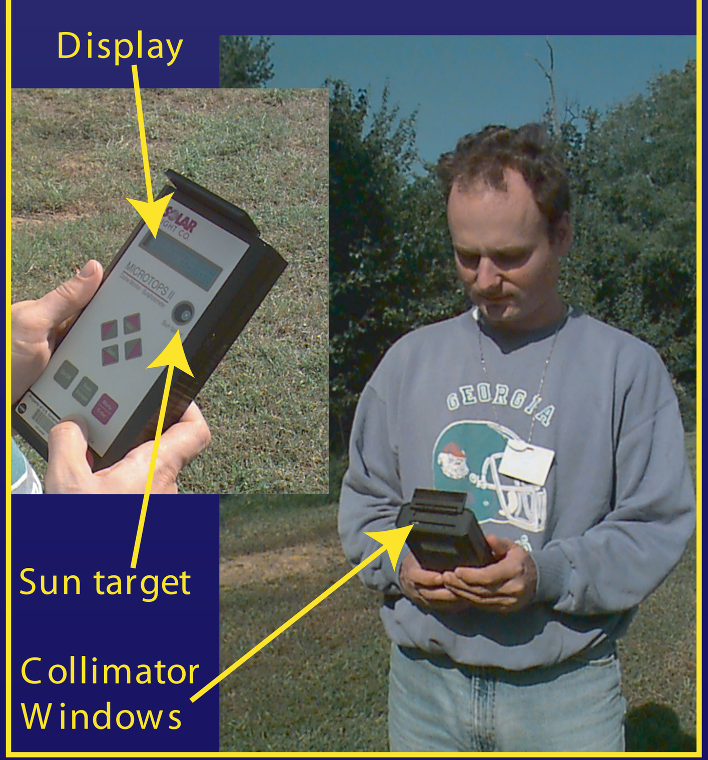
Two steps were taken to reduce pointing errors. First, the measurement protocol was changed to keep the maximum (rather than average) value of a sequence of measurements. Several sets of these sequences are made for each intended data point. Once on shore, a second screening algorithm was applied. This algorithm uses statistics computed for each group of measurements. If the normalized variance of a group is above a threshold, the highest AOT measurement is discarded as a pointing error. The normalized variance is then recalculated. This is repeated until the normalized variance is reduced below the threshold or the number of points becomes too small to calculate variance.

Several versions of this protocol were tested on a recent California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruise, and a post-processing algorithm was developed to remove pointing errors. These results were compared to concurrent measurements using the old protocol. Finally, a separate post-processing algorithm was created for data already gathered with the old protocol, based on statistics calculated by the instrument at the time of capture.

Background

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 440nm, 500nm, 675nm, 870nm, and 936nm), along with the ambient pressure, and latitude and longitude coordinates.

Figure 1: Microtops II in Use



Aerosol optical thickness (AOT, or $\tau_{(\lambda)}$) values are calculated for each band from instrument voltages using the following relationship (Frouin et al. 2001, and Volz 1959):

$$V_{(\lambda)}=V_{o(\lambda)}\left[{}^{d_o}/_{d}\right]^2 \exp\left[-(M\,\tau_{(\lambda)})\right] t_{g(\lambda)} \qquad (1)$$

where:

λ signifies the wavelength of the detector band;
$V_{(\lambda)}$ is the measured detector voltage in band λ;
$V_{o(\lambda)}$ is the voltage expected at the top of the atmosphere, and expresses the calibration for band λ;
${}^{d_o}/_{d}$ accounts for the EarthÐsun distance as it varies with the day of the year;
M is the airmass, which represents the atmospheric path length of a ray of light from the sun (airmass is based on the sun zenith angle);
$\tau_{(\lambda)}$ is the aerosol optical thickness; and
$t_{g(\lambda)}$ is the transmission of absorbing gases.

If the sun photometer is not pointed accurately at the sun, the value for $V(\lambda)$ decreases, thus increasing the calculated AOT. These high values add a bias that confuses subsequent cloud screening algorithms and reduces the effectiveness of data merger.

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Example

Figure 2: Microtops II data with pointing errors

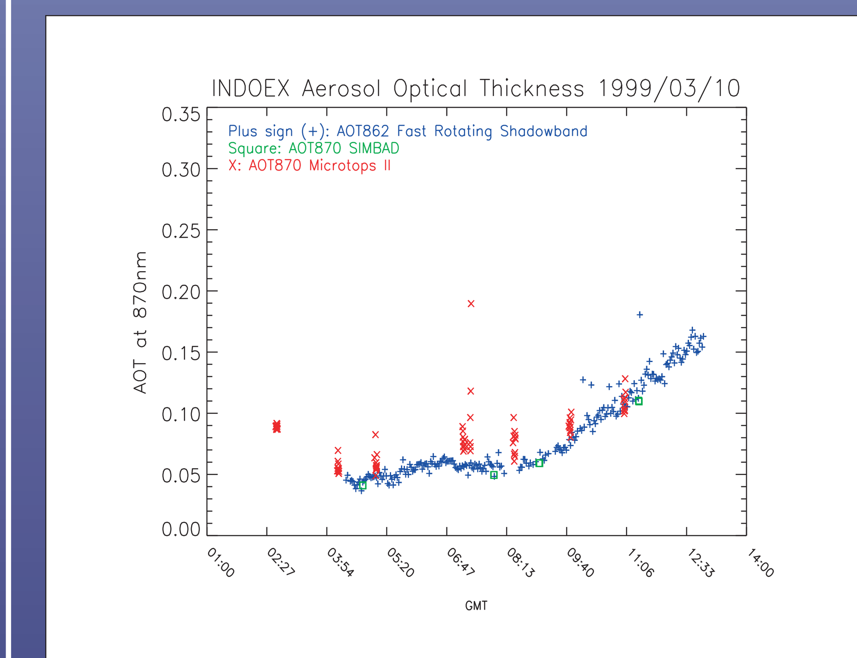


Figure 2 shows AOT values from several instruments. The range of the Microtops II values are well beyond the known error of the instrument (0.015) (Pietras et al. 2001). Note the bias associated with Microtops measurements with respect to the Fast Rotating Shadowband Radiometer (FRSR) and SIMBAD data (Reynolds et al. 2000, and Fougnie et al. 1999). It is clear that the lowest AOTs for each set of Microtops II points represent the actual physical values. Theoretically, the FRSR cannot have pointing problems in the manner of the Microtops II instrument, as it uses a different method for determining AOT than measuring the direct solar intensity. Like the Microtops II, the SIMBAD is pointed directly at the sun, however, it avoids pointing problems by using a higher measurement rate (10Hz) and a post-processing algorithm (Fougnie et al. 1999).

Screening

The Microtops II instrument has a default screening protocol intended to solve the pointing error problem. Figure 2, above, and Porter et al. 2001, illustrate that the default protocol is not sufficient for unstable platforms such as a boat at sea. If the Microtops II is to be used as part of the SIMBIOS Project, a method to correct for pointing errors must be found.

Figure 3: Default Microtops II Screening

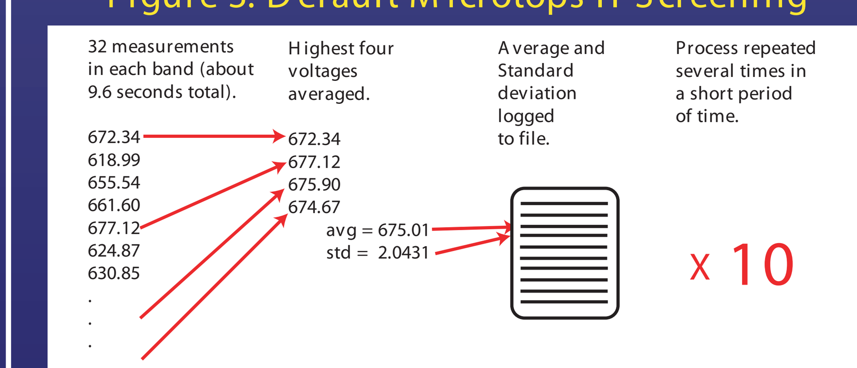
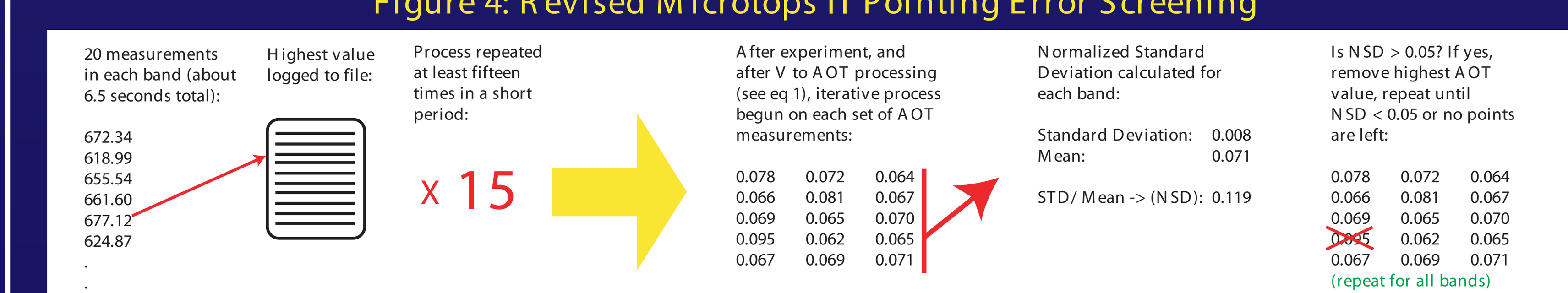


Figure 3 shows the default screening protocol for the Microtops II sun photometer. It works well when it is deployed on a stable platform. Unstable platforms, such as the deck of a ship at sea, can make it difficult to keep the instrument pointed at the sun for the duration of the measurement. Of course, this is very dependent on sea roughness and the user's skill.

To reduce the possibility of recording data with pointing error contamination, two steps were taken. First, the measurement protocol was changed. Unlike the default protocol, which saves the average of the 4 largest (out of 32) voltage values, the new protocol logs the largest single value of 20 measurements. This has several advantages. The largest voltage is the only value recorded, so the chance of keeping a contaminated point is minimized. In addition, the total time needed to make this measurement is smaller than with the default protocol, so more measurements can be taken in a short period of time. After the experiment, a post-processing algorithm is applied. This algorithm calculates a normalized standard deviation (NSD) value for each set of measurements in each band. If the NSD is above a threshold of 0.05, the lowest voltage (highest AOT) value is removed, and the NSD recalculated. This is repeated until it is less than 0.05 or there are not enough points left to calculate the standard deviation. The passed points are those that passed this iterative process in all bands. Figure 4 shows this screening method.

Figure 4: Revised Microtops II Pointing Error Screening



Results

Figure 5: New Protocol and Error Screening Results

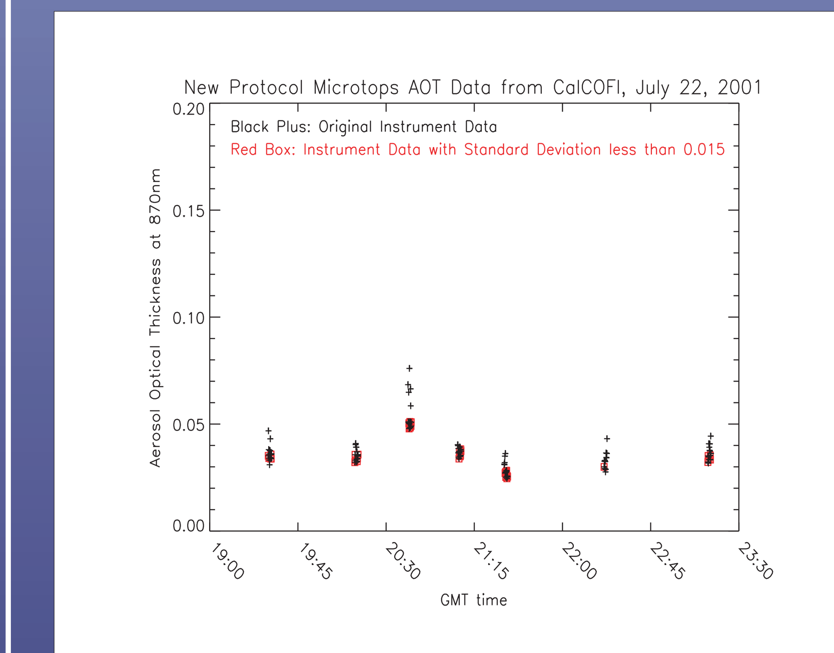


Figure 5 shows results from a recent CalCOFI cruise off the coast of California, where Microtops II measurements were made under moderately rough sea conditions using the new protocol. Once on shore, the data were screened according to the method shown in Figure 4. The black crosses in Figure 5 denote original data, while the red boxes surround points that passed the iterative screening algorithm. Note how the lowest AOT values in each data set are passed; however, this is not uniformly so, as points are passed based on results in all bands.

While the new protocol and processing algorithm will reduce pointing errors in new data, several years of data have already been archived with the old protocol. The SeaWiFS Bio-optical Archive and Storage System, (SeaBASS), contains Microtops II AOT data from 1997 to the present. To remove data with pointing errors, raw voltage files were reprocessed and sent through a screening algorithm. This algorithm removes points whose standard deviation, in terms of AOT, exceeds the instrument error of 0.015. Figures 6 and 7 show examples of old data which have been reprocessed to remove pointing errors.

Figure 6: Reprocessed Microtops II Data from Old Protocol - Rough Conditions

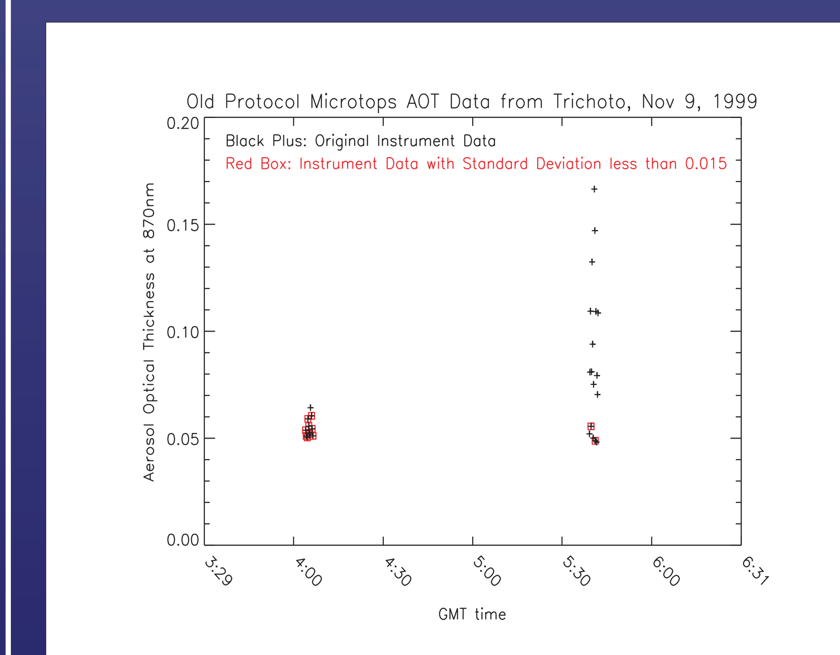
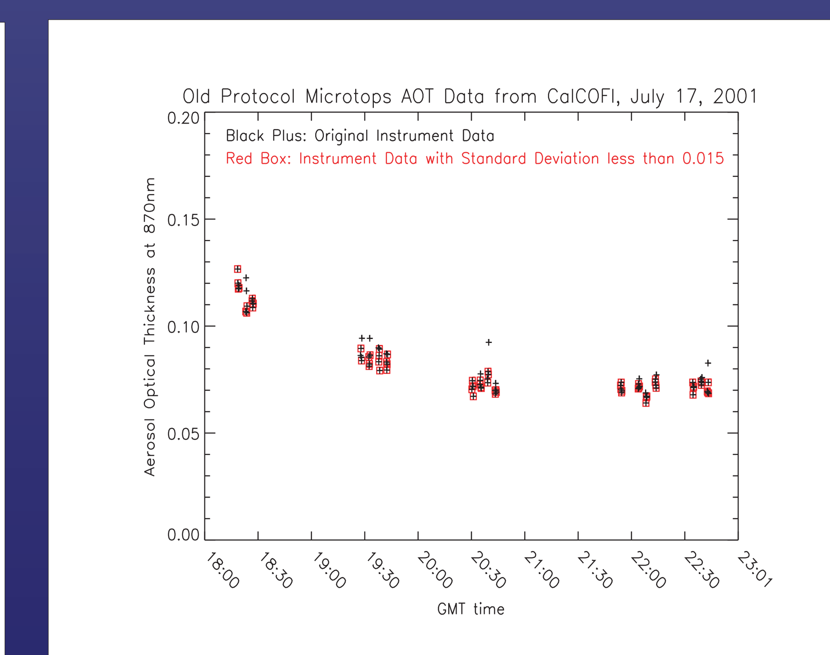


Figure 7: Reprocessed Microtops II Data from Old Protocol - Calm Conditions



Acknowledgments

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References

SIMBIOS Project: simbios.gsfc.nasa.gov
SIMBAD: polaris.ucsd.edu/~simbad
INDOEX: www-indoex.ucsd.edu
SeaBASS Database: seabass.gsfc.nasa.gov
FRSR: www.gim.bnl.gov/instruments/prp
AERONET: aeronet.gsfc.nasa.gov
Solar Light Company: www.solar.com
CalCOFI: www.calcofi.org

Fougnie, B., R. Frouin, P. Lecomte, and P-Y. Deschamps, 1999: Reduction of skylight reflection effects in the above-water measurement of marine diffuse reflectance. Applied Optics, 38, 3844-3856.

Frouin, R., B. Holben, M. Miller, C. Pietras, J. Porter, and K. Voss, 2001: "Sun and sky radiance measurements and data analysis protocols," In Fargion, G., R. Barnes, and C. McClain, In Situ Aerosol Optical Thickness Collected by the SIMBIOS Program (1997-2000): Protocols, and Data QC and Analysis. NASA Tech. Memo. 2001-209982, NASA Goddard Space Flight Center, Greenbelt, Maryland, 26-42.

Pietras, C., M. Miller, R. Frouin, T. Eck, B. Holben, and J. Marketon, 2001: "Calibration of sun photometers and sky radiance sensors," In Fargion, G., R. Barnes, and C. McClain, In Situ Aerosol Optical Thickness Collected by the SIMBIOS Program (1997-2000): Protocols, and Data QC and Analysis. NASA Tech. Memo. 2001-209982, NASA Goddard Space Flight Center, Greenbelt, Maryland, 11-21.

Porter, J.N., M. Miller, C. Pietras, and G. Motell, 2001: Ship-based sun photometer measurements using Microtops sun photometers, J. Atmos. Ocean. Tech., 18, 765-774.

Reynolds, R.M., M.A. Miller, and M.J. Bartholomew, 2000: Design, operation, and calibration of a shipboard fast rotating shadowband spectral radiometer, J. Atmos. Ocean. Tech., 18, 200-214.

Volz, F.E., 1959: Photometer mit Selenphotoelement zurspektralen Messung der Sonnenstrahlung und zer Bestimmung der Wallenlangenabhangigkeit der Dunsttrubung. Arch. Meteor. Geophys Bioklim. B10, 100-131.