SAFARI 2000 Atmospheric Radiation Measurements, Hand-held Hazemeters, Zambia

Abstract

In conjuction with the AERONET participation in SAFARI 2000, the USDA Forest Service deployed hand-held hazemeters in western Zambia from mid-June to late September 2000. Thirty-eight hazemeters were deployed within a 900 km x 900 km region in western Zambia to verify and study the aerosol properties in MODIS data. The hand-held measurements were compared with satellite measurements. The hazemeter data were used to examine the effects of inhomogeneous atmosphere on MODIS aerosol product validation and to investigate the dependency of MODIS aerosol measurements on look angle and ground vegetation.

Background Information

Investigators:

Darold E. Ward (pyroward@aol.com)

Brent N. Holben (brent@ltpmail.gsfc.nasa.gov)

David M. Giles (dgiles@ltpmail.gsfc.nasa.gov)

Wei Min Hao (whao@fs.fed.us)

Project: SAFARI 2000

Data Set Title: SAFARI 2000 Atmospheric Radiation Measurements, Hand-held Hazemeters, Zambia

Sites: Various sites in Zambia, southern Africa

SAFARI 2000 data are available for the following local measurement sites: Alene_High_School;

Chililabombwe; Forestry_Kaoma; Itezhi_Tezhi_Basic; Kafue_Hydrologic; Kalongola; Kananja_Chilanda; Kangaya_Basic; Kapiri_Basic; Kasalu_Basic_School; Kasapa_Basic_School; Kashinakaji_School; Kisasa_Basic; Kitima_Basic_School; Litoya; Livingstone_Met_Dpt; Lubu_Basic_Middle; Lukulu_basic; Lusaka_Met_HQ; Makotolo_School; Met_Kaoma; Miombe; Misamfu_Research; Mongu; Mwayasunka; Mwinilunga; Nalusanga_School; Ndola_Meteorology; Saluzhinka_Basic; Senanga; Shamputa_School; Shikoswe_Basic; Sichili_Primary; Sikufele_School; Sioma_Basic_School; Sitaka; St_Marys; St_Patrics; and Zambezi_Met_Office.

Data Set Citation:

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Data Set Link: http://aeronet.gsfc.nasa.gov/links.html [Internet Link]

Data File Information

The data contains numeric aerosol values at various wavelengths. The data files are stored as ASCII table files, one file per site per year, in comma-separated-value (.csv) format.

Hazemeter Data Description

Header Parameter	Description
Site	The site name
Lat	Site latitude in degrees
Long	Site longitude in degrees
PI	Site principal investigator(s)
His/Her e-mail	Site principal investigator(s) email address(es)
t0	Initial starting point of data period (used with time_offset to plot time more effectively in spreadsheet)
Column Parameter	**Description**
Date	Date of measurement

Time	Time of measurement (GMT)
Time_offset	Time offset from t0
AOT_XXX	Aerosol optical thickness for wavelength channel XXX (-100 = data not available)
Water	Water Vapor measurement in centimeters (0 = data not available)
Air Mass	Optical airmass

Hazemeter Overview

The USDA Forest Service deployed hand-held hazemeters in western Zambia from mid-June to late September 2000. Thirty-eight hazemeters were deployed within a 900 km x 900 km region in western Zambia (**Figure 1**) to verify and study the aerosol properties in MODIS scenes. The instrument measurements were compared with satellite measurements. The hazemeter data were used to examine the effects of inhomogeneous atmosphere on MODIS aerosol product validation and the dependency of MODIS aerosol measurements on look angle and ground vegetation were investigated.

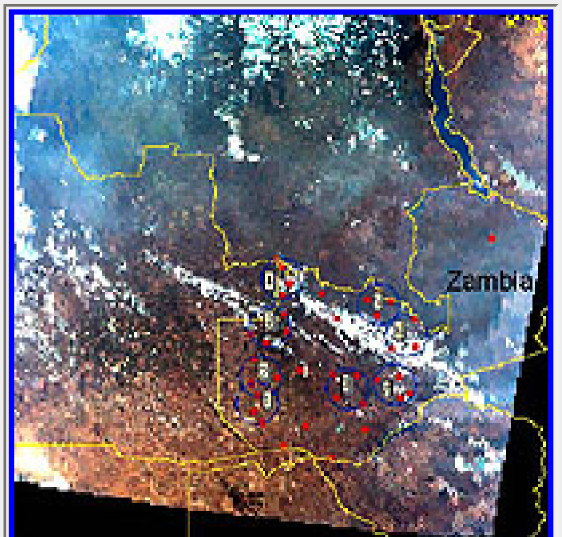

Figure 1. The study region in western Zambia with hazemeter sites (red dots) and co-located AERONET and hazemeter sites (numbered) on a MODIS image, August 23, 2000.

Hazemeter Description

In 1999, 12 hazemeters were deployed in Zambia to study AOT levels resulting from agricultural burning practices in Zambia. These early hazemeters were simple 2-channel devices similar to the instruments used in the GLOBE program (Brooks and Mims 2001). Measurements were taken by aiming the instrument's sensors towards the sun using an alignment bracket, and the time and maximum output of the sensors were recorded in a notebook. An inexpensive voltmeter was used to indicate the amplified sensor output, and a wristwatch was used to time the readings. Although the system worked reasonably well, it had a major drawback. It was difficult to keep the instrument pointing at the sun while simultaneously trying to determine the maximum reading. This method also required extensive manual recordkeeping.

In 2000, a low-cost, technologically advanced, easy-to-use hazemeter was developed. This instrument has four spectral bands, automatic maximum detection, an accurate internal clock, and non-volatile storage that minimizes the need to record data manually. It is easily operated at remote sites and can collect and store information for more than 120 days with two 9-volt transistor batteries. A separate battery maintains the internal clock for more than two years. Hazemeter data acquisition and storage are controlled by a PIC16F877 microcontroller programmed in PIC assembly language. Between data collections, the instrument is in low-power mode for conserving battery, with only CMOS (***c**omplementary **m**etal **o**xide **s**emiconductor memory)* control and real-time clock circuits energized. Pressing the control button powers up all remaining circuits to begin the measurement. The hazemeter measures six analog channels: solar intensity at four spectral bands, temperature, and battery voltage. A combination of Light Emitting Diodes (LEDs) and a phototransistor are used to sense solar energy received at nominal wavelengths of 380, 530, 680, and 880 nm (**Table 1**). Solar sensor signals are amplified, buffered, and converted by the analog to digital microcontroller to a unipolar 10-bit digital value. The hazemeter reads each spectral band about 600 times a second to catch the maximum reading made when the instrument is pointed at the sun correctly. Every 32 readings are added and averaged to form a reading that reduces random noise for each band. Each new average value is compared to previous high and low values for each spectral band. The maximum value for the red solar sensor is displayed for the current measurement. When the value displayed no longer increases, pressing the control button stores the time, a difference between the maximum and minimum average reading that compensates for the minimum or dark reading, and other information in nonvolatile memory. This step also powers down the instrument until the next measurement. Readings are made approximately every half an hour, every day during periods of full sunshine. An RS-232 port is used to transfer several months of readings collected in the microcontroller data file to a computer for additional computation.

Table 1. Spectral bands used to measure aerosol optical thickness over land.

MODIS band (nm)	AERONET band (nm)	Hazemeter band (nm)
not available	870	880 (850-905)
660 (620-670)	670	680 (680-690)
550 (545-565)	500	530 (510-550)
470 (459-479)	440	not available
not available	380	380 (360-410)

Hazemeter Calibration

Calibration data were collected in Mongu by the AERONET sun photometers and hazemeters on June 11 and 12, 2000. Hazemeter measurements were taken on the first, second, or both days. After the SAFARI 2000 campaign, hazemeter data were downloaded to the AERONET server and processed into the hazemeter database. A specialized program written at NASA/Goddard called "demonstrat" processes the raw data. This software was used to perform an inter-calibration between each hazemeter and the Mongu AERONET sun photometer during one of the calibration days. The selection of the calibration period depended upon the availability of hazemeter measurements and the stability of the sun photometer aerosol optical thickness profile. An intercalibration was performed when three or more hazemeter and sun photometer measurements were coincident during a one hour period within 2 hours of solar noon. A nearly constant sun photometer aerosol optical thickness profile was required during the same period. The 'demonstrat' program calculated the new calibration coefficient for a hazemeter using the sun photometer calibration coefficient. The sun photometer aerosol optical thickness was interpolated to the closest hazemeter filter wavelength to calculate an interpolated sun photometer aerosol optical thickness. Assuming this value was equal to the hazemeter aerosol optical thickness at the same wavelength, the measured hazemeter voltage and optical air mass were used to calculate the new hazemeter calibration coefficient. Hazemeter data were reprocessed using the new calibration coefficients to obtain calibrated aerosol optical thickness. Cloud screening was implemented by removing data with aerosol optical thickness >5.0 and 380-880 angstrom exponent <0.8 to remove coarse particles.

Comparison of Hazemeters and Sun Photometers

The AOT data measured by co-located hazemeters and AERONET sun photometers at the AERONET sites in Zambezi, Ndola, Mongu, Mwinilunga, and Kaoma were compared. The purpose was to ensure the validity of using hazemeters to verify the MODIS AOT measurements. The results are summarized in **Figure 2**. The AOT measured by both instruments agree over a wide range: t = 0-0.8 at 880/870 nm (**Figure 2a**) and t = 0-2.0 at 530/500 nm (**Figure 2c**). The AOT data from hazemeters and sun photometers at 680/670 nm are linearly correlated with a correlation coefficient $R^2 = 0.98$, but the t ratio of sun photometers to hazemeters is 1.31 (**Figure 2b**). The discrepancy may be caused by the uncertain center wavelength of the LEDs in the hazemeters or calibration error. We corrected all the original hazemeter data at 680 nm by a factor of 1.31 in order to be consistent with the AERONET data. The hazemeter AOT data agree with the sun photometer AOT data at 380 nm from clean atmosphere to heavily polluted atmosphere (t = 2.5), with the exception of some data collected in Zambezi and Ndola (**Figure 2d**). These results demonstrate that the hazemeters developed by the Forest Service can be used to monitor a broad range of aerosol optical thickness in clean atmosphere and polluted atmosphere caused by biomass burning.

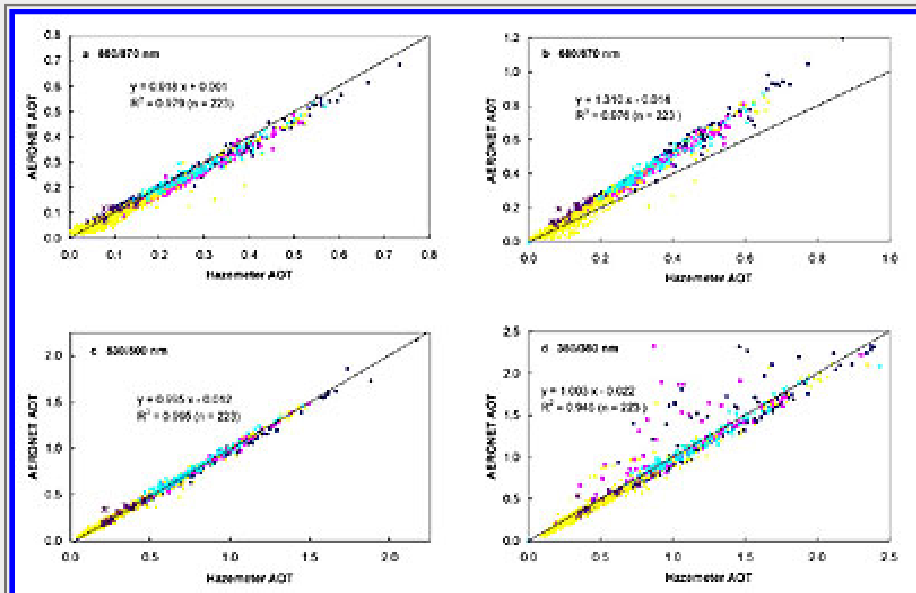

Figure 2. Comparison of AOT measurements between hazemeters and AERONET sun photometers from mid-June to late September 2000 at (a) 880/870 nm, (b) 680/670 nm, (c) 530/500 nm, and (d) 380/380 nm.

Comparison of MODIS and Hazemeters

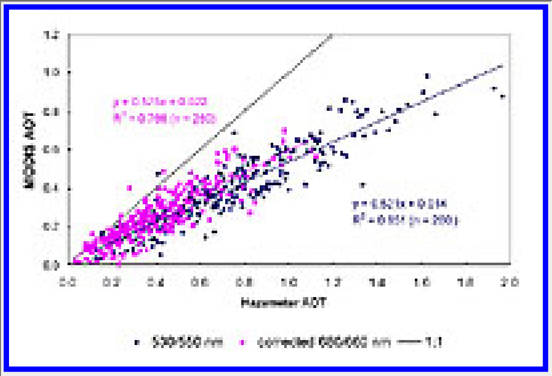

Figure 3. Comparison of AOT measurements between MODIS and hazemeters at 530/550 nm and 680/660 nm from August 20 to September 20, 2000.

We deployed 38 hazemeters to measure aerosol optical thickness in western Zambia from mid-June to late September 2000. **Figure 3** shows the results of comparisons in AOT measurements between MODIS and hazemeters at 38 sites. The MODIS data are substantially lower than the hazemeter data. The ratio of MODIS AOT to hazemeter AOT is 0.52 at 530/550 nm and 0.58 at 680/660 nm. These ratios are consistent with the ratios of MODIS AOT to sun photometer AOT. Schmid et al. (2002, 2003) measured aerosol optical thickness from 354 nm to 1558 nm near Kaoma on September 1, 2000, using the NASA Ames Airborne Tracking 14-channel Sunphotometers (AATS-14) onboard the University of Washington CV-580. By comparing the MODIS data to the AATS-14 data, they concluded that the ratios of the MODIS AOT to the AATS-14 AOT were 0.736, 0.569, and 0.447 at 470 nm, 550 nm, and 660 nm, respectively. All the measurements of aerosol optical thickness by sun photometers, hazemeters, and AATS-14 are in agreement, suggesting that MODIS AOT data may be underestimated by about 40%-50%. In the current MODIS AOT retrieval algorithm, the single scattering albedo is assumed to be 0.90. Eck et al. (2003) reported the average single scattering albedo to be 0.86, 0.83 at 440 nm and 670 nm, respectively, in Zambezi during August and September 2000. By using a lower single scattering albedo value of 0.88 at 440 nm and 0.84 at 670 nm in the MODIS retrieval algorithm, Ichoku et al. (2003) have shown that the AOT measurements by MODIS and sun photometers became comparable in these two spectral bands.

Additional Sources of Information

Data Set Link: http://aeronet.gsfc.nasa.gov/links.html [Internet Link]

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