Inter-comparison of Aerosol Optical Depth values measured by Portable Sunphotometer and AERONET/SKYNET ground stations

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1. Introduction

It is widely recognized that aerosols can directly interact with solar radiation, leading to a radiative forcing effect at the top of the atmosphere (TOA) that impacts the radiometric quality of optical satellite imagery. To ensure accurate radiometric quality, it is essential to measure aerosol optical depth in a simple and accurate manner. AERONET and SKYNET are two well-known ground-based aerosol-monitoring networks that employ instruments such as CIMEL CE-318 sunphotometers, POM-02 skyradiotometers, and the portable MICROTOPS II sun photometer manufactured by the Solar Light Company, USA (Holben, 1998; Dubovik et al., 2002; Morys et al., 2001). However, AERONET sun photometers or SKYNET radiometers cannot be deployed universally or on-demand when AOD data are required, such as during irregular field campaigns. Therefore, there is a great need for alternative devices like the MICROTOPS II, which are portable and cost-effective sun photometers for such purposes (Ichoku et al., 2002). While this device is relatively portable and easy to operate, there is some variability in its measurements that makes it challenging to assess its accuracy. Thus, the objective of this study is to evaluate the accuracy of the MICROTOPS II by comparing its measurements with those of AERONET and SKYNET.

2. Materials and methods

2.1 Dataset used

For this study, measurements were conducted using the MICROTOPS II sun photometer alongside the reference measurements from AERONET and SKYNET. The MICROTOPS II measurements were taken at intervals of 1 to 3 seconds, with one or more measurements in the sequence being as close in time as possible to the actual moment of the AERONET sun photometer and SKYNET radiometer measurements. To ensure accuracy and prevent cloud contamination, the MICROTOPS II measurements were conducted on clear days, near the reference measurement site, and around local solar noon time. The instruments were operated by individuals who accurately pointed them towards the Sun target. In this study, two MICROTOPS II sun photometers were used to measure AOD at five wavelengths (440 nm, 500 nm, 675 nm, 870 nm, 936 nm, and 1020 nm) at the Incheon, Daejeon, and Uiwang sites, as shown in Table 1 and Figure 1. The reference measurements were taken from the KORUS_NIER (37.569N, 126.640E) site from AERONET and the Daejeon (36.384N, 127.361E) site from SKYNET.

Table 1. List of data and observation parameters used in this study.

Site	date	Data	Reference Data
Incheon	MAY/29/2024	Microtops II	KORUS_NIER_Incheon (CIMEL-318)
Uiwang	JUN/06/2024		SNU_Seoul(CIMEL-318)
Daejeon	JUN/03/2024		Daejeon(POM-02)

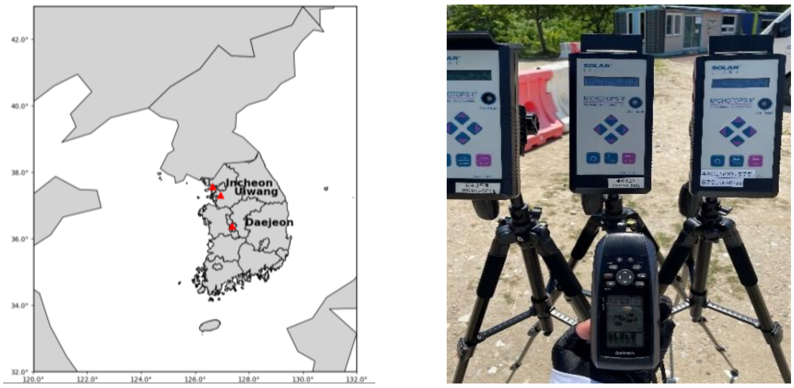

Figure 1: location of sites (left) and measurements using MICROTOPS II sun photometers(right).

The first measurement was conducted in Incheon on May 29, 2024. The Incheon site is located in the western part of South Korea, approximately 0.68 km away from the KORUS_NIER site of AERONET. On a clear day, data collection using the MICROTOPS II sun photometers took place from 10:46:43 to 12:36:00 KST. The second observation was conducted in Daejeon on June 3, 2024. The Daejeon site is situated in the central region of South Korea and is approximately 0.39 km away from the SKYNET Daejeon site. On a partially cloudy day, June 3, 2024, data were collected using the MICROTOPS II devices from 10:59:32 to 12:30:55 KST. The third measurement was conducted near Seoul, South Korea, on June 6, 2024. The site is located approximately 15.81 km away from the SNU (Seoul) site of AERONET. On a cloudy and hazy day, data were acquired from the MICROTOPS II sun photometers from 10:15:42 to 11:12:08 KST.

2.2 Methodology

This study used the two MICROTOPS II sun photometers assigned serial numbers, which are 28817 and 22511. The main focus of this discussion is to compare the AOD measurements obtained from the MICROTOPS II with the reference data from AERONET and SKYNET. For AERONET AOD data, Level 1.0 data without cloud screening were utilized to match the MICROTOPS II measurements. The CIMEL-318 sun photometer used the 870 nm, 675 nm, 500 nm, and 440 nm channels, which are comparable to the MICROTOPS II measurements. Since SKYNET Level 1.0 data without cloud screening were not available, Level 2 data were used instead. To assess the accuracy of the MICROTOPS II measurements, the Bias and Root Mean Square Error (RMSE) of the reference data were calculated. This was done by comparing the reference AOD measurements to the corresponding MICROTOPS II AOD measurements taken within ±1 minute of the AERONET/SKYNET observation times.

3. Results

The results of the analysis indicate that the Root Mean Square Error (RMSE) of the AOD observations between MICROTOPS II and AERONET at wavelengths of 440 nm, 500 nm, 675 nm, and 870 nm were 0.0001, 0.0013, 0.0006, and 0.0000, respectively, on clear days. On cloudy days, the RMSE at these wavelengths were 0.0002, 0.0030, 0.0039, and 0.0054, respectively. These findings suggest that the AOD measurements obtained from MICROTOPS II and AERONET are very similar. Additionally, the RMSE of AOD observations between MICROTOPS II and SKYNET at wavelengths of 500 nm, 675 nm, and 870 nm were 0.0038, 0.0003, and 0.0004, respectively. Figure 6 presents scatter plots that include the acquired data from MICROTOPS II and the simultaneous reference data categorized by date. The relationship between the AODs from MICROTOPS II and AERONET/SKYNET appears to be significantly good for MICROTOPS II number 28817, but not as strong for MICROTOPS II number 22511.

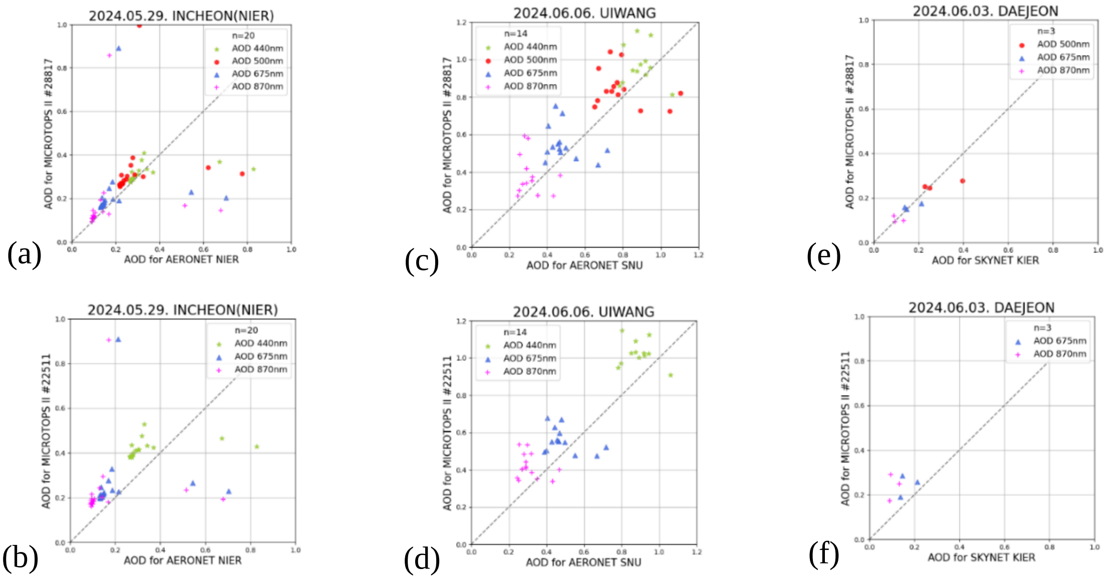

Figure 2: Scatterplot of aerosol optical depth between MICROTOPS II(#28817, #22511) and CIMEL-318, POM-02 : Incheon(a, b), Uiwang(c, d), Daejeon(e, f).

Table 2. Bias and RMSE of AOD between the MICROTOPS and AERONET.

wavelength	**MICROTOPS II #28817 (Incheon)**		**MICROTOPS II #22511 (Incheon)**		**MICROTOPS II #28817 (Uiwang)**		**MICROTOPS II #22511 (Uiwang)**	
	Bias	**RMSE**	**Bias**	**RMSE**	**Bias**	**RMSE**	**Bias**	**RMSE**
440nm	0.0075	0.0001	0.1075	0.0115	0.0144	0.0002	0.0716	0.0051
500nm	0.0364	0.0013	-	-	0.0546	0.0030	-	-
675nm	0.0238	0.0006	0.0599	0.0036	0.0621	0.0039	0.0695	0.0048
870nm	0.0045	0.0000	0.0692	0.0048	0.0736	0.0054	0.1071	0.0115

Table 3. Bias and RMSE of AOD between the MICROTOPS and SKYNET (in Daejeon).

wavelength	**MICROTOPS II #28817**		**MICROTOPS II #22511**	
	Bias	**RMSE**	**Bias**	**RMSE**
500nm	-0.0615	0.0038	-	-
675nm	-0.01645	0.0003	0.0931	0.0087
870nm	-0.01875	0.0004	0.1558	0.0243

4. Conclusion

Based on the comparison of AERONET data observed during the same time frame as the MICROTOPS II measurements (between 10:30 AM and 12:30 PM), the Aerosol Optical Depth at 500 nm (AOD_{500}) on a clear, cloudless day (May 29, 2024, in Daejeon) had daily averages of 0.2445, 0.2742, and 0.3232 for AERONET, MICROTOPS II #28817, and MICROTOPS II #22511, respectively. On a day with clouds and haze (June 6, 2024, in

Uiwang), the daily averages were 0.6689, 0.7544, and 0.7269, respectively. For comparison with SKYNET data at 675 nm, the Aerosol Optical Depth at 675 nm (AOD_{675}) on a clear day (June 3, 2024, in Daejeon) showed values of 0.1652, 0.1720, and 0.2330 for AERONET, MICROTOPS II #28817, and MICROTOPS II #22511, respectively. The MICROTOPS II measurements generally exhibit a similar pattern to the ground-based observation stations (AERONET/SKYNET). However, MICROTOPS II #22511, which is an older device, tends to provide slightly higher readings. The standard deviation for all wavelengths is within 0.2, indicating the validity of the results.

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