Evaluation of Calitoo Handheld Sun Photometer for Classroom Use

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Background

Atmospheric particles of liquids and solids, called aerosols, can have harmful effects on both animals and vegetation depending on their levels. Human activity is a cause of these harmful aerosol levels. Certain aerosol particulates affect ease of breathability. Current satellites including MODIS, MISR, and TOMS measure aerosols by visible (nadir and multiplex) and UV reflection, respectively. Ground-based measurements used handheld sun photometers can determine the presence of aerosols through solar voltage readings and aerosol optical depth calculation, allowing for many schools worldwide measure and submit atmospheric data through the Global Learning and Observation to Benefit the Environment (GLOBE) program. An important parameter measured by participating GLOBE schools is Aerosol Optical Thickness (AOT).

Sun Photometer

GLOBE Sun Photometer

Since 1998, the GLOBE program has relied on the GLOBE sun photometer, an inexpensive individually-produced device which necessitates additional device measurements for each calculation. Development began in 2010 of the Calitoo, a handheld sun photometer for use in the GLOBE program which automates many of the previous measurements necessary for AOT calculation.

Measurements

AOD measurements for 8-15 were taken at a test site approx. 877m SSW from the LaRC CAPABLE site (AERONET). Visibly clear (clouds <10%) days at LaRC, researchers made 3 measurements every 15 minutes (6/3/2014 to 7/25/2014). In total, 10,116 unique Calitoo wavelength AODs were measured from a total of 3,872 button clicks. The 3 measurements were averaged to create 1,124 data points. AERONET was being serviced much of 6/2014 and of the 1,124 Calitoo data only 238 were within 7 minutes of an AERONET reading thus comparable.

Data Comparisons with AERONET

The AOD measurements from NASA’s Aeronet Network (AERONET) used in figure 4 (a), and (b) is recorded with a research-grade sun photometer. Much like the GLOBE photometer, it is a remote-sensing passive instrument that takes column measurements.

Whereas the GLOBE sun photometer measures at two wavelengths, red (625) and green (505), Calitoo measure 3 wavelengths including red (619), green (540), and blue (465, not depicted here). Angstrom exponent was applied to AERONET readings at 465, 540, and 619, respectively, for comparison at Calitoo wavelengths. For classroom application, GLOBE data favored favorably when compared with AERONET. The Calitoo wavelength data points trend similarly although 1 of the 6 devices, Calitoo-S2 in the data, consistently trended higher and more erratically and another device, Calitoo-40 in the data, consistently trended higher than only at 619, suggesting possible calibration issues. Such issues in 2 of 6 devices pose potential issues in classrooms with only 1 device. Sky condition measurements, compared by a clear and somewhat hazy day, are shown above. With the exception of higher-trending devices, Calitoo measurements show precision but lack accuracy. Adjustments to device calibrations are advised.

Ease of Use and Classroom Suitability

The aperture reading hole used to align the device with the sun is less than 2mm and requires much focus and stability for alignment, a potential pitfall in younger users.

The addition of a backlit screen would allow for greater visibility of readings outdoors.

The similar GLOBE sun photometer loses accuracy with high temperatures and it is possible Calitoo does as well. More research is needed.

Researchers had mixed responses on the single center button. While one admired its simplicity, another responded “…To have a separate on/off switch as well as a separate switch to toggle between the modes (reading and measuring) would make the Calitoo much more user-friendly.”

Tenum, Calitoo’s manufacturer, responded promptly to any questions. Calitoo data downloads easily into a .txt file which is convertible thru delineation. Calitoo use decimal commas not decimal points to separate place values though words have been translated to English.

Calculating AOD

When taking a voltage reading, Calitoo automatically calculates the following values and calculates the AOT instantaneously using a variant of the Beer-Lambert Law:

\[ I(\lambda) = I_0(\lambda) \exp(-\tau(\lambda) + \tau(\lambda) + \tau(\lambda)) \]

User Variability

A user variability study was done consisting of changing from the random multi-user data collection to a single researcher collecting data using all devices. Precision among the devices is shown in the data to increase with a single user however could also be attributed to experience using the instrument suggesting a long learning period. Among the data, one of three researchers had measurements consistently less precise regardless of device. In a classroom with many students potentially using a single device the likelihood for a loss of precision should be considered.

Catching AERONET Incident

On 7/25/2014 there was a simulated plane crash at 367m from AERONET at CAPABLE. Though Calitoo readings were being taken simultaneously and recorded no significant change during the time of the crash, AERONET spiked to .24 AOD at 13:57 UTC. Wind direction, plotted here for the time of the crash, shows wind direction NNW all morning with a abrupt change at 13:54 UTC signaling the crash disruption in AERONET AOD. This data is significant for the potential for high-value equipment readings to be globally misrepresented based on localized events and the benefit of inexpensive portable devices used in schools as additional/broader validation.

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The Test Site and the AERONET site are not CAPABLE. They will only be near the same area as seen here, creating a good comparison location.