Frequently Asked Questions

1. What is a sun photometer and what does it measure?

A sun photometer is a type of light meter that measures the amount of sunlight . Most sun photometers measure the amount of sunlight for a narrow range of colors or wavelengths. All sun photometers should measure only the sunlight arriving directly from the sun and not the sunlight scattered from molecules and aerosols. Therefore a sun photometer is pointed directly at the sun and the light is collected through a small aperture (hole or opening) that prohibits scattered sunlight from reaching the instrument's detector.

2. The GLOBE sun photometer uses a light-emitting diode (LED) as a sunlight detector. What is an LED?

A light-emitting diode is a semiconductor device that emits light when an electrical current flows through it. The actual device is a tiny chip only a fraction of a millimeter in diameter. In the GLOBE sun photometer, this chip is housed in a plastic housing about 5 mm in diameter. You can find these devices in a wide range of electronic instruments and consumer products. The physical process that causes LEDs to emit light also works the other way around: if light shines on an LED, it produces a very small current. The electronics in your sun photometer amplifies this current and converts it to a voltage.

Generally, the wavelength of light detected by an LED is shorter than the wavelength of light emitted by the same LED. For example, certain red LEDs are relatively good detectors of orange light. The LED in the GLOBE sun photometer emits green light at about 565 nm. It detects light with a peak at about 525 nm, which is a little further into the blue part of the light spectrum than the emission color.

3. What is the field of view of a sun photometer, and why is it important?

The equation that describes theoretically how to interpret sun photometer measurements requires that the instrument should see only direct light from the sun — that is, light that follows a straight line path from the sun to the light detector. This requirement can be met only approximately because all sun photometers will see some scattered light and direct light from the sky around the sun.

The cone of light a sun photometer's detector sees is called its field of view, and it is desirable to have this cone as narrow as possible. The GLOBE sun photometer's field of view is about 2.5 degrees, which GLOBE scientists have concluded is a reasonable compromise between desires for accuracy and practical considerations in building a handheld instrument. The basic tradeoff is that the smaller the field of view, the harder the instrument is to point accurately at the sun. Very expensive sun photometers, with motors and electronics to align the detector with the sun, typically have fields of view of 1 degree or less. Studies have shown that the error introduced by somewhat larger fields of view is negligible for the conditions under which a GLOBE sun photometer should be used.

4. How important is it to keep the sun photometer from getting hot or cold while I'm taking measurements?

The LED detector in your sun photometer is temperature-sensitive, so its output is slightly influenced by its temperature. Therefore, it is very important to protect your instrument from getting too hot in the summer or too cold in the winter. In the summer, it is essential to keep the instrument case out of direct sunlight when you are not actually taking a measurement. In the winter, it is essential to keep the instrument warm — you can tuck it under your coat between measurements. Never leave your sun photometer outside for extended periods of time.

The sun photometer case itself provides some protection from temperature changes that can affect the electronics inside. If you follow these precautions and take your measurements as quickly as possible, then your measurements will be acceptable. In extreme conditions (winter or summer), you should consider making an insulating housing for your sun photometer. You can use styrofoam or other foam plastic. Cut holes for the on/off switch and the sunlight aperture, and a channel for sunlight to get from the front alignment bracket to the target on the back bracket. The hole for the sunlight aperture should be no smaller in diameter than the thickness of the insulating material itself, and in no case should it be smaller than about 1 cm.

5. I dropped my sun photometer. What should I do now?

Fortunately, the components inside your sun photometer are virtually indestructible, so they should have survived being dropped. Check the case for cracks. Even if the case is cracked, you should still be OK. Just tape over the cracks — use something that is opaque, such as duct tape. Open the case and make sure that everything looks OK. In particular, make sure that the battery is still firmly attached to the terminals on the battery holder. If the alignment brackets have moved or are loose as a result of the fall, straighten them and retighten the screws. Apply a little cyanoacrylate glue ("super glue") at the base of each alignment bracket. Then you should realign your sun photometer by following the alignment protocols.

When you have done these things, try making a measurement. If measurements look OK, they probably are, as the actual calibration of your instrument will not be affected by this kind of accident.

6. How do I know if my sun photometer is working properly?

When you turn your sun photometer on without pointing it at the sun, you should measure a voltage in the range of about (0.000 to 0.020 V) (10 to 20 mV). When you point your instrument directly at the sun, the voltage should increase to a value in the range of about 1 to 2 V. Only in very hazy conditions, late in the afternoon, or early in the morning, should you see a sunlight voltage less than .5 V. If you do not see the expected voltages, then your sun photometer is not working.

The most likely reasons for a sun photometer not to work are that the battery has come loose from the connectors on the battery holder or that the battery is too weak to power the electronics. If the battery seems to be seated properly in the battery holder, then test the voltage. As indicated in the procedure for changing your sun photometer's battery, you should replace the battery if the voltage is less than 7.5 V. You should check the battery no less frequently than once every three months. If you still believe you have a problem, contact GLOBE for help.

7. What does it mean to calibrate a sun photometer?

A sun photometer is considered to be calibrated if its extraterrestrial constant is known. This is the voltage you would measure with your sun photometer if there were no atmosphere between you and the sun. As an exercise, you could think about pointing your sun photometer at the sun from the open cargo bay of the space shuttle as it orbits Earth above the atmosphere. The voltage you measure would be your instrument's extraterrestrial constant. This value depends primarily on the wavelength at which your sun photometer detects light and also on the distance between Earth and the sun. (This distance varies slightly because Earth follows a slightly elliptical, rather than a circular, path around the sun.)

Note that, for this exercise, you do not have to worry about limiting the field of view. Why? Because outside the atmosphere there are no molecules or aerosols to scatter sunlight. Hence, your sun photometer will see only direct sunlight.

As a practical matter, sun photometers can be calibrated by inferring the extraterrestrial constant from measurements made at Earth's surface. This is called the "Langley plot" method. These measurements are difficult to make at low elevation sites with variable weather. GLOBE sun photometers are calibrated against reference instruments that have been calibrated using measurements taken at Mauna Loa Observatory, which is widely accepted as one of the best locations for such work.

It is an interesting project to make your own Langley plot calibrations and compare the results with the calibration assigned to your sun photometer. If you would like to do this, contact GLOBE.

8. Can I make my own sun photometer?

You can purchase a sun photometer kit. Constructing a sun photometer involves soldering some electronic components, which is a skill students need to learn from someone who has done it before. You can start taking measurements as soon as you have assembled your instrument, however, at some point, you must send your sun photometer to the GLOBE Atmospheric Haze Science Team for calibration before your data can be accepted into the GLOBE Data Archive.

9. How often must I take sun photometer measurements?

The protocols ask that you take measurements every day, weather permitting. In some parts of the world, it is possible to go many days without having weather suitable for taking these measurements. It is highly desirable to have a plan for taking measurements on weekends and during holiday breaks (especially during extended summer holidays).

10. How can I tell whether the sky is clear enough to take sun photometer measurements?

The basic rule is that the sun must not be blocked by clouds during a measurement. It is OK to have clouds near the sun. This can be a difficult decision, because you are never supposed to look directly at the sun. You can look at the sky near the sun by blocking the sun with a book or notebook. An even better idea is to use the corner of a building to block the sun. It is very helpful to wear sunglasses when you make these decisions because they protect your eyes from UV radiation. Orange-tinted sunglasses will help you see faint clouds that might otherwise be invisible.

If you have concerns about a measurement, indicate them in your qualitative description of sky conditions when you report the measurement. Thin cirrus clouds are notoriously difficult to detect, but they can dramatically affect sun photometer measurements. If you see cirrus clouds in the hours before or after a measurement, be sure to include that in your sky description.

11. What are aerosols?

Aerosols are particles suspended in air. They range in size from a fraction of a micrometer to a few hundred micrometers. They include smoke, bacteria, salt, pollen, dust, various pollutants, ice, and tiny droplets of water. These particles interact with and scatter sunlight. The degree to which they affect sunlight depends on the wavelength of the light and the size of the aerosols. This kind of particle-light interaction is called Mie scattering, named after the German physicist Gustav Mie, who published the first detailed mathematical description of this phenomenon in the early part of the twentieth century.

12. What is optical thickness?

Optical thickness (or optical depth) describes how much light passes through a material. The amount of light transmitted can be quite small (less than a fraction of 1%) or very large (nearly 100%). The greater the optical thickness, the less light passes through the material. As applied to the atmosphere, aerosol optical thickness (AOT) describes the extent to which aerosols impede the direct transmission of sunlight of a certain wavelength through the atmosphere. In a very clear sky, AOT can have values of 0.05 (about 95% transmission) or less. Very hazy or smoky skies can have AOT values in excess of 1.0 (about 39% transmission).

Percent transmission through the atmosphere is an alternate way to describe the same phenomenon. There is a simple relationship between AOT and percent transmission:

transmission (expressed as a percent) = $100\ e^{(-AOT)}$

Look at Table AT-AH-1 to see the percent transmission for several values of AOT. Any scientific calculator has an e^x function key. Try to reproduce one or more of the examples in this table to check if you understand how to use a calculator to convert AOT to percent transmission.

13. What is Beer's Law?

August Beer was a nineteenth-century German physicist who worked in the field of optics. He developed the principle known as Beer's Law, which explains how the intensity of a beam of light is reduced as it passes through different media. Other nineteenth-century physicists also examined this law and applied it to the transmission of sunlight through the atmosphere. Hence, the equation used to describe how sun photometers work is usually referred to as the Beer/Lambert/Bouguer law. As applied to a sun photometer, Beer's Law is

$$V = V_o(r/r_o)^2 e^{-m}[^{\text{“AOT + “Rayleigh(p/po)}}]$$

Where r/r_o is earth-sun distance in astronomical units, m is the relative air mass, “AOT is the aerosol optical thickness, “Rayleigh is the optical thickness due to Rayleigh scattering, and p/po is the ratio of current atmospheric pressure to standard atmospheric pressure. You need to be comfortable with exponential and logarithmic functions to use this formula to make your own calculations of aerosol optical thickness. Also, you need to know your sun photometer’s calibration constant (V_o). If you would like to do this calculation on your own, you will need to obtain the calibration constant for your photometer from the archive on the GLOBE web site.

14. What is relative air mass (m)?

Relative air mass (m) is a measure of the amount of atmosphere through which a beam of sunlight travels. At any location or elevation, the relative air mass is 1 when the Sun is directly overhead at solar noon. (Note: At any latitude greater than about 23.5 degrees, north or south, the sun is never directly overhead, so the sun can never observed directly through a relative air mass of 1.) A simplified formula for relative air mass is m = 1/sin(elevation) where “elevation” is the angle of the sun above the horizon. This calculation is sufficiently accurate for relative air masses up to about 2. Larger values require a more complicated formula that corrects for the curvature of the Earth’s surface.

15. What is Rayleigh scattering?

Molecules of air scatter sunlight. Air molecules scatter ultraviolet and blue wavelengths much more efficiently than red and infrared wavelengths. (This is why the sky is blue.) This process was first described in the nineteenth century by the Nobel-prize-winning British physicist John William Strutt, the third Baron Rayleigh.

16. How accurate are aerosol measurements made with the GLOBE sun photometer?

The accuracy of sun photometer measurements has been studied for decades by atmospheric scientists, and it remains a topic of some debate. There are some inherent limitations to measuring atmospheric aerosols from Earth’s surface, and there are also some limitations imposed by the design of the GLOBE sun photometer. Measurements made carefully according to the protocols should be accurate to within less than about 0.02 AOT units. For very clear skies, with AOT values of perhaps less than 0.05, this is a significant percentage error. However, even operational “professional” sun photometers claim accuracies of no better than 0.01 AOT units. Thus, the accuracy of measurements made carefully with a GLOBE sun photometer are comparable to measurements made with other sun photometers.

Unlike some other GLOBE measurements, there is no easily accessible standard against which to check the accuracy of AOT calculations. GLOBE aerosol measurements will be subjected to scrutiny by GLOBE investigators and others for the foreseeable future. Nevertheless, it is fair to say that GLOBE aerosol measurements can achieve a level of accuracy that can be extremely useful to the atmospheric science community.

17. Will scientists really be interested in my aerosol measurements?

Compared to the previous question, the answer to this one is easy: an only slightly qualified “Yes.” Comparatively few sun photometers are in use around the world. Since recent studies have shown that aerosols can block considerable sunlight, thus causing a cooling effect on the Earth’s climate, there is renewed interest in sun photometer measurements. Upcoming Earth-monitoring satellite missions will focus on global characteristics of the atmosphere and its constituents. It is essential that reliable ground-based data measurements be available to calibrate satellite instruments and validate their measurements. GLOBE schools provide the *potential* to establish a global aerosol monitoring network that is otherwise unattainable.

On a regional scale, there is essentially no comprehensive monitoring of aerosols produced naturally by water vapor, naturally occurring forest and brush fires, dust, pollen, gases emitted by plants and trees, sea salt, and volcanic eruptions. The same is true for monitoring aerosols produced by automobile emissions, coal-burning power plants, intentional burning of forests and rangelands, certain industrial and mining operations, and dust from unpaved roads and agricultural fields. Again, GLOBE schools provide the *potential* for addressing these topics.

Here's the qualification to the "Yes." In all but a few very specialized situations, aerosol measurements must be taken in the same place for many months, and even for years, in order to have lasting scientific interest. It is sometimes difficult to keep in mind the long-term value of taking the same measurements day after day. (This is not just a problem for aerosol measurements, of course.) In the case of aerosols, persistence is especially important due to the long time scales required to observe and analyze significant changes in the atmosphere. However, if you follow the protocols and provide careful measurements (especially during the summer), then there is no doubt that scientists will value your contribution now and in the future.

Aerosols – Looking At the Data

Are the data reasonable?

Perhaps your first thought about determining whether your data are reasonable would be to consider the voltages measured using your sun photometer. This is not as easy as it might seem! A sun photometer converts light from the sun to a voltage; this is what you measure and report to GLOBE. The relationship between the intensity of the light and the voltage produced is determined by the sensitivity of the detectors in your sun photometer (a green or red light emitting diode) and the gain provided by your sun photometer's battery-powered amplifier. This relationship is different for every GLOBE sun photometer, so each instrument has its own calibration constants (one for each of the two channels) that allow GLOBE's computers to calculate aerosol optical thickness from the voltages you report.

The GLOBE sun photometer produces a small output voltage even when the sun is not shining on the detector. This "dark voltage," should be small, but how small? GLOBE performs some range checks on both the sunlight and dark voltages. However, reasonable voltages fall within a wide range of values. In some cases, your sun photometer's dark voltage may be only a few tenths of a millivolt. If so, it may display as 0 when you are using a 2 V (or 2000 mV) range setting on your digital voltmeter.

So, it is not easy to predict what "reasonable" voltages are for your sun photometer. However, after you have done the *Aerosol Protocol* a few times, you will get a good sense of what dark voltages your instrument produces and what sunlight voltages to expect under certain sky conditions. Remember that generally these ranges will be different for the green and red channels.

It is much easier to determine whether the aerosol optical thicknesses calculated from your measurements at green and red wavelengths are reasonable. Table AT-AE-2 gives some typical ranges for aerosol optical thickness (AOT).

Table AT-AE-2

Sky condition	Green channel	Red channel
Extremely clear	0.03-0.05	0.02-0.03
Clear	0.05-0.10	0.03-0.07
Somewhat hazy	0.10-0.25	0.07-0.20
Hazy	0.25-0.5	0.02-0.40
Extremely hazy	>0.5	>0.4

The relationship between these numerical values and the sky condition description (required as part of your data reporting) are only approximate, and may vary depending on local conditions.

Note that red AOT values are typically less than green AOT values. This is due to the fact that typical aerosols scatter green light more efficiently than red light. (The larger the AOT, the more light is being scattered away from the direct beam of sunlight that reaches your sun photometer's detector.) If the red AOT is larger than the green, it is not *necessarily* wrong, but it is an unusual enough occurrence that it should trigger a closer examination of the conditions under which the measurements were taken.

What do scientists look for in these data?

As noted above, green AOT values are somewhat higher than red AOT values. When the Science Team looks at your data, they will check that the relationship between the two channels appears reasonable.

The *Aerosol Protocol* requires that you report three sets of sun photometer measurements taken within the span of a few minutes. Assuming that you are pointing your sun photometer carefully and consistently toward the sun, differences among the three voltages for each channel are a measure only of the variations in the atmosphere at the time you are taking your measurements. If the differences are large, it may mean that clouds are drifting across the sun while you are taking measurements.

Scientists will also look carefully at cloud cover and type reports and will compare the AOT values calculated from the voltage measurements with reports of sky color and haziness. Cirrus clouds are of particular concern, as they can greatly reduce the transmission of sunlight even when they are almost invisible.

AOT tends to vary seasonally. Warm and humid days in temperate and equatorial climates can produce photochemical smog, especially in urban areas. Consequently, AOT tends to be higher in the summer than in the winter. This seasonal cycle can be difficult to find in GLOBE data, as many GLOBE schools do not report data during summer vacations. Figure AT-AE-1 shows some aerosol data from East Lincoln High School, Denver, NC. Students made some measurements through the spring of 2000 and another class restarted the measurement program in the fall of 2000. Some of the values (especially the very low values) appear to be in error. Although it appears to be the case that warm weather produces higher AOT values, the lack of summertime measurements means that this conclusion cannot really be supported by these limited data.

Note also in Figure AT-AE-1 that there are some very high AOT values recorded in 1999. There are several possible explanations for these values. One possibility is, of course, that these data represent actual very hazy conditions. Another possibility is that students were initially unfamiliar with the sun photometer and recorded sunlight voltages that were too low (which will lead to AOT values that are too high). A third possibility is that there were some clouds between the observer and the sun. The AOT values themselves do not help us choose among these possibilities. The additional information scientists need to make decisions about the quality of sun photometer measurements can be obtained only by looking at all the measurements and their accompanying metadata.

One of the most exciting opportunities for students working with the *Aerosol Protocol* is to compare their measurements with other ground- and satellite-based measurements. Such comparisons can serve both as a check on GLOBE measurements and on the performance of other sun photometers. One source of aerosol data is the Aerosol Robotic Network (AERONET), managed by NASA's Goddard Space Flight Center. This ground-based network has about 50 sun photometers in operation at various locations around the world. The AERONET sun photometers are automated, solar-powered instruments. Their advantage is that they can operate unattended even in remote locations, broadcasting the results of their pre-programmed measurements to satellites, which then beam data to a central ground station for processing. The primary disadvantage of these automated devices is that there is no human observer to make decisions about whether a sun photometer measurement should be made at a particular time. Algorithms are applied to "screen" the measurements for cloud contamination. However, these algorithms are not perfect. They may, for example, suffer from the same lack of ability to distinguish thin cirrus clouds as ground-based observers. Thus, comparisons of automated and manual measurements provide a fascinating and extremely important check on the performance of both systems.

Figure AT-AE-2 shows a comparison of GLOBE sun photometer data with data from AERONET sun photometers. (AERONET data are publicly available online.) AERONET makes measurements every few minutes throughout the day. The GLOBE data sometimes fall near the lower range of AERONET values within a day. A more detailed examination of these data with an expanded time scale (to look at individual days) would clarify the relationship between these two datasets; this would make an excellent student project.

Figure AT-AE-3 shows comparisons between AOT values derived from the MODIS satellite and measurements made by students at East Lincoln High School, Denver, North Carolina, USA. (The MODIS data points are connected with solid lines, but this is only to make the data easier to follow; there is no reason to expect that missing MODIS data would fall along the lines.) Note that the GLOBE data again tend to cluster near the lower MODIS AOT values.

Some of the MODIS values in Figure AT-AE-3 seem very high. Figure AT-AE-4 offers some insight into why this might be so. These measurements from Drexel University include the percentage of daytime cloud cover. Clearly, some

Figure AT-AE-1: Sun photometer data (minimum AOT from a set of three) from East Lincoln High School, Denver, NC, USA.

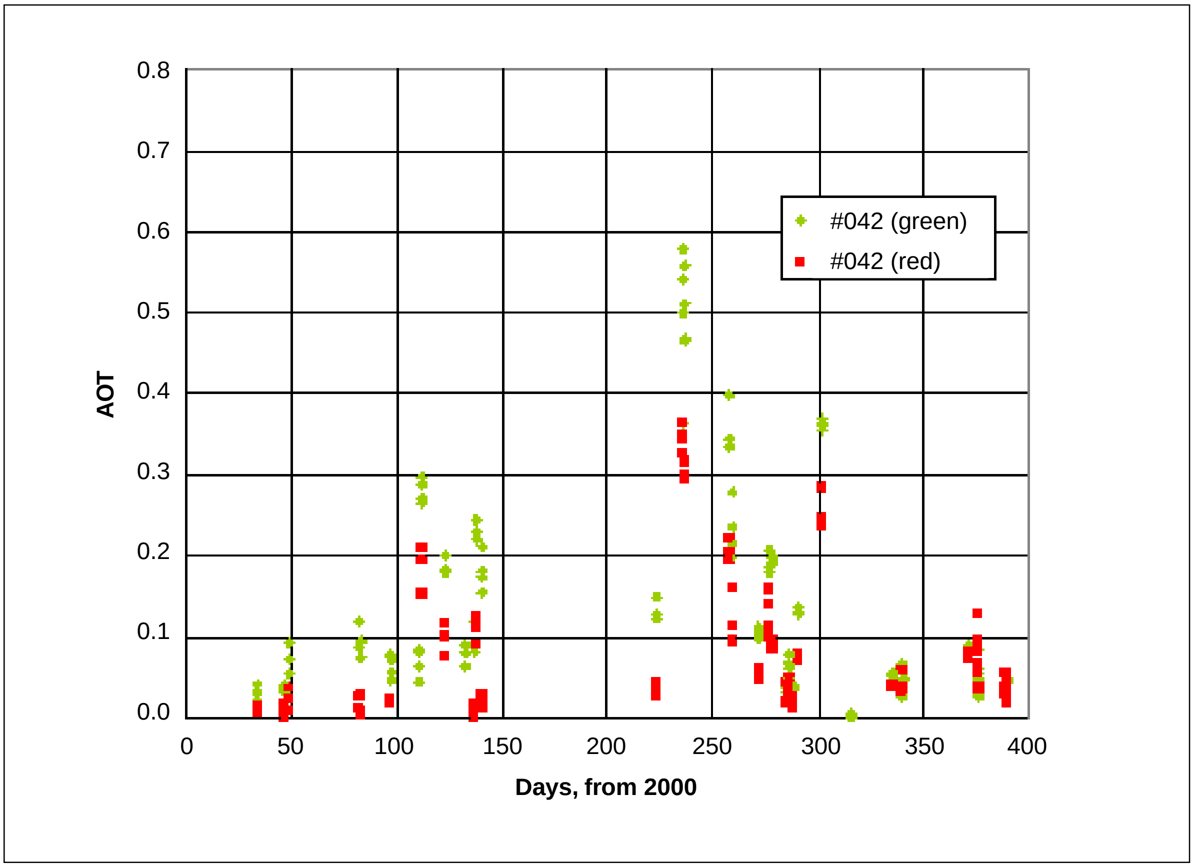


Figure AT-AE-2: Comparison of GLOBE sun photometer measurements made at Drexel University, Philadelphia, Pennsylvania, USA, with a nearby AERONET sun photometer.

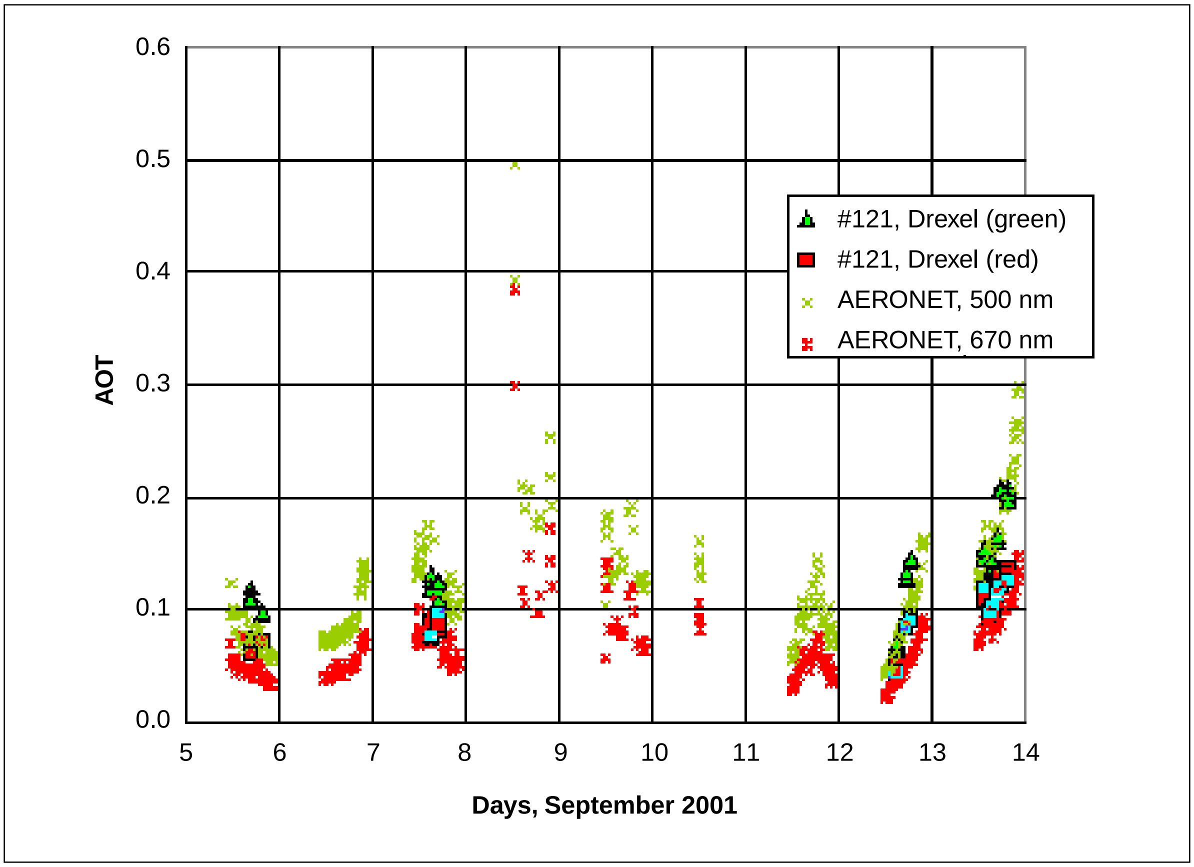


Figure AT-AE-3: Comparison of MODIS data and GLOBE sun photometer measurements made at East Lincoln High School, Denver, NC, USA.

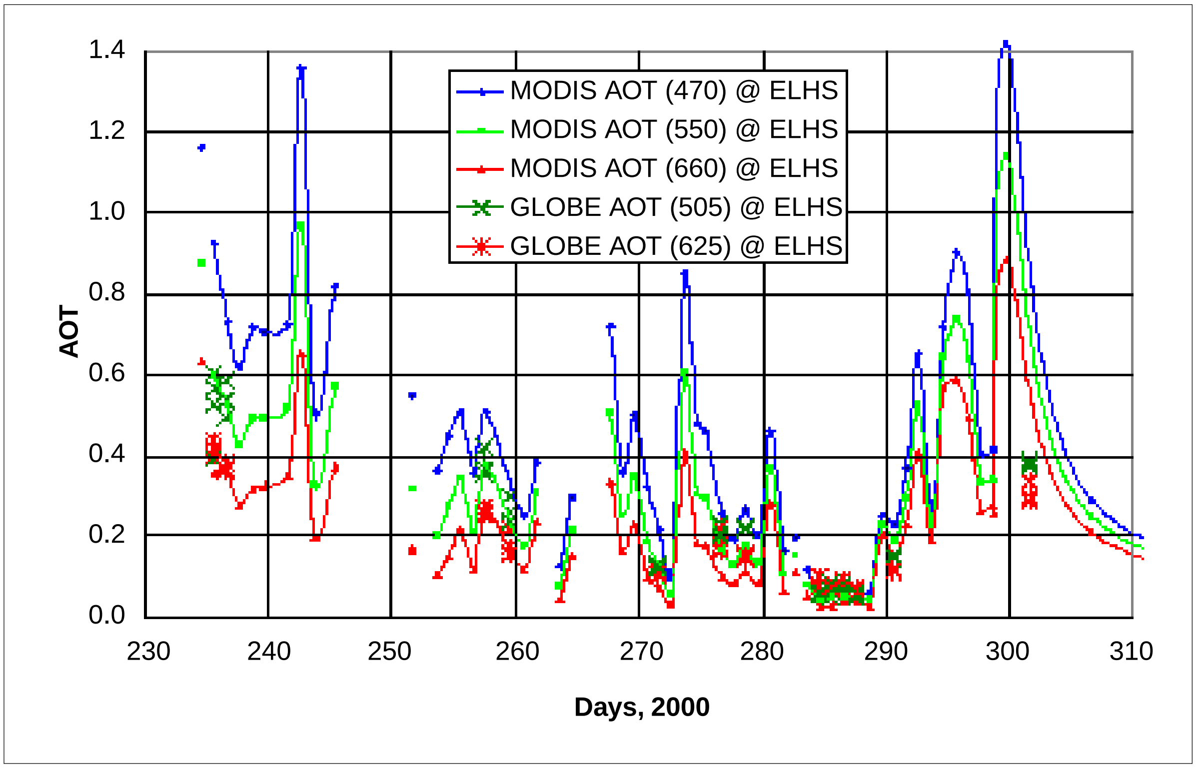
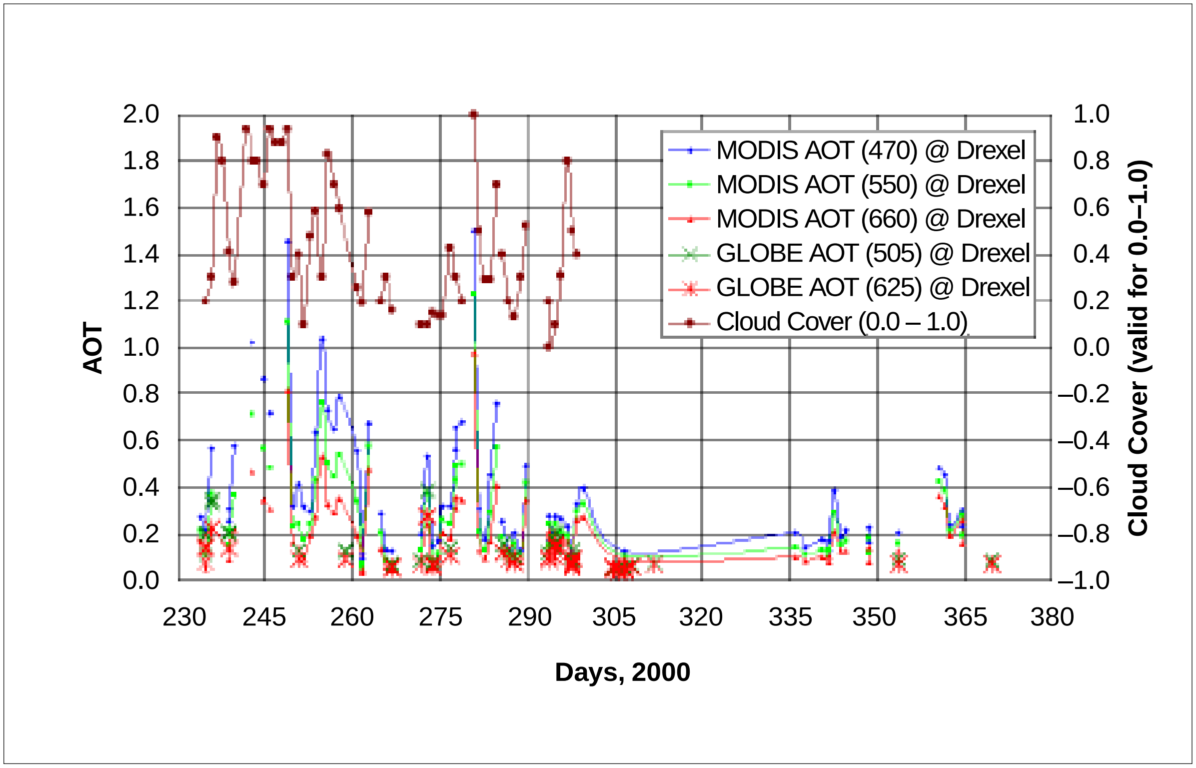


Figure AT-AE-4: Comparison of MODIS data, GLOBE sun photometer measurements, and cloud cover at Drexel University, Philadelphia, Pennsylvania, USA.



of the very high MODIS AOT values are associated with cloudy days. Drexel University is located in an urban area with a mixture of water (two rivers flow through Philadelphia), residential and commercial urban development, and green space (a large park). This kind of complicated surface is the most difficult for data reduction algorithms to analyze and the results shown in Figure AT-AE-4 may indicate problems with cloud discrimination over complicated surfaces. Whatever the explanation, Figure AT-AE-3 shows clearly the importance of carefully reporting metadata that define the conditions under which sun photometer measurements are made.

When GLOBE student sun photometer measurements are made carefully, data such as shown in Figures AT-AE-2 and AT-AE-3 can provide extremely valuable information for scientists who are involved in understanding the global distribution of aerosols. The ability of human observers to characterize the circumstances and quality of their measurements provides an opportunity that unattended and satellite-based instruments can never match.

Locally, aerosol optical thickness can be influenced by air quality, season, relative humidity, natural and human-caused events such as volcanoes, forest fires and biomass burning, agricultural activity, windblown dust, and sea spray. High values of aerosol optical thickness, no matter what the cause, may be linked to human health through their influence on respiratory problems such as asthma. All these connections provide many possible sources for student research projects.

Calculating Aerosol Optical Thickness (Advanced Students Only)

When you report voltage measurements from your sun photometer to GLOBE, GLOBE's computer calculates the aerosol optical thickness (AOT) and reports this value. This calculation is too complicated for most GLOBE students to do on their own. However, if you are familiar with logarithmic and exponential equations, you can calculate AOT yourself using the following formula:

$$AOT = [\ln(V_o/R^2) - \ln(V - V_{dark}) - a_R(p/p_o)m]/m$$

Where:

ln is the natural (base *e*) logarithm

V_o is the calibration constant for your sun photometer. Each channel (red and green) has its own constant, which you can obtain from the GLOBE Web site.

R is the Earth-sun distance expressed in astronomical units (AU). The average Earth-sun distance is 1 AU. This value varies over the course of a year because the Earth's orbit around the sun is not circular. An approximate formula for R is:

$$R = \frac{(1 - \Sigma^2)}{[1 + \Sigma \cos(360^\circ \bullet d/365)]}$$

Where Σ is the eccentricity of the Earth's orbit, approximately equal to 0.0167, and d is the day of the year. (Eccentricity is a measure of the amount by which the Earth's orbit differs from a circle.) For leap years, you can substitute 366 for 365. Note that this equation predicts that the minimum value for R occurs at the beginning of the year. The actual minimum Earth-sun distance occurs, in fact, in early January but not on January 1.

V and V_{dark} are the sunlight and dark voltage from your sun photometer.

a_R is the contribution to optical thickness of molecular (Rayleigh) scattering of light in the atmosphere. For the red channel a_R is about 0.05793 and for the green channel it is about 0.13813.

p is the station pressure (the actual barometric pressure) at the time of the measurement.

p_o is standard sea level atmospheric pressure (1013.25 millibars).

m is the relative air mass. Its approximate value is:

$$m = 1/\sin(\text{solar elevation angle})$$

where solar elevation angle can be obtained from the *Making a Sundial Learning Activity* or by using a clinometer.

When GLOBE calculates AOT, it uses a series of equations to more accurately calculate the Earth-sun distance. For relative air mass, it uses those same astronomical equations to calculate solar position from your longitude and latitude and the time at which you took your measurement. Then it uses the calculated solar elevation angle to calculate relative air mass, using an equation that takes into account the curvature of the Earth's atmosphere and the refraction (bending) of light rays as they pass through the atmosphere.

As a consequence of using these more complicated equations, GLOBE's AOT values will not agree exactly with the calculation described here. The smaller the AOT, the greater the difference is likely to be. Consider this example:

Date: July 7, 1999

Sun photometer calibration constant (V_o): 2.073 V

Solar elevation angle: 41°

Station pressure: 1016.0 millibars

Dark voltage: 0.003 V

Sunlight voltage: 1.389 V

Sun photometer channel: green

July 7, 2001, is the 188th day of the year, so:

$R = (1 – 0.0167^2)/[1 + 0.0167 \bullet \cos(180^o \bullet 188/365)] = 1.0166$

The relative air mass is:

$m=1/\sin(41^o) = 1.5243$

Then, aerosol optical thickness is:

$AOT = [\ln(V_o/R^2) - \ln(V - V_{dark}) - a_R(p/p_o)m]/m$

$\ln(V_o) = \ln (2.073/1.01662^2) = \ln(2.00585) = 0.6960$

$\ln(1.389-0.003) = \ln(1.386) = 0.3264$

$a_R(p/p_o)m = (0.1381)(1016/1013.25)(1.5243) = 0.2111$

$AOT = (0.6960 - 0.3264 - 0.2111)/1.5243 = 0.1040$

GLOBE's calculated AOT value for these data is 0.1039, a difference small enough to ignore for these measurements.

In some situations, your AOT value may not agree this well with GLOBE's value. For example, if the solar elevation angle you observe with your solar gnomon is different from the value calculated by GLOBE – perhaps because the surface on which the gnomon is mounted is not exactly horizontal, or the gnomon itself is not exactly vertical – then the relative air mass calculated from your observed solar elevation angle will not be accurate. This will cause the AOT calculation to be in error.

AOT can be expressed as the percent of sunlight at a particular wavelength that reaches the Earth's surface after passing through a relative air mass of 1. For this example with the green channel,

$\%\ \text{transmission} = 100 \bullet e^{-AOT} = 100 \bullet e^{-0.1040} = 90.1\%$