Aerosols Protocol

Classroom Preparation Guide

Task

Record the maximum voltage reading that can be obtained by pointing your photometer at the sun.

Record the precise time of your measurement.

Observe and record cloud conditions, current air temperature, and relative humidity.

What You Need

- ❑ Calibrated and aligned GLOBE sun photometer
- ❑ Digital voltmeter (if your sun photometer does not have a built-in voltmeter)
- ❑ Watch, preferably digital or GPS receiver
- ❑ Aerosols Data Sheet
- ❑ Thermometer
- ❑ Hygrometer or sling psychrometer
- ❑ Field Guides for cloud cover and cloud type, relative humidity (digital hygrometer or sling psychrometer) and one air temperature protocol
- ❑ GLOBE Cloud Chart
- ❑ Barometer
- ❑ Pencil or pen

Getting Ready To Take Measurements

In order for the Science Team to interpret measurements made with your sun photometer, you must provide the longitude, latitude, and elevation of your observing site, as required for other GLOBE measurements. You do this once, when you define an Atmosphere Study Site. Other values and observations must be provided along with each measurement, as shown on the data entry form. The purpose of this section is to give you the information you need to complete the data entry.

Time

It is important to report accurately the time at which you take a measurement because the Science Team needs to calculate solar position at your site and that calculation depends on time. The GLOBE standard for reporting time is UT, which can be calculated from local clock time based on your time zone and the time of year. For this protocol, it is absolutely essential to convert local time to UT correctly; be especially careful when your local time is summer ("daylight savings") time. For example, you must add 5 hours to convert Eastern Standard Time to UT, but only 4 hours to convert Eastern Daylight Time to UT.

Time should be reported at least to the nearest 30 seconds. A digital watch or clock is easier to use than an analog one, but in either case you must set your timepiece against a reliable standard. The time accuracy requirements for this protocol are stricter than for the other GLOBE protocols. However, it is not difficult to set your clock or watch to meet this standard. You can get time online at www.time.gov. In many places, you can get an automated local time report by phone from a local radio or TV station. Your GPS receiver will report UT. In some places, you can buy a clock that sets itself automatically by detecting radio signals from a government-sponsored official time source. (In the U.S., for example, this so-called "atomic clock" signal is broadcast over station WWBV.)

It might be tempting to use the time stored in your computer as a standard. However, this is not a good idea, as (perhaps surprisingly) computer clocks are often not very accurate, and they must be set periodically according to a reliable standard. Note that some computer operating systems will automatically switch your computer clock back and forth between standard and summer ("daylight savings") time. You should be aware of when this change occurs if you need to manually convert time from your local clock time to UT.

The preferred time of day for reporting sun photometer measurements at most latitudes, during most of the year, is mid-morning. However, it is acceptable to take these measurements any time during the day between mid-morning and mid-afternoon. No matter what time you take measurements, be sure to report UT as accurately as possible, as noted above. The Science Team understands that it may be most convenient to take these measurements at the same time you collect your other atmospheric data. Measurements should be made at a relative air mass of no more than 2 whenever possible. (Refer to the Learning Activity that discusses relative air mass. A relative air mass of 2 corresponds to a solar elevation angle of 30 degrees.) During the winter in temperate and higher latitudes, the relative air mass at your location may always be greater than 2. You can still take measurements, but you should take them as close to solar noon as possible.

If you are taking sun photometer measurements in support of ground validation activities for Earth-observing spacecraft, then the measurement times will be based on the times of spacecraft overflights of your observing site.

Sky Conditions

When you record sun photometer measurements, you should also record other information about the sky, including cloud cover and cloud type, sky color, and your own assessment of how clear or hazy the sky is.

Sky color and clarity are subjective measurements but, with practice, you can learn to be consistent in your own observations. For example, you can easily learn to recognize the bright blue clear sky associated with low aerosol optical thickness. As the aerosol concentration increases, the sky color changes to a lighter blue color. It may appear milky rather than clear. In some places, especially in and near urban areas, the sky can have a brownish or yellowish tint due to air pollution (primarily particulates and NO_2).

When there are obvious reasons for high values of aerosol optical thickness, the Science Team needs to know about them. This is why you are also asked to comment about why you think the sky is hazy. It could be due to urban air pollution, a volcanic eruption, or dust from agricultural activity, for example.

Sun photometer measurements can be interpreted properly only when the sun is not obscured by clouds. This does not mean that the sky must by completely clear, but only that there must be no clouds in the vicinity of the sun. This is not necessarily a simple decision. It is easy to determine whether low- and mid-altitude clouds are near the sun, but cirrus clouds pose a more difficult problem. These clouds are often thin and may not appear to block a significant amount of sunlight. However, even very thin cirrus clouds can affect sun photometer measurements. For this reason, if you observe cirrus clouds earlier or later in the day relative to when you report measurements, you should note this fact on your data entry form.

Another difficult situation occurs in typical summer weather, especially near large urban areas. In this environment, very hazy skies and hot humid weather often make it difficult to distinguish cloud boundaries. Such conditions can produce relatively large values of aerosol optical thickness (any value greater than about 0.3-0.5) that may not represent the actual state of the atmosphere. It is important to describe such conditions whenever you report measurements.

To get a better idea of where cloud boundaries are, you can observe the sky through orange or red sunglasses, or through a sheet of translucent orange or red plastic. These colors filter out blue skylight and make clouds more distinct.

Never look directly at the sun, even through colored sunglasses or plastic sheets! This can damage your eyes.

Fog is another potential problem. It can make things look hazy. But fog (a stratus cloud at ground level) is not the same as atmospheric haze from aerosols. Conditions where the sun is shining through even light fog are unsuitable for taking sun photometer measurements. In many locations fog dissipates before mid-morning, so it will not affect your measurements.

Whenever you try to determine sky conditions before taking sun photometer measurements, you must block the sun itself with a book, a sheet of paper, a building or tree, or some other object. A sensible rule is that if you can see any shadows at all on the ground, you should not try to look at the sun. If in doubt, or if you believe you cannot determine sky conditions near the sun, do not take a measurement!

Temperature

The electronics in your GLOBE sun photometer, and especially its LED detectors, are temperature-sensitive. This means that the output will change under the same sunlight conditions as the sun photometer warms and cools. Therefore, it is important to maintain your sun photometer at approximately room temperature. To alert the Science Team to potential problems with temperature, we ask that you report air temperature along with your sun photometer measurements.

If you are taking sun photometer measurements at the same time you record temperature data from your weather station, you can use that current temperature. Otherwise, you must measure the air temperature separately. The preferred way to obtain air temperature values is to take them following the *GLOBE Temperature Protocols* using a thermometer that meets GLOBE standards mounted in an appropriate weather shelter. Alternatively, a value can be obtained from an online source or from a thermometer that does not necessarily meet GLOBE standards. Non-GLOBE temperature values should be reported as metadata on the *Data Sheet*, and not in the air temperature field.

In terms of instrument performance, the relevant temperature is not necessarily the outside temperature, but air temperature inside your sun photometer's case. Newer GLOBE sun photometers include a built-in sensor that monitors air temperature inside the instrument, near the LED detectors. These instruments have a rotary switch on the top of the case rather than a green/red channel toggle switch. If your sun photometer includes this feature, there is a place to report case temperature on the *Data Sheet*. The temperature, in degrees Celsius, is 100 times the voltage displayed on the voltmeter when the "T" channel is selected. For example, a voltage reading of 0.225 V corresponds to a temperature of 22.5˚ C. Ideally, this temperature should be in the low 20's.

There are some steps you should take to minimize temperature sensitivity problems. Keep your sun photometer inside, at room temperature, and bring it outside only when you are ready to take a measurement. In the winter, transport it to your observing site under your coat, for example, to keep it warm. In very hot or very cold weather, you can wrap the instrument in an insulating material such as an insulated sandwich bag, a towel, or pieces of plastic foam. In the summer, keep your instrument shielded from direct sunlight whenever you are not actually taking a measurement. You should practice taking and recording measurements so that an entire set of voltage measurements should take no more than two or three minutes.

Relative Humidity

Relative humidity is a useful addition to the Aerosols Protocol metadata because high (or low) values of relative humidity are often associated with high (or low) aerosol optical thickness values. There is a *Relative Humidity Protocol* available for this measurement, which requires a digital hygrometer or sling psychrometer, but it is also OK to use an online or broadcast value from within an hour of your sun photometer measurements. Online values should only be reported as comments while values you obtain following the *Relative Humidity Protocol* are valid GLOBE data and may be reported as such.

Barometric Pressure

Unlike the previous values described in this section, the station pressure at your observing site is *required* in order to calculate aerosol optical thickness. Unless your site is very close to sea level, the barometric pressure reported on weather broadcasts, in your local newspaper, and on the Web is not station pressure. Why? Because in such reports, the true barometric pressure has been adjusted to what it would be at sea level. This enables meteorologists to construct pressure maps that show the movement of air masses over large areas, independent of the varying elevation of the ground. Barometric pressure decreases roughly 1 mbar for every 10 meters of increased elevation. (See Figure AT-I-1 and the Barometric Pressure Protocol.)

calibrate your barometer, you will have to find a local reliable weather information source, which provides measurements of pressure. A weather service or weather bureau office, agricultural extension office, newspaper, radio, or television station may be useful here. Be sure that the reading is expressed as sea level pressure. At higher elevations, it may not be possible to calibrate your classroom barometer to give an equivalent sea level value.

In the Field

It is much easier for two people to take and record measurements than for one person working alone. If you can work as a team, divide up the tasks and go through several practice runs before you start recording real measurements.

1. Connect a digital voltmeter to the output jacks of your sun photometer.

   If your sun photometer has a built-in digital voltmeter, you can skip this step. If you need a separate voltmeter, do not use an analog voltmeter, which cannot be read accurately enough to be suitable for this task. Be sure to put the red lead in the red jack and the black lead in the black jack.

2. Turn the digital voltmeter and sun photometer on.

   If your sun photometer has a built-in digital voltmeter, the same switch turns on both the meter and the sun photometer and you do not need to worry about selecting an appropriate voltage range.

   If you are using an external voltmeter, select an appropriate DC volts range. Be careful not to use an AC volts setting. The appropriate range setting depends on your voltmeter. If it has a 2 V (volts) or 2000 mV (millivolts) setting, try that first. If your photometer produces more than 2 V, use the next higher range, often 20 V. Some voltmeters have auto-ranging capability, which means that there is only one DC volts setting and the voltmeter automatically selects an appropriate voltage range. If you are using an auto-ranging voltmeter, make sure you understand how to read voltages in this range.

Note that if a digital voltmeter is connected to your sun photometer when the photometer is turned off, you will get unpredictable readings on the voltmeter, rather than the value of 0 V you might expect. This is normal behavior for digital voltmeters. Erratic voltage readings will also occur if the battery in your sun photometer is too low to power the electronics. When you turn your sun photometer on, and it is working properly, the voltmeter should produce a stable reading of no more than a few millivolts indoors or if the sun is not shining on a detector, or a value in the range of roughly 0.5-2 V when sunlight is shining on the detector.

3. If your sun photometer has a rotary switch on the top of the case, select the “T” setting and record the voltage.

   Multiply the voltage reading times 100 and record this value.

4. Select the green channel on your sun photometer (because the GLOBE data entry page asks for the green channel first).

5. Hold the instrument in front of you about chest-high or, if possible, sit down and brace the instrument against your knees, a chair back, railing, or some other fixed object. Find the spot made by the sun as it shines through the front alignment bracket.

   Here is an important safety rule:
   Under no circumstances should you hold the sun photometer at eye level and try to “sight” along the alignment brackets!

   Adjust the pointing of your instrument until the spot of sunlight shining through the front alignment bracket shines on the rear alignment bracket.

6. Adjust the pointing until the sunlight spot is centered over the appropriate colored dot on the rear alignment bracket. Record this value on your *Data Sheet*.

   Your sun photometer case will have either one or two round holes on the front of the case. If it has one hole, the rear alignment bracket will have two colored alignment dots - one green and one red. The sunlight spot must be centered around the green dot when you are taking green-channel measurements and around the red dot if you are taking red-channel measurements. If your sun photometer has two holes, the rear alignment bracket will have one blue alignment dot. The sunlight spot must be centered around this dot regardless of whether you are taking green- or red-channel measurements.

   When you adjust the pointing of your photometer so that the sunlight spot is centered around the alignment dot, the sunlight shining through the aperture hole(s) on the front of the case is centered over the LED detector(s) inside the case. It takes a little practice to learn how to center the sunlight spot over the alignment dot. Be sure the pointing is stable before you record voltages. It may help to steady your instrument against a chair, post, or other stationary object. The entire measurement process should not take more than 15 or 20 seconds for each reading of each channel. Be sure to record all the digits displayed on your voltmeter.

   Unless the sky is very hazy, or unless you are taking measurements late in the afternoon or early in the morning, the voltage should increase to more than 0.5 V. If you are using an auto-ranging voltmeter, the range will change automatically when you point your photometer directly at the sun (from a range appropriate for displaying the dark voltage to a range appropriate for displaying the sunlight voltage).

   Small movements of the sun photometer will cause the voltage to vary by a few millivolts. Even when your sun photometer is completely still and properly aligned with the sun, the voltage will still vary a little. This is due to fluctuations in the atmosphere itself. The hazier the atmosphere, the larger these fluctuations. Do not try to average the voltmeter readings. It is important to record only the maximum voltage you obtain during a few seconds of measurement time, starting only after the pointing of your instrument has been stabilized. There is a slight time delay between the time when the voltage output from your instrument changes and when that change is reflected in the digital reading. With a little practice, you can learn to compensate for this time delay.

7. Record the time at which you observed the maximum voltage as accurately and precisely as possible. An accuracy of 15-30 seconds is required.

8. While still pointing your sun photometer at the sun, cover the aperture with your finger to block all light from entering the case. Take a voltage reading and record this dark voltage reading on your *Data Sheet*.

   Note that the dark voltage **must** be reported as volts rather than millivolts, regardless of the range setting of your digital voltmeter. It is critical to report both the dark voltage and sunlight voltage in units of volts. It is important to record the dark voltage accurately, reporting all the digits displayed on your voltmeter. The dark voltage should be less than .020 V (20 mV). Depending on the characteristics of your instrument and the range setting of your voltmeter, the dark voltage may display as 0 V If so, report 0.000 V for the dark voltage.

9. Select the other channel (the red one, assuming you have started with the green channel) and repeat steps 6-8.

   After you gain experience with your sun photometer, it will be unnecessary to repeat step 8 after every sunlight voltage measurement. Indeed, the dark voltages should not change during a set of measurements. If this value changes by more than a millivolt or so, it means that your instrument is getting too hot or cold during the measurement and you need to develop a measurement strategy that prevents this from happening.

10. Repeat steps 4-9 at least twice and no more than four times.

    This will give you between three and five pairs of green/red measurements in all. It is a good idea to be consistent about the order in which you record measurements; you should record green, red, green, red, green, red, green, red, green, red.

    The time between measurements is not critical as long as you record the time accurately. However, as noted above, you should try to minimize the total time required to collect a set of measurements. Remember that your measurements will not be accurate if your sun photometer is significantly colder or warmer than room temperature.

11. If your sun photometer has a rotary switch on the top of the case, select the "T" setting and record the voltage.

    Multiply the voltage reading times 100 and record this value.

12. Turn off both the sun photometer and the voltmeter (if your instrument does not have a built-in digital voltmeter).

    You can disconnect a separate voltmeter or leave it plugged into the output jacks, depending on whether your class uses the voltmeter for other purposes.

13. Note any clouds in the vicinity of the sun in the *Comments* section of the *Aerosols Data Sheet*. Be sure to note the type of clouds by using the GLOBE Cloud Chart.

14. Do the *Cloud Protocols* and record your observations on the *Aerosols Data Sheet*.

15. Do the *Relative Humidity Protocol* and record your observations on the *Aerosols Data Sheet*.

16. Read and record the current temperature to the nearest 0.5˚ C following one of the air temperature protocols.

    There are four *Field Guides* from which to choose listed in the *Student Preparation Guide*. Be careful not to touch or breathe on the thermometer.

17. Complete the rest of the *Aerosols Data Sheet*. This may be done back in the classroom.