

Micrometeorological measurements

Adapted by Jesse Brunner from a lab by Richard Mack and Al Black

24 August 2014

Goals:

- To learn to use apparatus for measuring microclimate.
- To demonstrate spatial variation in microclimate.
- To practice summarizing and graphing data

Standard macrometeorological observations (e.g., extrapolations from weather stations, satellite data) are often inadequate for describing local environmental conditions because temperature, wind, and radiation can vary significantly over short vertical or horizontal distances. We will use micrometeorological equipment to illustrate these differences in contrasting locations on campus.

A word about the equipment: While the equipment you will be using is designed for field use, some pieces are fragile and can be expensive to replace. Take care not to slam, drop, or jar the equipment! Turn the instruments off when they are not in use.

The teaching assistant will demonstrate the proper use of each piece of equipment.

Temperature

Copper/Constantan Thermocouple Thermometer. This thermometer is used to measure the temperature of air or surfaces. The sensor is simply a soldered junction of copper and constantan wires. Constantan is an alloy of 60% copper and 40% nickel. The thermocouple generates a voltage proportional to the difference in temperature between a measuring junction (the one you can see) and a reference junction which electronically mimics 0C. In the voltmeters we will use the voltage output is internally converted into degrees Celsius.

Advantages to using thermocouple thermometers are that the sensors are cheap (pennies apiece), response time is rapid, and they are small enough to be very versatile, e.g., they can be inserted into plant or animal tissue or soil and then left there to allow repeated measurements over time. Disadvantages are that their output per degree is small (40 microvolts per degree) so very sensitive (and therefore expensive) voltmeters are required to measure small differences in temperature.

Infra-red Thermometer. This instrument uses a non-contact method used to measure the temperature of surfaces, all of which emit infra-red (IR) radiation (heat). Although the

sensing unit measures radiant flux from any surface, the instrument converts this to degrees Celsius. The amount of IR radiation emitted by a surface depends on the temperature of the surface. The IR thermometer should be allowed to equilibrate to ambient temperature before use.

Maximum-Minimum Thermometer. This thermometer records the highest and lowest temperature measured over a period of time. It is used primarily for locations that are difficult to reach routinely (i.e., isolated field sites) and for which only information on temperature extremes is needed. The thermometer must be shielded from direct sunlight. We use an aluminum shield that blocks sunlight while still allowing wind movement over the thermometer.

Wind

Hot-wire Anemometer. This anemometer is capable of measuring low wind speeds with great sensitivity. For example, it could be used to estimate the turbulence caused by the wings of a caged butterfly. The instrument's sensor operates by heating wires to maintain a constant temperature; the amount of current added or subtracted from the circuit to maintain the temperature is used to measure the wind speed. These wires are delicate, so be careful not to damage it!

Three-cup Anemometer (demonstration). This is the standard instrument used to measure wind speed in the macroclimate (such as at weather stations). Although it can be used to measure average wind speed over relatively long periods of time, it is insensitive to very low wind speeds.

Short-wave radiation

Pyranometer. This sensor measures the total amount of short-wave (solar) radiation received at a location. This instrument uses a silicon photovoltaic sensor in which semiconducting materials are used to form a positive-negative (P-N) junction. Absorption of photons by the sensor establishes a voltage difference between the P and N materials which is proportional to the photons absorbed. The voltage output is read from the microvoltmeter. The TA will provide the conversion factor for reading the sensor.

Quantum Sensor. This sensor operates on the same principal as the pyranometer but, all short- and long-wave radiation is filtered out. Only the photosynthetically active radiation (within the 400 to 700 nm wavelengths) is measured. Photosynthetically active radiation (PAR) has units of $\mu\text{mol m}^{-2} \text{s}^{-1}$. The TA will provide the conversion factor for reading the sensor.

Humidity

Sling Psychrometer. This instrument consists of a pair of mercury-in-glass thermometers, one with a wet bulb and the other with a dry bulb. The wet bulb will read a lower temperature due to the evaporation of water from its surface. The rate of evaporation and therefore depression of wet bulb temperature is related to the vapor density of the air, so the difference

between wet bulb and dry bulb temperatures can be used to estimate the relative humidity of the air. If the air is nearly saturated with vapor, little water will evaporate from the wet bulb and so the difference in temperature between wet and dry bulbs will be relatively small. Alternatively, there will be much more evaporation in dry air at the same temperature, causing a larger difference in wet and dry bulb temperatures. Relative humidity is the ratio of ambient vapor density to saturation vapor density at ambient temperature and is generally expressed as a percentage.

To use the sling psychrometer, wet the wick with distilled water (DON'T TOUCH THE WICK or allow it to get soiled) and sling it for at least 1 minute. Immediately record the wet and dry bulb temperatures, then sling the psychrometer for another 15 sec. If, after 15 sec, you get the same temperatures, determine relative humidity from the slide rule on the psychrometer case (or from an appropriate table). If the temperatures have changed from your initial reading, repeat the 15 sec reading until you obtain two successive readings that are the same.

Precipitation

Tipping-Bucket Rain Gauge. This is a large funnel that collects rain. In the center of the funnel, a hole delivers rain to a tipping bucket, which fills to a precise volume (equivalent to 0.01 inches or 0.25 mm of rain) before tipping to one side and exposing another bucket to be filled. The gauge records the number of tips to indicate cumulative precipitation. Millimeters of rain is determined by multiplying inches by 25.4.

Standard NOAA rain gauge This rain gauge consists of a funnel attached to a 2-cm diameter graduated cylinder that sits inside a larger cylinder (20 cm or 50 cm). The larger container collects all precipitation over 25 mm (9.8 inches). Measurements are taken every 24 hours.

Lab Exercise

In this lab you will choose two microhabitats to compare. Then for each of three micrometeorological measurement you will:

1. Formulate a null and alternative hypothesis (be sure to state which habitat will be warmer/wetter/etc. than the other).
2. Take five replicate measurements in each habitat with the appropriate equipment that will allow you to eliminate hypotheses. Don't forget the units.
3. Interpret your results. State whether you reject or fail to reject the null hypothesis. Think about the results in terms of what may have caused them.

NOTE: Make sure that you include all short-wave (pyranometer) or photosynthetically active radiation (Quantum sensor) for the assignment.

You will need to average your replicate measurements and calculate the standard error (SE) of the mean. The standard error is $SE = \frac{s}{\sqrt{n}}$, where s is the standard *deviation* and n is

your sample size (here, $n = 5$). The standard deviation is calculated by taking the difference between each observation and the mean, squaring these values, adding them all up, dividing by n , and then taking the square-root of the whole thing. Or put another way,

$$s = \sqrt{\frac{\sigma(x_i - \bar{X})^2}{n}},$$

where x_i is the i^{th} observation and \bar{X} is the mean. You can calculate this by hand, or look for the `stdev()` function in Excel.

Variable 1: Radiation (PAR or Shortwave)

Hypotheses:

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Habitat	Measure 1	Measure 2	Measure 3	Measure 4	Measure 5	Average	Std Error
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A

B

Interpretation:

Variable 2:

Hypotheses:

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Habitat	Measure 1	Measure 2	Measure 3	Measure 4	Measure 5	Average	Std Error
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A

B

Interpretation:

Variable 3:

Hypotheses:

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Habitat	Measure 1	Measure 2	Measure 3	Measure 4	Measure 5	Average	Std Error
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A

B

Interpretation:

Lab Assignment

Create two micrometeorological figures with descriptive captions (5 pts each).

Figure 1: The first figure must summarize the different amounts of all shortwave radiation (measured with the Pyranometer) OR photosynthetically active radiation (measured with the Quantum sensor) in the two microhabitats.

Figure 2: The second figure can report the differences between microhabitats in any of the other measurements made in lab. Make sure you clearly label your figure.

- You will not need to graph each replicate measurement, but *only the averages and standard errors* (as error bars or “whiskers”).
- Each version of Excel seems to graph data differently, so poke around, ask your friends or TA, and be patient. You’ll get it and the reward is knowing how to do something very useful!
- Please start each caption with the figure number, followed by a brief, descriptive sentence. For instance, “Figure 1. Photosynthetically active radiation in cars with and without tinted windows. Error bars represent the standard error of the mean.” If more information is needed to understand the graph, then included it after this brief description.

Points will be assigned according to this rubric:

	Points	Possible
Correct axis labels (with units)		/2 pts
Clear, concise, and adequate presentation of data		/2 pts
Clear, descriptive caption		/1 pts

Spreadsheets

Spreadsheet programs such as Microsoft Excel, OpenOffice Calc, and Google Sheets are among the most accessible ways to organize, analyze, and plot data. Microsoft Excel is available on nearly all university library and computers and most of you probably have it. Unfortunately, the look and feel, and more importantly the functionality of Excel varies tremendously depending on the version and operating system you use. This makes it difficult for your TAs to teach everyone to use Excel; they would have to make several demonstrations for nearly everything we do! So instead, **we ask that you download and use Apache OpenOffice** for this class (<https://www.openoffice.org/>). It is free, open-source, cross platform and does pretty much everything we need, as well. In fact it is often simpler to use

than Excel. If you are comfortable with Excel, Google's Sheets, or another program, it is fine for you to keep using it, but you are on your own. If you think you might need help, get and use OpenOffice.

One last note: **it is your responsibility to learn to use a spreadsheet.** The TAs will demonstrate some things and can help you trouble shoot, but their primary role is teaching you *ecology*, not how to use a computer. You will find that most employers will assume that you are comfortable with the things we are doing here, so consider it preparation for the Real World.