

GLOBE Instrument Specifications

All GLOBE instrument specifications described below represent the minimum specifications necessary to collect scientifically valid data. GLOBE schools may use instruments that meet or exceed these specifications. For example, the GLOBE specifications for pH paper call for a range of 2 to 9 pH units. A pH paper with a range of 1 to 14 exceeds specifications and may be used by GLOBE schools.

Atmosphere/Climate

Cloud Cover/Type - All Skill Levels

Instrument Specifications: Cloud Chart

The GLOBE cloud chart shall display at least one visual example of each of the 10 basic cloud types - cirrus, cirrostratus, cirrocumulus, altostratus, altocumulus, cumulus, nimbostratus, stratus, cumulonimbus, stratocumulus. Sky cover will be visually estimated. The GLOBE Program will provide a cloud chart to each trained U.S. teacher and to each GLOBE Program Country Coordinator.

Aerosols – Middle, Secondary

Instrument Specifications: Sun Photometer

The GLOBE sun photometer has two optical/electronic channels, one with an effective aerosol optical thickness wavelength of 505 nm and the other with an effective AOT wavelength of 625 nm, where “effective aerosol optical thickness wavelength” is defined in Brooks, David R., and Forrest M. Mims III: Development of an inexpensive handheld LED-based Sun photometer for the GLOBE program. *J. Geophys. Res.* 106(D5), 4733-4740, 2001. (That is, the algorithms presented in this paper are an integral part of the instrument specification.) The LED detectors for each channel must be obtained directly from the GLOBE Aerosols Science Team. The detectors and their associated battery-powered electronics are housed in an enclosed plastic or metal box approximately 15 cm long by 5 cm high by 8 cm wide. The detectors must be mounted in a plane such that the LED chips themselves (embedded in a standard T-1-3/4 epoxy housing) are 12.5 cm from one end of the case and that end must contain a 5.5 mm (7/32") diameter sun aperture hole. The round end of the LED housing, which acts as a lens in usual LED applications, must be flattened and polished. There must be a clear line of site from this aperture hole to each detector. No internal light baffling is required. Sunlight is aligned on the detectors through the use of two alignment brackets mounted on the outside of the case. Sunlight passes through a round hole in the front bracket and then shines upon two alignment marks on the rear bracket (one for each channel). When the sunlight spot is centered over an alignment mark, it should also be centered over the LED for the corresponding channel. (Alternate means of aligning the sun on the detectors are acceptable.) The electronics consist of two low-power op-amp-based transimpedance amplifiers (or their functional equivalents) to convert the LED current to a voltage on the order of 1-2V in full sunlight. Noise, gain, temperature drift, and other op amp performance characteristics should be similar to that of Linear Technology LTC1050 or LTC1051 op amps. (Generic 741-type op amps or their dual equivalents are not suitable for this instrument.) Bypass capacitors should be included in the resistive feedback loops to prevent self-oscillation. The sun photometer's output should be monitored either by attaching an external digital voltmeter to pin jacks mounted on the case, or through a built-in digital meter. A built-in meter should display at least three digits to the right of the decimal point for output in the 1-2V range.

Instrument Specifications: Digital Voltmeter

A digital voltmeter (or multimeter) with a DC volts setting that is either: (i) auto-ranging within the range 0-20VDC or (ii) manually selectable for range settings of 0-2VDC and 0-20VDC. For inputs

of less than 10VDC (that is, up to 9.999V), the meter must display three digits to the right of the decimal point.

Water Vapor – Middle, Secondary

Instrument Specifications: GLOBE/GIFTS water vapor instrument

The GLOBE/GIFTS water vapor instrument is based on the same principle as and similar in design to the GLOBE sun photometer, the specifications for which are described in detail under Aerosols. Both use light emitting diodes (LEDs) to measure the strength of sunlight in select wavelengths. While the GLOBE sun photometer detects visible light in the green and red part of the spectrum, the water vapor instrument detects infrared rather than visible light. This instrument concept was first developed and described in the scientific literature by a member of the *Water Vapor* protocol Science Team [Mims, Forrest M. III, Sun photometer with light-emitting diodes as spectrally selective detectors, *Applied Optics*, 31, 6965-6967, 1992]. The calibrations of the LEDs for this instrument require access to highly specialized equipment and data and they cannot be duplicated by students in the lab or in the field. These instruments can be obtained from the GLOBE Water Vapor Team.

Barometric Pressure – All Skill Levels

Instrument Specifications: Aneroid Barometer

The aneroid barometer must have a clear scale with a pressure range between 940 and 1060 millibars. The scale should be readable to the nearest whole millibar and have an accuracy of 3.5 millibars over its entire range. A set needle should be on the face of the barometer. The barometer must be calibratable. This barometer will be most useful for stations whose elevation is less than 500 meters above sea level. Schools at higher elevations will need to use an altimeter.

Instrument Specifications: Altimeter

An altimeter is a special type of aneroid barometer designed to provide heights (using standard temperature and pressure values), as well as true atmospheric pressure readings. The scale must be given in millibars and extend from 650 millibars to 1050 millibars. Accuracy must be 3.5 millibars over the range of the instrument. The altimeter must be calibratable. This instrument is for the measurement of atmospheric pressure at elevations over 500 m.

Instrument Specifications: Digital Barometric Pressure Sensor

Barometric pressure values may also be collected with a digital barometric pressure sensor. This sensor must have a pressure range of between 940 and 1060 mbars with one mbar resolution and an accuracy of 3.5 mbars over its entire range. Barometric pressures reported from the sensor must be station pressures.

Relative Humidity – All Skill Levels

Instrument Specifications: Digital Hygrometer

A digital hygrometer or sensor must provide a digital readout of relative humidity to the nearest 1%. Over a range of 20-95%, accuracy must be at least 5%. The digital hygrometer should include a stand to allow the unit to be placed upright on the floor of the instrument shelter, while measurements are being taken. Calibration is done by the manufacturer and should be warranted for at least two years, with subsequent recalibration available. Batteries should be included. The unit should not be left outside on a daily basis.

Instrument Specifications: Sling Psychrometer

The wet bulb and dry bulb temperatures shall be measured with a sling psychrometer, which consists of two spirit-filled thermometers. The thermometers shall be readable only in degrees Celsius, with scales marked in increments of 1.0° C, and the scales must be capable of supporting temperature estimations to the nearest 0.5° C over a range of –1° C to 35° C. The psychrometer must be in a sturdy protective case or have spirit bulbs mounted on a rigid plate, and be provided

with handle necessary for whirling or slinging. Thermometers must be factory calibrated to an accuracy of $+1.0^{\circ}\text{C}$, which will provide relative humidity accuracy of 5%. Both scales should be adjustable for calibration, or the spirit bulbs replaceable. Each scale must be clearly marked to indicate Celsius. Siting and installation instructions are provided in the *Atmosphere Chapter*.

Instrument Specifications: Calibration Thermometer

The Calibration Thermometer described in Air Temperature may be used for this measurement.

Instrument Specifications: Maximum/Minimum Thermometer

The Maximum/Minimum Thermometer described in Air Temperature may be for this measurement.

Instrument Specifications: Instrument Shelter

The Instrument Shelter described in Air Temperature will be used for this measurement.

Surface Ozone – All Skill Levels

Instrument Specifications: Ozone Chemical Strips

The ozone chemical strips contain a solution of tin(II) chloride dihydrate and 1,5-diphenylcarbazide dissolved in reagent-grade acetone. When exposed to air, ozone reacts with the mixture and triggers a colorimetric reaction resulting in the formation of a pink color. Ground level ozone concentrations can be measured by quantifying the color change on an exposed chemical strip using an ozone optical reader.

Instrument Specifications: Ozone Test Strip Scanner

The ozone test strip optical reader operates as a simple spectrophotometer consisting of a light emitting diode (LED) emitting light near 540nm, and a photo diode that captures the reflected light off the exposed chemical test strip and converts it into an electrical voltage. The reader must be calibrated so that the voltage measured can be displayed as an ozone concentration in parts ozone per billion parts of air (ppb). Zero ozone level must be set by inserting an unexposed ozone test strip into the reader and storing the voltage produced. Any absorption at 540 nm above this value will be measured as a specific ozone concentration.

Instrument Specifications: Ozone Measuring Station

Directions for constructing an ozone measuring station are provided in the *Instrument Construction, Site Selection, and Set-Up* section of the *Atmosphere Chapter*.

Instrument Specifications: Wind Direction Instrument

Any device capable of displaying wind direction, such as weathervane. Directions for constructing a wind direction instrument are provided in the *Instrument Construction, Site Selection, and Set-Up* section of the *Atmosphere Chapter*.

Precipitation, Liquid - All Skill Levels

Instrument Specifications: Rain Gauge

Precipitation will be measured with a clear view plastic rain gauge with a collector that is at least 102 mm in diameter. The rain gauge must be at least 280 mm in height with a scale indicating rain collected of 0.2 mm or less on an inner clear cylinder. It must have the capacity to measure rainfall of 280 mm without overflowing. The shape of the outer part must also be cylindrical, and overflow from the inner cylinder shall be directed to the outer part of the rain gauge. The outer cylinder must be capable of being used in the inverted position to gather a snow sample for measurement of the water content of snow. The rain gauge must be provided with the necessary hardware for installation on a pole. Instructions for siting are provided in the GLOBE Program *Teacher's Guide*.

Instrument Specifications: Electronic Tipping Bucket

An electronic tipping bucket rain-measuring instrument may be used in conjunction with an automated weather station. The tipping bucket must have a resolution of at least 0.25 mm.

Precipitation, Solid - All Skill Levels

Instrument Specifications: Snowboard

The depth of daily snowfall will be measured with a plywood board, painted white, which is approximately 40 cm X 40 cm x at least 1 cm thick.

Instrument Specifications: Rain Gauge

The rain gauge described in Precipitation, Liquid will be used for this measurement.

Instrument Specifications: Snow Depth Pole

For snow depths less than 1 meter, a meter stick is recommended. When the snow is deeper than one meter, a snow depth pole is used. This can be made from a 2 meter pole by placing two meter sticks end to end on this pole.

Precipitation pH - All Skill Levels

The same instruments described in Hydrology: Water pH will be used for this measurement.

Air Temperature - All Skill Levels

Instrument Specifications: Digital Max/Min Thermometers

Digital max/min thermometers may be used. These must have either an accuracy of $\pm 0.5^\circ$ Celsius or a precision of at least $\pm 0.5^\circ$ Celsius and an error offset that is temperature independent. These thermometers can either be digital single-day max/min thermometers that are checked and reset each day or digital multi-day max/min thermometers that log temperature values for multiple days. Digital multi-day max/min thermometers must be able to record max/min temperatures over 24-periods that can be set to begin and end within one hour of local solar noon.

Instrument Specifications: Liquid-filled Maximum/Minimum Thermometer

Air temperature can be measured with a U-shaped maximum/minimum thermometer. The maximum/minimum thermometer shall be readable only in degrees Celsius, with maximum and minimum scales marked in increments of 1.0° C, and the scales must be capable of supporting temperature estimations to the nearest 0.5° C. The thermometer must be in a sturdy protective case, and be provided with the necessary hardware for installation. It must be factory calibrated to an accuracy of $\pm 1.0^\circ$ C. Both scales must be adjustable for calibration. Each scale must be clearly marked to indicate Celsius, and have indicators such as "+" and "-" on each scale to indicate direction of increasing and decreasing temperature. In addition, each scale must be clearly marked to identify which scale is maximum and which is minimum. Siting and installation instructions are provided in the GLOBE Program *Teacher's Guide*.

Instrument Specifications: Digital Temperature Sensor

Digital temperature sensors may also be used to monitor temperature. These must have either an accuracy of $\pm 0.5^\circ$ Celsius or a precision of at least $\pm 0.5^\circ$ Celsius and an error offset that is temperature independent.

Instrument Specifications: Calibration Thermometer

The maximum/minimum thermometer will be calibrated with a second thermometer which is an organic liquid-filled thermometer with a temperature range of -5° C to 50° C. The thermometer must be factory calibrated and tested with standards traceable to N.I.S.T (The National Institute of Standards and Technology - United States) to an accuracy of $\pm 0.5^\circ$ C, with 0.5° C scale divisions. It must be supplied with a metal jacket with holes at the bulb end to allow for circulation and a hole at the top by which to hang the thermometer in the instrument shelter for calibration of the maximum/minimum thermometer.

Instrument Specifications: Instrument Shelter

An instrument shelter is required to house the maximum/minimum thermometer and the calibration thermometer to assure scientifically usable air temperature measurements. The instrument shelter

must be constructed of a material with a thermal insulation value which equals or exceeds that of seasoned white pine wood (approximately 2.0 cm thick). It must be painted white with exterior grade paint. The shelter must be vented, and be large enough to allow air circulation around the thermometer. The inside dimensions must be at least 45 cm high, 24.0 cm wide, and 12.0 cm deep. The shelter must have a hinged door on the front, be louvered on the front and sides, and have holes in the bottom and holes at the uppermost part of the sides to increase ventilation if the louvers do not extend to the top of the sides. The door must contain a lock. The instrument shelter must be mountable onto a wall or post. The top of the shelter must slope downward toward the front. The parts of the shelter must be securely fastened to each other, either using screws or with nails and glue. Joints must be sealed with weather resistant caulking compound. Detailed instructions on constructing an instrument shelter are provided in the *Instrument Construction, Site Selection, and Set-Up* section of the *Atmosphere Chapter*.

Surface Temperature – Middle, Secondary

Instrument Specifications: Infrared Thermometer (IRT)

The Infrared thermometer should be a handheld instrument. It must have an accuracy of $\pm 1^\circ \text{C}$ over a range of -32°C to 72°C .

Automated Weather Station– Optional, Middle, Secondary

Instrument Specifications: Automated Weather Station

A weather station must be attached to a data logger and computer, and be capable of logging data at 15-minute intervals. Data entry is simplified if the software for the weather station supports the option to “Export GLOBE Data”. The sensors attached to the weather station must meet the following specifications: **Temperature:** Must have either an accuracy of $\pm 0.5^\circ \text{C}$ or a precision of at least $\pm 0.5^\circ \text{C}$ and an error offset that is temperature independent. **Barometric Pressure:** Must have a pressure range of between 940 and 1060 mbars with one mbar resolution and an accuracy of 3.5 mbars over its entire range.

Relative Humidity: Must have a digital readout of relative humidity to the nearest 1%. Over a humidity range of 20-95%, accuracy must be at least 5%. **Rainfall:** Must have a resolution of at least 0.25 mm.

Anemometer: Must have a precision of $\pm 5\%$ and a range of at least 0-34 m/s. You may report data taken using any sensors that meet these specifications. In order to perform a weather station protocol and related email data entry these sensors must be attached to a weather station that is capable of logging data at 15-minute intervals. If one or more of the sensors of your weather station do not meet the above specifications, you may still report data collected with the sensors that do meet specifications.

Hydrology

Water Temperature: - All Skill Levels

Instrument Specifications: Organic Liquid-filled Thermometer

The calibration thermometer or digital temperature sensor described in Air Temperature will be used for this measurement.

Transparency - All Skill Levels

Instrument Specifications: Secchi Disk Apparatus (for deep water sites only)

5 m length of rope and a disk with a diameter of 20 cm. The disk shall be colored with paint or other appropriate means such that alternate quadrants of each side are black and white. The disk must be made so that it will not be disfigured or damaged by repeated immersion in water,

including sea water. It must be weighted such that it remains horizontal while it is lowered by the rope in the water.

Instrument Specifications: Turbidity Tube (for surface water)

Clear plastic tube, approximately 1.2 m long and 4.5 cm diameter with a white cap that fits securely on the end of the tube. The end cap must display a pattern consisting of alternating black and white quadrants on the side that is viewed by looking down the tube.

Water pH - All Skill Levels

Note: The instrument requirements for this measurement vary according to skill level. Please select the appropriate instrument for your students.

Skill Level - Primary

Instrument Specifications: pH Paper

The pH of standing water at this skill level will be measured with pH paper which can be purchased in strips or rolls. The pH paper must have an accuracy of at least ± 1.0 pH units, with a range of 2 to 9 pH units. For water samples with low conductivity the pH paper must be accurate in low conductivity levels.

Skill Level - Middle, Secondary

Instrument Specifications: pH Meter

The pH of standing water at this skill level will be measured with a pH meter. The pH meter must have an accuracy of 0.1 pH unit, and a range of pH 1 to pH 14, at temperatures from 0 C to 50 C. The device shall automatically compensate the reading when it is placed in solutions of differing temperature. The pH meter must be capable of being calibrated using at least two known pH buffer solutions: pH 4, 7, or 10.

Skill Level - Middle, Secondary

Instrument Specifications: Buffers

pH buffer solutions are required to calibrate the pH pen and meter. The buffer solutions should have a value of pH 4.0, pH 7.0 and pH 10.0.

Dissolved Oxygen - Middle, Secondary Skill Levels

Instrument Specifications: Dissolved Oxygen Kit

A dissolved oxygen test kit can be purchased. Teachers or manufacturers who wish to use or prepare another version should ensure that it also meets the following requirements:

- Enables measurement of dissolved oxygen with an accuracy of at least ± 1 mg/L
- Contains all the chemicals and special containers to perform this measurement based on the Winkler titration method. This method is described in *Standard Methods for the Examination of Water and Wastewater*, 19th edition, 1995, a publication of the American Public Health Association, Washington, DC.
- Contains clear instructions for using the kit to make this measurement using a procedure based on the Winkler titration method.

Alkalinity - Middle, Secondary Skill Levels

Instrument Specifications: Water Alkalinity Kit

A water alkalinity kit can be purchased. Teachers or manufacturers who wish to use or prepare another version should ensure that it also meets the following requirements:

- Enables measurement of total alkalinity with an accuracy of at least 6.8 mg/L as CaCO_3 (low range, under 136 mg/L), and 17 mg/L as CaCO_3 (high range, above 136 mg/L).

- Contains all chemicals and containers needed to perform the alkalinity titration, including: 1) Bromocresol green-methyl red indicator and scoop for adding the required amount to the sample, 2) sulfuric acid for titration, and method of delivering acid to sample to achieve the required accuracy, 3) measuring containers and bottles for titration. This method is described in 19th edition, 1995, a publication of the American Public Health Association, Washington, D.C.
- Contains clear instructions for using the kit to make this measurement, based on acid titration to a Bromocresol green-methyl red end point.
- Plastic gloves and safety goggles

Instrument Specifications: Safety Equipment

Plastic gloves and safety goggles must be used in making this measurement.

Electrical Conductivity (for fresh water sites) - All Skill Levels

Instrument Specifications: Electrode-type Total Dissolved Solids Tester (Conductivity, or TDS, Meter)

This device shall measure electrical conductivity of liquid solutions using two metal electrodes separated by a fixed distance. The device shall be designed to be hand-held, and battery powered, with no electrical power cord attached. The device shall employ a method to automatically compensate the indicated conductivity value relative to changes in the temperature of the solution. The measurement range shall be at least from 0-1990 microSiemens/cm, with a resolution of 10 microSiemens/cm, an accuracy of +/- 2% full scale, and an operating temperature of 0-50 C. The device shall be capable of calibration using a standard solution.

Instrument Specifications: Calibration Standard

A standardized solution of KCl and water or NaCl and water that has a conductivity of between 500 +/- 0.25% and 1500 +/- 0.25% microSiemens at 25C.

Salinity (for brackish and salt water sites) - All Skill Levels

Instrument Specifications: Hydrometer Method

The same instrument described in Soil Particle Size will be used for this measurement. A 500 mL clear plastic cylinder and an organic liquid-filled thermometer for use with the hydrometer are required. The 500 mL cylinder for Soil Particle Size may be used. The calibration thermometer for Air Temperature may be used.

Instrument Specifications: Salinity Titration Method - Optional, Middle, Secondary Skill Levels

A salinity kit can be purchased. Teachers or manufacturers who wish to use or prepare another version should ensure that it also meets the following requirements:

- Range: 0 - 20 parts per thousand (ppt)*
- Smallest increment: 0.4 ppt
- Method/chemistry: chloride titration
- Approximate number of tests: 50
- Contains clear instructions for using this kit to make this measurement, based on the chloride titration method.*Titrator must be refillable for use in higher salinity waters.

Nitrate - Middle, Secondary Skill Levels

Instrument Specifications: Water Nitrate Kit

A nitrate kit can be purchased. Teachers or manufacturers who wish to use or prepare another version should ensure that it also meets the following requirements:

- Range: 0 - 10 ppm NO₃-N (typical water) or a range with the highest concentration greater than what is typically observed for your water body (polluted water.)

- Smallest increment: 0.05 ppm NO₃-N for the range 0 -1 ppm NO₃-N; 0.5 ppm NO₃-N for the range 1 - 5 ppm NO₃-N; 1 ppm NO₃-N for the range 5 - 10 ppm NO₃-N; 2 ppm NO₃-N for concentrations greater than 10 ppm NO₃-N
- Contains clear instructions for using this kit to make this measurement.

Freshwater Macroinvertebrates – Optional, Middle, Secondary

Instrument Specifications: Kicknet

Must have dimensions of 1 m X 0.9 m, and made of 0.5 mm mesh netting.

Instrument Specifications: D-net

Must be a “D”-shape with a 40 cm long base, and made of 0.5 mm mesh netting.

Instrument Specifications: Quadrat

Must be a square with internal dimensions of 1 m X 1 m. Can be made from locally available materials.

Instrument Specifications: Sieves

There are two sieves required:

1. a sieve with mesh netting of 0.5 mm or smaller
2. a sieve with mesh netting of 2-5 mm

Soil Characterization

Soil Slope - All Skill Levels

Instrument Specifications: Clinometer

A clinometer as described in Land Cover specifications.

Soil Profile - All Skill Levels

Instrument Specifications: Camera

A camera with color film or digital camera.

Instrument Specifications: Meter Stick

A durable ruler with gradations every cm and mm.

Instrument Specifications: Soil Auger (optional)

See soil auger types listed under Soil Moisture.

Soil Structure - All Skill Levels

Instrument Specifications: None

Color - All Skill Levels

Instrument Specifications: Color Chart

A soil color chart designed especially for the GLOBE Program can be purchased. It contains at least 200 colors and uses the Munsell System of Color Notation. This flip chart is weather-resistant and has large color chips which are edge-mounted for ease of reading. The color range includes all hues found in the full set of International soil colors, yet provides a selected set of values and chroma to aid color identification for students. Manufacturers who wish to prepare another version should contact the GLOBE Program for the complete list of colors.

Soil Consistence - All Skill Levels

Instrument Specifications: None

Soil Texture- All Skill Levels

Instrument Specifications: None

Free Carbonates - All Skill Levels

Instrument Specifications: Vinegar

Distilled white vinegar. Household vinegar may be used.

Instrument Specifications: Acid Squirt Bottle

A bottle capable of safely holding at least 200 mL of acid is required.

Sample Preparation for Bulk Density, Particle Size, Soil pH, and Fertility Protocols - All Skill Levels

Instrument Specifications: Sieve

Number 10 sieve with 2 mm mesh attached to a frame.

Soil Bulk Density - All Skill Levels

Instrument Specifications: Graduated Cylinder -100 mL

Glass graduated cylinder with a capacity of 100 mL marked in 1 mL or smaller divisions, with graduations covering at least the range from 10 mL to 100 mL.

Instrument Specifications: Balance and Augers

The same balance and auger used for Gravimetric Soil Moisture will be used for Bulk Density.

Instrument Specifications: Soil Sample Cans and Other Soil Containers

Cans and containers should meet the same specifications as given for these items for Gravimetric Soil Moisture.

Soil Particle Size - All Skill Levels

Instrument Specifications: Hydrometer

The hydrometer used should meet the following requirements:

- Calibrated to specific temperature for water and sample (e.g. 15.6 C / 15.6 C
- Range (specific gravity / no units): 1.0000 - 1.0700
- Smallest increment (no units): 0.0005

Instrument Specifications: Thermometer

The Calibration Thermometer described in Air Temperature will be used for this measurement.

Instrument Specifications: 500 mL Clear Plastic Graduated Cylinder One 500 mL capacity plastic graduated cylinder, marked at least at the 500 mL level. Cylinder must be clear plastic, not frosted plastic and not glass.

Instrument Specifications: Dispersing Solution

Sodiumhexametaphosphate powder or a 10% solution of either sodiumhexametaphosphate or a detergent that does not produce suds.

Soil Particle Density – All Skill Levels

Instrument Specifications: 100 mL Erlenmeyer flask

A heat-resistant Erlenmeyer flask with a cap, capable of holding 100 mL of solution.

Instrument Specifications: Heat source

A heat source capable of bringing 100 mL of a water and soil solution to a gentle boil and maintaining this boil for at least 10 minutes.

Soil pH - All Skill Levels

Instrument Specifications: pH measurement devices

The same instruments described in Hydrology: Water pH will be used for this measurement.

Instrument Specifications: Graduated Cylinder -100 mL

The same instrument as described in Bulk Density will be used for this measurement.

Soil Fertility - Middle, Secondary Skill Levels

Instrument Specifications: Soil NPK (Macronutrients) Kit

The test kit must:

- Contain unit-dose reagents and containers needed to extract soil nutrients from 50 samples and to perform 50 tests of each: soil nitrogen; soil phosphorus; and soil potassium.
- Employ methods based on the Spurway extraction method, the zinc reduction/chromotropic acid method for nitrogen, the ascorbic acid reduction method for phosphorus, and the sodium tetraphenylboron (turbidimetric) method for potassium.
- Contain clear instructions, including diagrams, for using the kit.
- Contain a water resistant color chart for interpreting the results of colorimetric tests and a turbidity chart for the turbidimetric test.

Soil Moisture

Gravimetric Soil Moisture - All Skill Levels

Instrument Specifications: Balance

This balance must have the capacity to weigh 300 grams with an accuracy of +/- 0.1 gram. It can be either mechanical or electronic. It is assumed that a balance is available locally, for example in a high school science laboratory.

Instrument Specifications: Drying Oven (soils)

Drying oven capable of holding a temperature of 95 C - 105 C for at least 10 hours or a temperature of 75 C - 95 C for 24 hours. The oven must be ventilated, and have interior dimension of at least 25 cm x 30 cm x 25 cm. It is assumed that an oven is available locally, for example in a high school science laboratory.

Instrument Specifications: Microwave Drying Oven

Any microwave oven compatible with school use.

Instrument Specifications: Soil Sample Cans

15 round sample tins. A metal container with a diameter 7 cm, and height 5 cm, with a removable cover is appropriate as are small round, cleaned food cans. Cans must be capable of having a small hole punched in their bottoms.

Instrument Specifications: Other Soil Containers

15 containers large enough to have soil samples transferred into them directly from an auger without loss of sample. Glass jars, plastic food containers with lids, or other containers that can be covered and that can hold the soil samples while they are dried in the drying oven selected.

Instrument Specifications: Dutch Auger For Combination Soils

Dutch (or Edelman) auger for combination soils with a head having the minimum dimensions of 7 cm wide and 18 cm long. The unit (head and shaft inclusive) should be at least 120 cm long in order to be suitable to dig a hole up to 1m deep. It should be of one piece welded construction.

Instrument Specifications: Dutch Sand Auger

Auger designed for sandy soils with a head having the minimum dimensions of 7 cm wide and 18 cm long. The unit (head and shaft inclusive) should be at least 120 cm long in order to be suitable to dig a hole up to 1m deep. It should be of one piece welded construction.

Instrument Specifications: Bucket Auger

Bucket (or Riverside) auger designed for hard and brittle soils with a head having the minimum dimensions of 7 cm wide and 18 cm long. The unit (head and shaft inclusive) should be at least 120 cm long in order to be suitable to dig a hole up to 1m deep. It should be of one piece welded construction.

Instrument Specifications: Peat Auger

Auger designed for peat soils with a head having the minimum dimensions of 7 cm wide and 18 cm long. The unit (head and shaft inclusive) should be at least 120 cm long in order to be suitable to dig a hole up to 1m deep. It should be of one piece welded construction.

Soil Moisture Sensor - Optional, Secondary Skill Level

Instrument Specifications: Soil Moisture Sensor

This should be a ceramic block sensor that uses an electrical resistance method for soil water matric potential measurement. One of the best ceramic block sensors is called a Watermark block and is the one recommended for this measurement.

Instrument Specifications: Soil Moisture Meter

There are two meters you might use. One is manufactured by Delmhorst and reads 0 to 100 (dry to wet). The other is made by Watermark and reads 0 to 200. Both are acceptable by the GLOBE data system. Please contact the GLOBE soil moisture science team if you have a different kind of sensor or meter.

Instrument Specifications: PVC Piping

The PVC pipe assists in placing the soil moisture sensors in the ground. It should be 90 cm in length and approximately 2 cm in diameter. Additional PVC piping is required to mark the location of the sensors. These should be 23 cm long with a diameter of approximately 5 cm. Four pieces of this material are required.

Infiltration — Optional, All Skill Levels

Instrument Specifications: Dual Ring Infiltrometer

Two concentric metal cylinders. The inner one must have a diameter of 10 cm to 25 cm. The outer one must have a diameter at least 10 cm larger than the inner cylinder. Both cylinders should be 10 to 15 cm high and open at both ends. Steel cans may be found which will work for this apparatus.

Soil Temperature

Soil Temperature- All Skill Levels

Instrument Specifications: Soil Thermometer

A 11 cm to 20 cm stainless steel probe, heavy-duty construction dial or digital thermometer with a range of at least -10 to 50 degrees C (Celsius scale required) and an accuracy of 1% full scale (over a range of no more than 200 degrees C) or better is required. The sensor should be in the bottom third of the probe. The sensor should give stable readings after less than 60 seconds in an isothermal bath. Batteries, if required, should be included. The sensor should be adjustable with the calibration procedure and achievable accuracy clearly stated. Dial thermometers must be sealed against fogging and be covered with shatterproof glass or plastic. Scale graduations of 1.0 degrees C and 0.1 degrees C are preferred for dial and digital thermometers, respectively. Glass stem thermometers are NOT acceptable.

Instrument Specifications: Digital Maximum and Minimum Thermometers

See *Digital Maximum and Minimum Thermometers* listed under Air Temperature.

Automated Soil and Air Monitoring – Optional, Middle, Secondary

Instrument Specifications: 4-Channel Data Logger

A self contained, programmable data logger capable of collecting and storing data from four temperature sensors (one air, possibly internal, and three soil - external channels). Data logger must be capable of collecting data at 15 and 60 minute intervals (sampling frequency) and storing at least 3750 measurements (time/date stamped) per channel (8kb capability is preferred) in nonvolatile memory. The time accuracy must be ± 1 minute per week. The temperature must be recorded with at least 7 bits of resolution. The logger must be powered by a user-replaceable lithium-grade battery, with a continuous use lifetime of one year. It must have operational ranges of -20 to +70 degrees Celsius in a 0 - 95% relative humidity, non-condensing environment.

Instrument Specifications: Data Logger Computer Interface and Software

Computer interface cables and appropriate software for launching the logger and retrieving the data must be available. The computer interface must be MS WINDOWS compatible. MAC compatibility is desired but not essential. The software must allow the data to be exported as an ASCII text file and should provide some basic graphical display of the data.

Instrument Specifications: Air and Soil Temperature Sensors

Air temperature can be sensed internally if the response time is less than 15 minutes, otherwise, a short (0.3 meter) cable (and 4th external channel) must be available. The soil temperature sensors must be designed to work for years buried up to 1 meter deep in unsaturated soils. Their cables must be between 3 and 6 meters in length. All sensors and cables must be weather and sun-resistant since they will be deployed outside on a continuous basis. All sensors should have an accuracy of ± 0.5 degrees Celsius (at 20 degrees Celsius) and a range of -30 to +100 degrees Celsius.

Instrument Specifications: Watertight Box

Instructions for constructing a watertight box are provided in the *Automated Soil and Air Temperature monitoring Protocol*.

Instrument Specifications: Desiccant

100 mL of CaSO_4 or other dehydrating agent.

Instrument Specifications: Instrument Shelter

The Instrument Shelter described in Air Temperature will be used for this measurement.

Automated Soil Moisture and Temperature Stations – Optional, Middle, Secondary

Instrument Specifications: Automated Soil Moisture and Temperature Station

A soil moisture/temperature station must be attached to a weather station with a data logger attached to a computer, and be capable of logging data at 15-minute intervals. Data entry is simplified if the software for the weather station supports the option to "Export GLOBE Data". Ideally there will be four soil moisture sensors, three temperature sensors for soil, and one optional temperature sensor for air. However, you may use fewer sensors.

The sensors used with the soil moisture/temperature station must meet the following specifications:

Temperature: sensors must be designed to work for years buried up to 1 meter deep in unsaturated soils. Their cables must be between 3 and 6 meters in length. All sensors and cables must be weather and sun-resistant since they will be deployed outside on a continuous basis. All sensors should have an accuracy of ± 0.5 degrees Celsius (at 20 degrees Celsius) and a range of -30 to +100 degrees Celsius.

Soil Moisture: ceramic block sensors that use an electrical resistance method for soil water matrix potential measurement. One of the best ceramic block sensors is called a Watermark block and is the one recommended for this measurement.

Land Cover/Biology

Land Cover - All Skill Levels

Instrument Specifications: Landsat Thematic Mapper (TM) Image, MultiSpec software.

The GLOBE Program will provide a TM image to all US schools. MultiSpec software is available for downloading from the Internet.

Species Identification - All Skill Levels

Instrument Specifications: Dichotomous Keys

Dichotomous keys for tree identification are not available from a central supplier; they need to be acquired locally.

Biometry

Layout of the Biology Site - All Skill Levels

Instrument Specifications: Tape Measure

50 m tape, graduated one side, marked in 2 mm or smaller units.

Tree Circumference - All Skill Levels

Instrument Specifications: Tape Measure

The tape measure described in Layout of the Biology Site will be used for this measurement.

Tree Height - All Skill Levels

Instrument Specifications: Tape Measure

The tape measure described in Layout of the Biology Site will be used for this measurement.

Instrument Specifications: Clinometer

The clinometer may be made by students from plans in the GLOBE Teacher's Guide, or may consist of a moveable dial within a metal case and lens viewer. For the moveable dial version, the scale must be graduated from 0-90° in 1° units.

Canopy Cover - All Skill Levels

Instrument Specifications: Densiometer

The densiometer may be made by students according to instructions in the GLOBE Teacher's Guide.

Ground Cover - All Skill Levels

Instrument Specifications: None

Grass Biomass - All Skill Levels

Instrument Specifications: Balance

This balance must have the capacity to weigh 300 grams with an accuracy of +/- 0.1 gram. It can be either mechanical or electronic. It is assumed that a balance is available locally, for example in a high school science laboratory.

Instrument Specifications: Drying Oven (plants)

This oven must be capable of holding samples at 50-70 C for up to two days and must be ventilated to allow moisture to escape. The interior dimensions of the oven must be at least 25 cm x 30 cm x 25 cm. It is assumed that an oven is available locally, for example in a high school science laboratory. The oven should be designed for drying biological samples or food and should not be a conventional cooking oven, which could present a fire hazard in this application.

Earth as a System

Green-Up – All Skill Levels

Instrument Specifications: Dichotomous Keys

Dichotomous keys for tree identification are not available from a central supplier; they need to be acquired locally.

Instrument Specifications: Camera

It is assumed that a camera with color film or digital camera is available locally.

Green-Down – All Skill Levels

Instrument Specifications: Plant Color Guide

A guide made of weather-resistant paper that contains reference color chips based on the Munsell System of Color Notation. The following colors should be displayed: 5G 8/4, 5G 7/4, 5G 6/2, 5G 4/2, 5GY 3/2, 5GY 4/8, 2.5Y 8/6, 2.5Y 8/12, 5YR 7/12, 5GY 7/12, 5GY 6/10, 5GY 5/10, 2.5Y 6/6, 5Y 8/4, 7.5YR 8/4, 7.5YR 6/4, 7.5YR 5/4, 7.5YR 3/4, 5R 3/4, 2.5R 4/2, 2.5R 4/4, 2.5R 4/6, 2.5R 4/8, 2.5R 4/12. Each color chip must be positioned near a cutout that allows color comparison between plant leaves and the reference chips.

Instrument Specifications: Local Plant Identification Guide

Local Plant Identification Guides for tree identification are not available from a central supplier; they need to be acquired locally.

Instrument Specifications: Camera

It is assumed that a camera with color film or digital camera is available locally.

Budburst - All Skill Levels

Instrument Specifications: Local Plant Identification Guide

Local Plant Identification Guides for tree identification are not available from a central supplier; they need to be acquired locally.

GPS

Latitude, Longitude and Elevation of GLOBE Study Sites - All Skill Levels

Instrument Specifications: Global Positioning System (GPS) Receiver

The instrument must be capable of:

- Preferably capable of expressing latitude and longitude in decimal degrees to the nearest 0.0001 degrees (may alternatively express in whole degrees, minutes and decimal minutes to the nearest 0.01 minutes, but this will require conversion before reporting readings to GLOBE) and
- Displaying time on screen in units of UT hours, minutes, and seconds,
- Using the WGS-84 map datum, and
- Displaying elevation in meters.