Introduction

Why study water vapor

The earth's climate supports life largely because of the atmospheric greenhouse effect and the impact of the hydrological cycle. Water vapor plays a key role in both of these, which makes learning about and observing water vapor a very important facet of the GLOBE program.

Although there are many atmospheric greenhouse gases, some naturally occurring and some resulting from industrial activities, water vapor is likely the most important because it is both sensitive to, and the cause of, variations in climate. For example, as the temperature of the earth's surface and atmosphere increase, the atmosphere is able to hold more water vapor. This additional water vapor, acting as a greenhouse gas, absorbs energy that would otherwise escape to space and causes further warming, increasing the atmosphere's capacity for water vapor. Additional interactions between water vapor, clouds, atmospheric motion, and radiation from both the sun and the earth for example, make this effect more interesting and more complicated. However, there are aspects of the role of water vapor as a greenhouse gas that are not well understood, mostly because we lack the necessary observations to test theoretical models.

In addition to its role as a greenhouse gas, water vapor greatly influences climate through the hydrological cycle. As water moves between the earth's atmosphere, oceans, and continents it transfers energy thus influencing variations in climate. In its vapor phase, water is able to move quickly through the atmosphere and redistribute energy associated with its evaporation and condensation. Not surprisingly, the movement of water vapor through the hydrological cycle is strongly coupled to precipitation and soil moisture, which have important practical implications in agriculture and beyond. Although the basic mechanics of the hydrologic cycle are well known, some details are poorly understood, mainly because we do not have sufficiently good observations of water vapor.

By finding methods for better measuring water vapor in the atmosphere, we will be able to better understand how the greenhouse effect and the hydrological cycle influence climate. Although measuring local humidity, another protocol for the GLOBE project, does help to do this, column water vapor measurements will lead to a more complete picture of water vapor concentration and variation throughout the atmosphere. Water vapor contained in a vertical column of atmosphere can be compared with horizontal humidity data to create a three dimensional picture of the distribution of water in the atmosphere.

"Water vapor in the climate system." Special report. December 1995
http://www.agu.org/sci_soc/mockler.html

What do we do with the data

Current measurement techniques show the monthly average amount of water vapor is not uniformly distributed across the earth (see figure 1). The general decrease of precipitable water from equator to the poles is a reflection of the global distribution of temperature. As expected, amounts of precipitable water are greatest over warm, equatorial regions and generally decrease towards the cold, polar regions. There are exceptions in the major desert regions, where the surface air is very dry despite its high temperature.

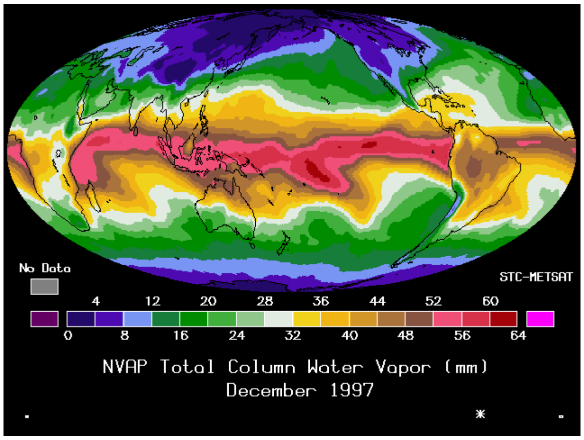


Figure 1. Mean amount of precipitable water vapor for the month of December 1997.

(Notice that the units most often used to quantify precipitable water vapor are millimeters of water. This is a measure of how much precipitation would occur if all of the water vapor in the column of atmosphere were to condense.)

Real time measurements of are taken with a variety of instruments. The Geostationary Operational Environmental Satellites (GOES) for example, make measurements of column water vapor, among others, and send the data back to the surface for processing. Composite pictures of the amount of water vapor can be created from these data (see figure 2). By viewing these images sequentially, like a movie, we can more easily visualize the movement and fluctuations in water vapor.

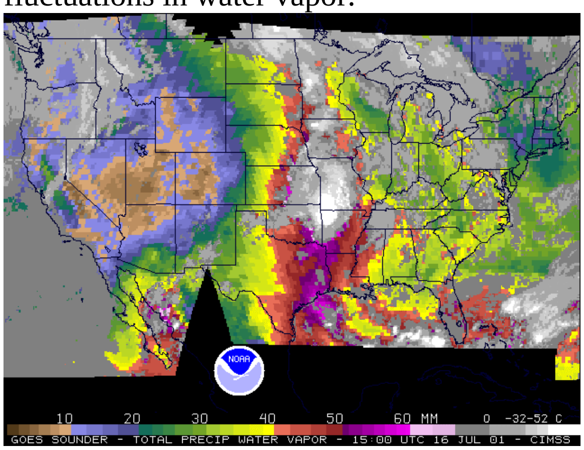


Figure 2. Real time data: precipitable water vapor. Taken from GOES on 7-16-2001.

With increasing technology, we will be able to increase the resolution, precision and frequency of water vapor measurements, thus improving our understanding of water vapor's role in climate changes. Future plans include a new satellite (called the Geosynchronous Imaging Fourier Transform Spectrometer - GIFTS) that will provide resolution much better than satellites in use now. In addition to this improved technology, schools participating in the GLOBE program will be able to help scientists by taking daily measurements of water vapor at their school sites.

Real time GOES satellite water vapor data
http://cimss.ssec.wisc.edu/goes/realtime/grtmain.html - snpw

What do we learn from data

Implications (?)
Current findings (?)

Satellite observations of liquid water path are growing in importance since many of the global climate models are now either incorporating or contain liquid water as an explicit variable.

"A new global water vapor data set"
http://www.cira.colostate.edu/climate/NVAP/bulletin.htm

How can we measure water vapor

Nearly all of the energy that the sun emits is in the form of electromagnetic waves, Though most of these electromagnetic waves are in the portion of the electromagnetic spectrum called ultraviolet, there is still energy in the visible and infrared regions. Much of this electromagnetic energy is absorbed, reflected or scattered by the molecules that make up our atmosphere, such as nitrogen, ozone or water vapor. Therefore, the energy that does reach the surface of the earth depends on the composition of the atmosphere.

Water vapor present in the atmosphere absorbs the sun's energy very strongly at particular energy levels in the infrared region while it absorbs little or no energy in others. This difference is what makes the detection of water vapor possible. First we can measure the amount of electromagnetic energy that reaches the earth's surface at energies where water vapor absorbs strongly. Then we can measure the amount of electromagnetic energy that reaches the earth's surface at energies where water vapor hardly absorbs at all. The ratio of these measurements is related to the amount of water vapor in the air.

In order to calculate a precise value for the amount of water vapor present in the atmosphere, however, we also need to know the "amount" of atmosphere between our instrument and the sun. If sunlight travels through more atmosphere, there would be more absorption even with the same concentration of water vapor. In order to accommodate the variable thickness of atmosphere between our instrument and the sun we must know our location and the time the measurement was taken. At solar noon, during the equinox, on the equator, is the sun directly overhead. This is when the sunlight passes through the least amount of atmosphere before reaching us. When the sun is rising or setting its light travels through more atmosphere. Also, during the summer months, the sun rises to a point further from the horizon that it does during the winter, creating a longer path for light to travel through. To correct for these differences, it is necessary to record the elevation of the sun when making water vapor measurements.

The GLOBE program has developed a device for making the particular measurements needed to calculate the total column water vapor. This device is called the sun photometer.

What is a sun photometer

The sun photometer is able to measure discrete energies using solid state electronic devices called light emitting diodes, or LEDs. These LEDs are used extensively in numerous electronic devices as tiny lights; when a current passes through them they emit light (one form of electromagnetic radiation) of a particular wavelength, depending on their particular composition. Conversely, when light of a particular wavelength strikes them, they will create a small current. This is what makes LEDs suitable for measuring discrete energies of electromagnetic radiation.

Common, commercially available LEDs can be used to measure the amount of energy in two particular regions, one where the absorption by water vapor is small, and another centered where the water vapor absorbs strongly. The sun photometer enables the current generated in those LEDs to be measured as voltage, which is known to be proportional to the incident energy. The ratio of these voltages is used to calculate the amount of water vapor in the atmosphere.

The measurement of the angle the sun above the horizon is accomplished by using a special device fixed to the top of the photometer. When tilted, a small indicator the device moves along a curved scale indicating the angle. This measurement is needed to correct for atmosphere thickness, called air mass.

What do schools contribute

Water vapor measurements are currently taken from satellites, balloons, aircraft, and many different ground-based stations. By participating in the GLOBE program, school communities can contribute significantly to the network that meteorologists rely upon for their data.

In addition to the global scientific community, schools can help their local communities by monitoring trends, minimums and maximums in water vapor data. Seasonal trends and daily fluctuations are expected, but abnormal or curious deviations can be spotted quickly.

Academically, the GLOBE program is closely aligned with the national science standards and many state essential learning requirements. At its most basic level, GLOBE is a great venue for K-12 educators and space scientists to discuss the core concepts that should be included in a strong science program. A table relating the GLOBE project to some of the national science standards and Washington state essential learning requirements is included on the following page.

2001 Washington state essential learning requirements for science
http://www.k12.wa.us/reform/EALR/standards/science.asp

1995 National Science Education Standards
http://www.nap.edu/readingroom/books/nses/html/

Examples of GLOBE: Atmosphere connections to national and Washington state learning standards for science

GLOBE aspect	National Science Content Standard	Washington State Essential Learning Requirement
Transfer of the sun's energy to the atmosphere by absorption of different wavelengths of electromagnetic radiation.	B: "Energy can be transferred by … light waves and other radiation, …"	1.1: "relating the ideas of frequency, wave length, and speed, and by relating energy to amplitude"
Understanding the greenhouse effect and its influence on weather.	F: "Some hazards, such as … severe weather, are rapid and spectacular. But there are slow and progressive changes that also result in problems for individuals and societies"	1.1: "correlate the chemical composition of … gases of the atmosphere with properties that determine their use to humans"
Movement of water vapor in the earth's atmosphere.	D: "Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing...."	1.2: "explain how patterns and arrangements of landforms, oceans, and atmosphere are determined by natural forces …"
Effects of changing water vapor and local temperatures	D: "Students use and extend their understanding of how the processes of radiation, convection, and conduction transfer energy through the earth system"	1.2: "analyze and explain the factors that affect physical and chemical changes, and how matter and energy are conserved in a closed system"
Relating solar energy to warmer atmospheric temperatures	D: "Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans."	1.3: "correlate global climate to energy transfer by the sun, cloud cover, the earth's rotation, and positions of mountain ranges and oceans"
Human contributions to the atmosphere/ greenhouse effect	F: "… many factors influence environmental quality"	1.3: "analyze the effects of natural events and human activities on the earth's capacity to sustain biological diversity"
Understanding basic weather models	A: "formulate and revise scientific explanations as models using logic and evidence"	2.1: "formulate and revise scientific explanations and models using logic and evidence; recognize and analyze alternative explanations and predictions"
Continued research on water vapor's role in weather systems	G: "In areas where data or understanding are incomplete, such as … questions surrounding global warming, new data may well lead to changes in current ideas or resolve current conflicts"	3.1: "know that science involves testing, revising, and occasionally discarding theories; understand that scientific inquiry and investigation lead to a better understanding of the natural world and not to absolute truth"
Contributing to the global data network	G: "Individuals and teams have contributed and will continue to contribute to the scientific enterprise" and E: "Many scientific investigations require the contributions of individuals from different disciplines…"	3.2: "analyze how scientific knowledge and technological advances discovered and developed by individuals and communities in all cultures of the world contribute to changes in societies"

Precipitable Water Vapor Protocol

Purpose
To measure the amount of precipitable water vapor in the column of atmosphere between the sun and the observer.

Student Outcomes
Students will learn that some of the sun's light is absorbed by water in the atmosphere.

Overview
Students point a GLOBE sun photometer at the sun and record the largest voltage readings they obtain on a digital voltmeter.

Time
About 10 minutes

Level
Middle and Secondary

Frequency
Every day, weather permitting
Mid-morning is preferred.

Key Concepts
Atmospheric composition
Variation in solar position
Optical thickness

Skills
Using a digital voltmeter
Recording data
Coordinating data from several sources

Materials and Tools
Digital voltmeter
Watch
Water Vapor data sheet
Pencil or pen
Calibrated GLOBE sun photometer
Tripod

Preparation
Practice switching the sun photometer
Practice using a digital voltmeter

Prerequisites
Aerosol Protocol
Barometric Pressure Protocol

Measure Precipitable Water Vapor
Taking measurements with the sun photometer requires about ten minutes from two people and a period of unobstructed sunlight during this time. Since most of the calibration of the photometer was performed during its construction, it is important to record the serial number before making measurements so proper processing of the data can be performed when reporting the data ***{to the website}.*** A step-by-step procedure follows.

1. Set up the tripod and screw the photometer to the top of the tripod using the screw hole on the bottom of the photometer (see below)

(*photometer on tripod*)

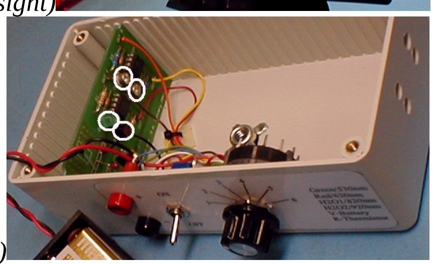
2. Connect your voltmeter to the photometer using the connecting wires.

The inexpensive voltmeter shown here (Kelvin 50LE) can be purchased from Kelvin Instruments if your school has no voltmeter (see below).

(*standard voltmeter*)

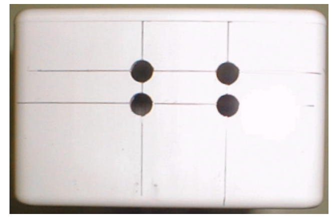
3. Turn the voltmeter on and test the photometer battery by turning the photometer dial to channel 5, labeled “V-Battery”. The battery voltage should be at least 7 volts. If it is lower, replace it as described in the aerosol protocol.
4. Record the date.
5. Switch the voltmeter to read volts.
6. Turn the photometer dial to channel 3 (labeled “H2O1/820nm”®) and prepare to read the voltage. This value is related to the energy from the sun that is *not* absorbed by water vapor.
7. Align the photometer so that the sun’s image in the sighting device illuminates the mark made during calibration (see below). This will assure that all the LEDs in the photometer will receive the direct sunlight needed for measurements.

(illuminated sight)



(LEDs inside)

8. Record the maximum voltage for channel 3 (labeled “H2O1/820nm”®).
9. Briefly cover the sunlight ports completely (see below) with your hand. Verify that the voltage drops to zero. If this does not happen, note it in the comments at the end.



(*sunlight ports*)

10. Record the precise local time. You should correct your digital watch with the time from http://www.time.gov/ before you make measurements.
11. Record the elevation angle of the sun using the instrument on the top of the photometer (see below).

(elevation angle device)

12. Turn the photometer dial to channel 4 (labeled “H2O2/920nm”®) and prepare to read the voltage. This value is related to the energy from the sun that *is* absorbed by water vapor. Make sure the photometer is aligned as it was in step 7 before proceeding.
13. Record the maximum voltage for channel 4 (labeled “H2O2/920nm”®)
14. Record the elevation angle of the sun using the instrument on the top of the photometer. This value should be close to the value obtained from step 11.
15. Turn the photometer dial to channel 6 to read the thermistor (labeled “R-Thermistor”).
16. Switch your voltmeter to read resistance instead of voltage.
17. Record the value of the resistance for the thermistor. This corresponds to the temperature inside the photometer.
18. Repeat steps 5 - 17 for at least two more sets of measurements.
19. Observe and record cloud type on the data sheet.

20. Observe and record cloud cover on the data sheet.
21. Observe and record anything else that might obscure the sky.
22. Observe and record the sky color.
23. Observe and record the sky condition.
24. Observe and record the local air temperature.
25. Observe and record the barometric station pressure reading as per the barometric pressure protocol.
26. Record any other information that you think may be important.
27. Once you've completed all these measurements you can add the universal time and amount of water vapor to the data sheet by submitting the data to the investigators:

http://tellus.ssec.wisc.edu/photometer/photo.html

Finding the correct time
http://www.time.gov/

Voltmeters from Kelvin Instruments
http://www.kelvin.com/

Data Submission

A simplified method for reporting the data to the Water Vapor Special Measurement Scientist Team via the web can be found at:

http://tellus.ssec.wisc.edu/photometer/photo.html

Your will need a Java enabled browser, and need to know the Instrument ID. If you do not have it, please contact Dr. Sanjay S. Limaye by e-mail: SanjayL@ssec.wisc.edu.

® *What do nm have to do with energy*

In the introduction, the photometer's function was explained in terms of the solar energy absorbed by water in the atmosphere. Why then, are the diodes labeled with "nm" instead of energy? The answer has to do with the relationship between wavelength and energy.

A nanometer, abbreviated nm, is a very short measure of length, a billionth of a meter. This unit is often used to measure the wavelength of a particular type of light. Since different types of light waves contain correspondingly different amounts of energy, they also have different wavelengths. So, in order to describe a particular energy of light, one could use a wavelength to describe the energy instead. Since the relationship between energy and wavelength is constant and predictable, a particular wavelength, expressed in nm, will always refer to the same energy.

On the photometer dial, 820 nm refers to the wavelength of light corresponding to the energy that is *not* absorbed by water vapor, while 920 nm refers to the wavelength of light corresponding to the energy that *is* absorbed.

Modeling water vapor effects

Purpose
To introduce students to the connections between water vapor and daily changes in local temperature.

Overview
Students will compare temperatures of two black plates, one covered with a pan of water and the other without.

Time
About 1 hour

Level
High school

Key Concepts
Absorption of heat
Transmission of energy

Skills
Recording and organizing data
Making predictions
Graphing

Materials and Tools
Two identical black metal plates
A heat lamp with a stand
Two thermometers
A stopwatch
A clear plastic tub filled with water
Four wooden blocks to support the tub

Background
It's no surprise that the temperature drops when the sun goes down. Is this drop in temperature predictable; what does it depend upon? In order answer these questions we need to determine what factors determine this temperature change. Specifically, our aim is to model the temperature change for two different situations: one where the amount of water vapor in the atmosphere is large and the other where the atmosphere is mostly dry.

Water vapor, although contributing less than 4% of the atmosphere's mass, does significantly change the heating and cooling rate of the earth below. This will influence the daily temperature changes during day and night. There are, of course, other factors that determine the magnitude of the temperature change, but water vapor contributes sufficiently to observe a relationship.

Preparation
Students should have sufficient practice making measurements with thermometers. Also, before actually taking data, students should be aware of which quantities they are recording. Creating a table for data beforehand is helpful in doing this. Sample tables are included as a guide.

What to do and how to do it
Set up the heat lamp (representing the sun) so that is shines down on the lab area from a height of about 1 meter. This can be best accomplished by placing the lamp near the edge of a table and shining it on the floor.

Next, place the two black pieces of metal on the floor about 30 cm apart such that both pieces receive the same heat from the lamp. Place thermometers near the center of the plates so that they can be read easily (see figure 1).

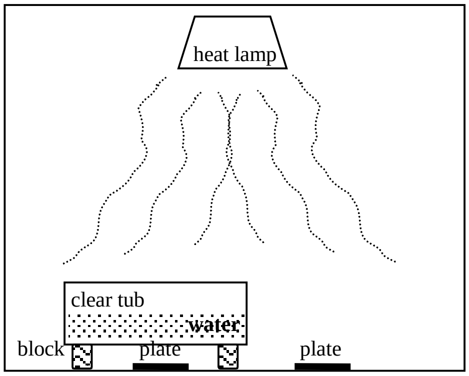


Figure 1. Experimental set-up.

Finally, place the wooden blocks around one of the metal pieces so that they can support the tub. Place the tub on the blocks so that is covers only one of the metal pieces then fill the tub with water. The bottom of the tub should be less than a few centimeters from the metal it covers

In this model, the lamp represents the sun, the metal pieces represent the earth, and the tub of water represents an atmosphere with much water vapor. By looking at the temperature change over time, we can see the difference between the parts of the earth where water vapor is abundant and where water vapor is scarce.

Turn on the lamp and start the stopwatch (simulating sunrise). Record each metal piece's temperature every 15 seconds. After 5 minutes, turn the lamp off (simulating sunset). Continue to record the temperatures every 15 seconds for another 5 minutes while the metal cools.

Time (s)	Covered plate temperature (°F)	Uncovered plate temperature (°F)
0	73	73
15	74	75
30	76	78
:	:	:

Figure 2. Sample values for temperature.

Once the data for temperature are gathered, plot the temperature of both plates for the entire 10 minutes. Several types of analysis can be performed at this point. It should be clear, for example, that the plate covered with water took longer to heat and longer to cool. How does this relate to water vapor in the earth's atmosphere? Since the sun's rays heat the earth below, the addition of something in the atmosphere between, such as water vapor, should change how the earth changes temperature.

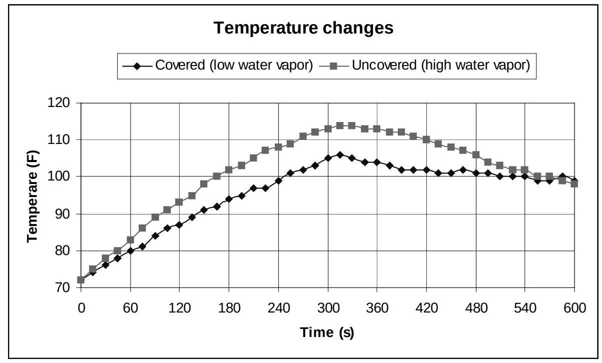


Figure 3. Sample graphs for heating and cooling of covered and uncovered plates.

Further questioning

Does additional water vapor in the atmosphere help the earth cool better, or does it help maintain its warmth?
Does water vapor have a greater effect during the warming of the earth during the day or the cooling of the earth at night?
How important is water vapor in forecasting the temperature?

Adaptations

It is possible to modify this experiment to replace the heat lamp with the real sun. Outdoor experiments are going to require longer heating and cooling times, however. Some common lab equipment, such as the Texas instruments calculators and the Venier Labpro with temperature probes, can be used to make periodic measurements from the heat of the day through sunset and into the cooler night. This would make for more realistic data.

Texas Instruments graphing calculators
http://education.ti.com/product/graph.html

Vernier Software and Labpro
http://www.vernier.com/

Modeling air mass

Purpose
To introduce students to the concept of total air mass and how the sun's angle changes the effective air mass.

Overview
Students will measure the amount of atmosphere the sun's rays must travel through before reaching an observer on the surface of the earth.

Time
About 30 - 45 minutes

Key Concept
Air mass

Skills
Measuring angles
Recording and organizing data
Graphing

Materials and Tools
Protractors or angle rulers
Rulers
Air mass worksheets
Graph paper

Level
Middle school

Background

Colorful skies often occur during sunsets and sunrises. This is mostly due to the increased thickness of atmosphere between the sun and us. When the sun's rays pass though the atmosphere, certain particular colors of light are absorbed, reflected or scattered by the molecules in the air. Blue light, for example, is scattered most easily by the atmosphere, coloring the sky its familiar blue hue. Since much of this blue light is scattered at right angles to the sun's rays, the radiation passing through is less blue. If sunlight passes through a great deal of atmosphere, like during sunset, less bluish light reaches an observer, leaving the brilliant reds and oranges.

The effects of relative atmospheric thickness are not limited to visible light, however. Infrared rays, the type used to detect water vapor for example, are also attenuated by an increasing atmosphere thickness. This is why determining the air mass between us and the sun is important for gathering data from the sun's rays. If the air mass were assumed to be constant, analyses of water vapor measurements would be skewed.

In this activity we will use a ruler, protractor and straight edge to simulate the path the sun's rays through the atmosphere for various positions of the sun.

What to do and how to do it

Handout the "Air Mass Worksheet" to all students. The procedure, diagrams and data tables are included on the worksheet (see appendix). Once the data is collected the data can be graphed on separate graph paper.

For sun angle and time confirmation, you can reference the following web sites http://susdesign.com/sunangle/ and http://www.time.gov/, respectively.

Further questioning: Of the recorded times, when is the air mass the least? Under which conditions would the air mass be the least during the entire year? Where on earth can the air mass be equal to 1?

Demonstrating air mass

Purpose
To demonstrate the concept of total air mass and how date and time change the effective air mass.

Overview
Students will observe the amount of atmosphere the sun's rays must travel through before reaching an observer on the surface of the earth.

Time
About 15 - 20 minutes

Key Concept
Air mass

Materials and Tools
A standard size globe
Masking tape
String

Level
High and middle school

Background

As the sun crosses the sky, its rays pass through different amounts of atmosphere, more during the sunrise and sunset, and less in the middle of the day. Since observing the sun's energy after it passes through the atmosphere is useful in determining such things as haze and water vapor content, it is important to know how much atmosphere separates the sun and the observer. By using a standard globe and a piece of string we can demonstrate how one particular ray reaches an observer.

What to do and how to do it

Tape a thin piece of string to your current location on the globe to represent a ray of light. Ask for a volunteer to pull the string taught by standing about 2 meters away. This student will represent the direction the sun's rays come from. Be sure to align the earth's axis correctly for the current time of year. Now rotate the globe to simulate a normal day from sunrise to sunset. The scaled thickness of the atmosphere on a standard globe is about 1 cm from the surface. Using a ruler, have a third person measure perpendicularly from the surface of the globe to the string about 1 cm from the surface. This represents the thickness of the atmosphere. You will notice that the length of string in this "atmosphere" increases as the sun's ray angle decreases. To make this more easily observed, one could exaggerate the atmosphere's thickness to 10 cm or so.

If you are unsure of the sun angle or time dependence, you can reference the following web sites http://susdesign.com/sunangle/ and http://www.time.gov/, respectively.

Further questioning: When is the air mass the least for your location on earth? Under which conditions would the air mass be the least during the entire year? Where on earth can the air mass be equal to 1? Is there a time and/or location when the air mass is *nearly* equal to 1?

Sanjay S. Limaye, GLOBE Water Vapor Special Measurement Protocol Scientist

Demonstrating infrared radiation

Purpose
To demonstrate to students to the concept of infrared radiation by visualizing the "invisible" light emitted from a TV remote.

Overview
Students will observe the normally invisible light emitted from a standard TV remote by using a night vision video camera.

Time
About 10 - 15 minutes

Key Concepts
Electromagnetic radiation
Infrared light

Materials and Tools
Video camera with night vision capability
TV or VCR remote control
TV monitor for the camera

Level
Middle and high school

Background

The sunlight that reaches the surface of the earth contains, of course, visible light. However, there is a great deal of energy delivered by the sun that isn't visible to our eyes. Infrared radiation is one such type energy. Infrared radiation is important because of its role in keeping the earth warm enough to sustain much of the life on earth (the greenhouse effect). Although we have observed the effect of infrared radiation before, as in heat lamps to keep french fries warm, actually seeing the light energy is impossible to do with our eyes. Now, with the help of a video camera we can "see" infrared radiation on a TV monitor.

Most new video cameras have a night vision mode which allows for low light recording. This feature actually converts infrared radiation into visible light, so when visible light levels are low, the camera converts the infrared radiation that people (and most objects) emit into visible light. To see this, we can use a standard remote control that uses infrared light to communicate with electronic devices.

What to do and how to do it

Connect the video camera to the monitor so the camera's view is seen on the TV. Show the students the front of a standard remote control (TV, VCR, CD player, *etc*.) while pressing a few buttons. The remote will produce a series of flashes that are invisible to our eyes. Now, looking at a monitor and pointing the remote at the video camera, the same remote can be seen to emit a series of white flashes (for those curious about the "language" that remote controls use to communicate, you can check out the site http://www.epanorama.net/irremote.html for more information).

Further questioning: What materials obscure the infrared light; are they the same materials that obscure visible light? Are there any materials that block visible light but allow infrared light through? How does this demonstration relate to solar heating?

Atmosphere Investigation

WATER VAPOR DATA SHEET

School name:_________________________ Sun photometer ID number:________________

Observer names: ____

Date when measurements were taken:_______________________________

Measurement	Local time (hh:mm:ss)	Universal time (hh:mm:ss)	Solar elevation angle (degrees)	Voltage	Water vapor (cm) (from GLOBE)
1* (820 nm)					
1* (920 nm)					
1* (Thermistor)			(resistance in kΩ)	kΩ	
2* (820 nm)					
2* (920 nm)					
2* (Thermistor)			(resistance in kΩ)	kΩ	
3* (820 nm)					
3* (920 nm)					
3* (Thermistor)			(resistance in kΩ)	kΩ	
4 (820 nm)					
4 (920 nm)					
4 (Thermistor)			(resistance in kΩ)	kΩ	
5 (820 nm)					
5 (920 nm)					
5 (Thermistor)			(resistance in kΩ)	kΩ	

* *Three sets of measurements of each channel are required. You may record additional measurements if you like.*

Cloud Type (*Check all types seen*)

Cloud type	
Cirrus	❒
Cirrostratus	❒
Cirrocumulus	❒
Altostratus	❒
Altocumulus	❒
Stratus	❒
Stratocumulus	❒
Cumulus	❒
Nimbostratus	❒
Cumulonimbus	❒

Cloud Cover (*Check one*)

Cloud cover	
No clouds (0%)	❒
Clear (0% - 10%)	❒
Isolated (10% - 25%)	❒
Scattered (25% - 50%)	❒
Broken (50% - 90%)	❒
Overcast (90% - 100%)	❒
Sky obscured	❒

Atmosphere Investigation-Water Vapor Data Sheet – Page 2

School name:_________________________Sun photometer ID number:_________________

Sky Obscured

Fog	❒
Smoke	❒
Haze	❒
Volcanic ash	❒
Dust	❒
Sand	❒
Spray	❒
Heavy rain	❒
Heavy snow	❒
Blowing snow	❒

Sky Color

Deep blue	❒
Blue	❒
Light blue	❒
Pale blue	❒
Milky	❒

Sky Condition

Unusually clear	❒
Clear	❒
Somewhat hazy	❒
Very hazy	❒
Extremely hazy	❒

Describe any conditions that might affect the sky clarity, such as urban smog, smoke from forest fire, or dust from agricultural activities:

____

____

____

____

Current air temperature:_____________°C   Barometric station pressure:__________mb

COMMENTS (METADATA): ____

____

____

____

____

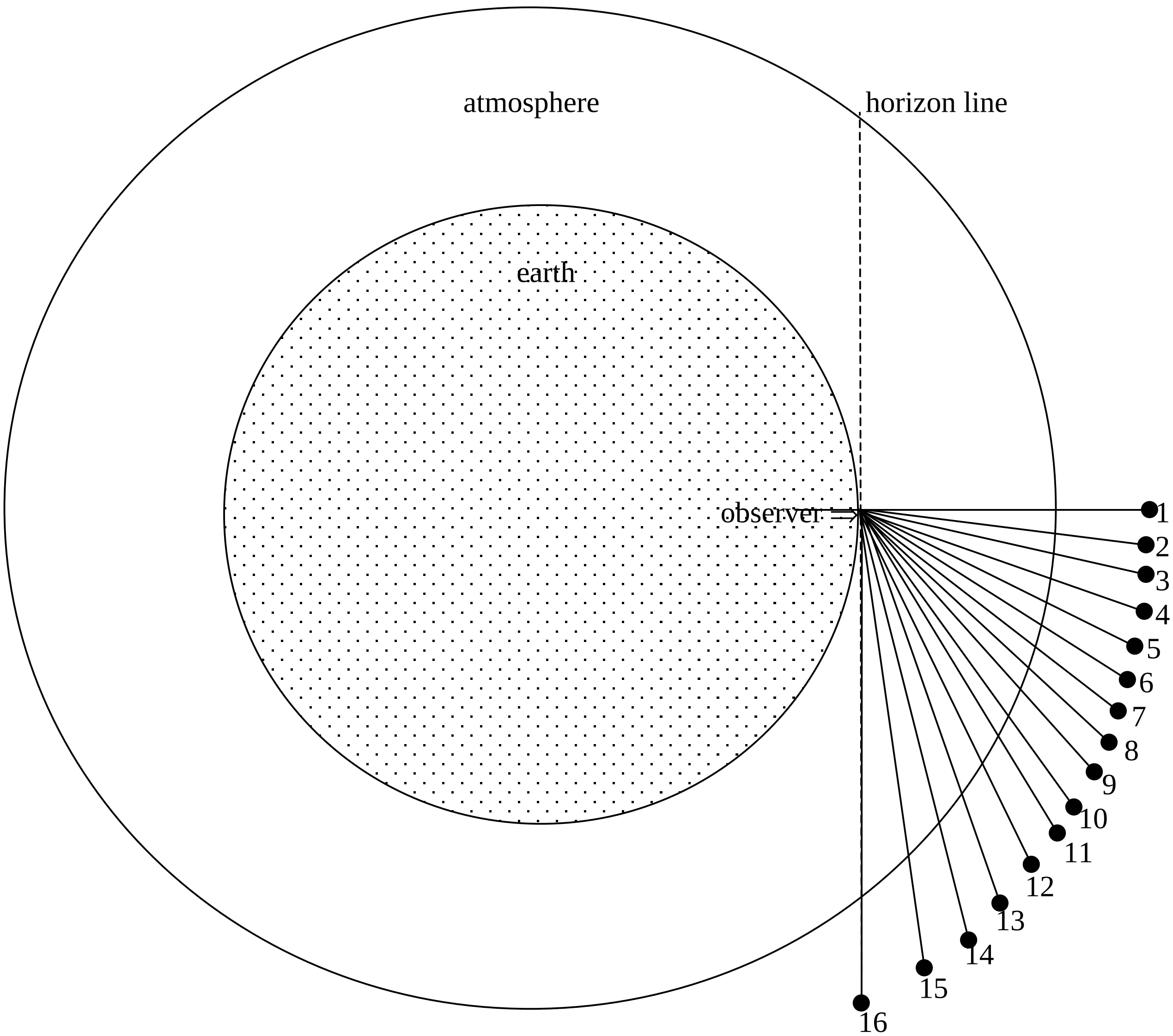
____

Date: Class: Name:

AIR MASS WORKSHEET

PROCEDURE

1. Measure the elevation angle for ray number one. This represents the path the sun's rays take during solar noon on the equinox at the equator. The angle should be 90°.
2. Measure and record the length of the atmosphere that ray number one passes through. Do this carefully since this will be the benchmark used to compare all other rays.



3. Measure and record the angle and length for the remaining 15 rays.
4. Calculate and record the number of ray one lengths that fit into each ray's length. This is the air mass. For example, if ray one travels through 25 mm of atmosphere and ray two travels through 27 mm, then the air mass for ray two is 27 mm/25mm = 1.04.
5. Graph the angle versus air mass.

Date: Class: Name:

AIR MASS WORKSHEET *(continued)*

DATA TABLE

Ray	Angle (°)	Length in atmosphere (mm)	Air mass
1	90		1.00
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			

QUESTIONS FOR EXTENDED THINKING:

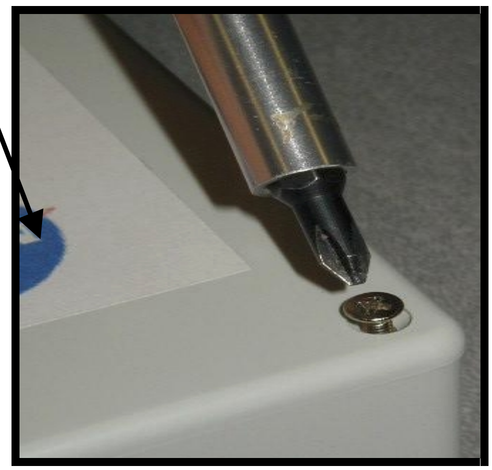
- Of the recorded times, when is the air mass the least?
- Under which conditions would the air mass be the least during the entire year?
- Where on earth can the air mass be equal to 1?

Replacing the Battery:

For best results, replace the 9-volt battery when the battery is drawn down to 7.5 – 8 volts. To replace the battery

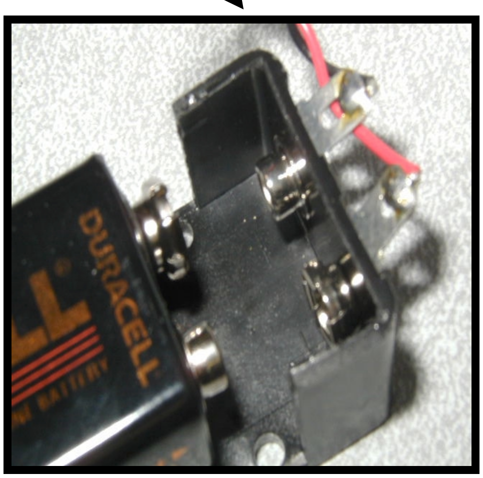
- Remove the top cover with a Phillips head screwdriver. (star-shaped)
- Carefully remove the battery holder from behind the circuit board. Replace battery.
- To ensure longest battery life, re-insert the battery holder with the plastic backing facing the circuit board.
  (Also to avoid any short-circuits that may arise from the direct contact of the battery with the circuit)
- Make sure the battery wires do not obstruct the view of the diodes. Replace the cover.

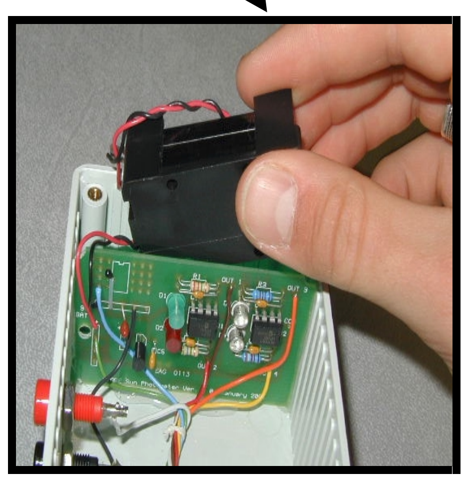
Unscrew the top



Replace the battery as shown

Take care while replacing the battery holder, ensure that the plastic backplate is in contact with the circuitry, and NOT the metallic cover of the battery! This will prevent damage to the circuit board and prevent battery from being shorted out.





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