Relative Humidity Protocol

Purpose

To measure relative humidity at an Atmosphere Study Site

Overview

Sling Psychrometer: Students check that the sling psychrometer has water in it to wet the bulb of one of the thermometers and read the temperature of the dry bulb thermometer. Then they sling the thermometers around for 3 minutes and read the wet bulb temperature. Relative humidity is determined from the wet and dry bulb temperature readings using a table or slide calculator.

Digital Hygrometer: Students place the digital hygrometer in the instrument shelter and return to read the value after at least 30 minutes.

Student Outcomes

Students learn to quantify humidity and that there is a limit to the amount of water vapor which the air can hold.

Students gain insight into why rain drops and snow flakes form and why there is precipitation.

Science Concepts

Earth and Space Science

- Weather can be described by quantitative measurements.
- Weather changes from day to day and over the seasons.
- Weather varies on local, regional, and global spatial scales.
- Water vapor content of the atmosphere is limited by temperature and pressure.
- Water vapor is added to the atmosphere by evaporation from Earth's surface and transpiration from plants.
- Precipitation forms by condensation of water vapor in the atmosphere.
- Condensation and evaporation affect the heat balance of the atmosphere.

Physical Science

- Materials exist in different states.

Geography

- Water vapor in the atmosphere affects the characteristics of the physical geographic system.

Scientific Inquiry Abilities

- Use a hygrometer or sling psychrometer to measure relative humidity.
- Use a thermometer to measure temperature.
- Identify answerable questions.
- Design and conduct scientific investigations.
- Use appropriate mathematics to analyze data.
- Develop descriptions and explanations using evidence.
- Recognize and analyze alternative explanations.
- Communicate procedures and explanations.

Time

5 minutes (digital hygrometer)
10 minutes (sling psychrometer)

Level

All

Frequency

Daily, preferably within one hour of local solar noon

Materials and Tools

If using a Digital Hygrometer:

- Instrument shelter
- Thermometer
- Watch
- *Atmosphere Investigation Data Sheet*

If using a Sling Psychrometer:

- Instrument shelter
- Calibration thermometer
- Psychrometric chart (optional)
- Watch or timer
- Bottle of distilled water
- *Atmosphere Investigation Data Sheet*

Prerequisites

None

Relative Humidity Protocol – Introduction

The atmosphere is made up a mixture of gases, one of which is water vapor. Water vapor is added to the atmosphere through evaporation and transpiration and removed when it condenses or freezes and precipitates. *Humidity* is the amount of water vapor present in the atmosphere. *Relative humidity (RH)* refers to this amount relative to the amount of water vapor in the atmosphere when the air is saturated.

The air is saturated when the liquid and gaseous forms of water are in balance at a given temperature. At saturation, relative humidity is 100%. When the relative humidity is over 100%, the air is *supersaturated* and the water vapor will condense or freeze to form new liquid water droplets or ice crystals.

$$RH = \frac{\text{amount of water vapor in the air}}{\text{amount of water vapor in the air at saturation}}$$

The amount of water vapor that may be present in the air at saturation depends upon the air temperature. The amount of water vapor that can exist in air at saturation increases as temperature increases. Table AT-RH-1 shows the relationship between temperature, saturation, and relative humidity. From this example you can see that if the temperature changes relative humidity can change even if the amount of water vapor in the air remains the same.

On a calm, clear day, air temperature tends to rise from sunrise until mid-afternoon and then fall until the following sunrise. If the amount of moisture in the air remains essentially the same during the course of the day, relative humidity will vary inversely with the temperature. That is, relative humidity will decrease from morning until mid-afternoon and rise again through the evening. See Figure AT-RH-1.

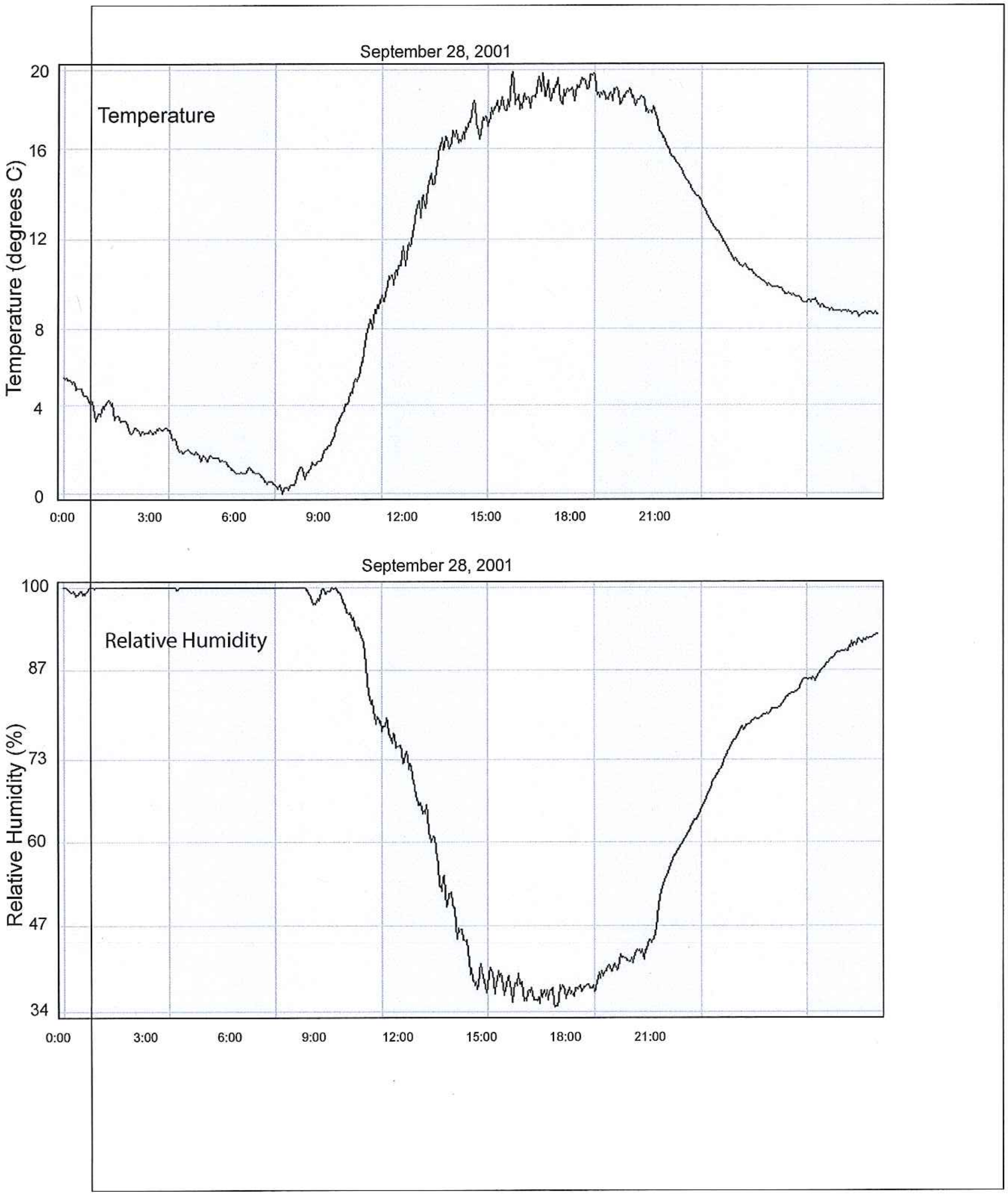
Water vapor in the atmosphere is an important part of the hydrologic cycle, and taking relative humidity measurements helps us to understand how rapidly water is moving from Earth's surface to the atmosphere and back again. By measuring water vapor in the atmosphere, the climate of a given location may be classified as arid (dry) or humid (moist). Relative humidity influences when clouds will form and precipitation will fall, therefore the amount of water in the atmosphere is important in determining the weather and climate of an area.

Relative humidity also affects the heating and cooling of the air. Since water has a significantly higher *heat capacity* than air, small amounts of water vapor can make considerable changes to the rate at which an air mass changes temperature. This accounts for the rapid cooling at night in the desert where the relative humidity is low, and the relatively slow nighttime cooling in more humid areas.

Table AT-RH-1

Air Temperature (°C)	**Water Vapor Present in air (g/m³)**	**Water Vapor Present at Saturation (g/m³)**	**Relative Humidity**
30	9	30	9 ÷30 * 100 = 30%
20	9	17	9 ÷ 17 * 100 = 53%
10	9	9	9 ÷ 9 * 100 = 100%

Figure AT-RH-1



Sling Psychrometer

The sling psychrometer is an instrument that consists of two thermometers attached to a sturdy housing, which can be whirled by hand. On one side, the "dry-bulb" thermometer measures the air temperature. On the other side, the "wet-bulb" thermometer (with a wick attached to the bottom of the thermometer) will be used to measure the temperature of air which is cooling by evaporation. Both thermometers show temperature decreasing as you go from bottom to top. The purpose of the measurement is find how much cooling by evaporation can take place at the time of the observation. The larger the difference between the dry-bulb temperature and wet-bulb temperature, the drier the air is. Using the air temperature and the wet-bulb temperature, the relative humidity can be determined easily. A scale for determining relative humidity is often found mounted to the instrument, or you may use an external psychrometric chart, which will come with the sling psychrometer. The standard sling psychrometer is shown in Figure AT-RH-3.

Before using your sling psychrometer, make sure that the columns of colored fluid are continuous because the columns may sometimes separate into segments during shipping. If there are gaps in the liquid column, grasp the thermometer by the case, making sure the thermometer is in an upright position, and shake the case until the liquid forms a continuous column. Do not press against the stem of the thermometer as this could cause breakage. You may need to tap the bottom of the thermometer against the palm of your hand as well. Each thermometer should also be calibrated against the calibration thermometer before use, and once every three months.

Questions for Further Investigation

How are *your* relative humidity observations related to air temperature?

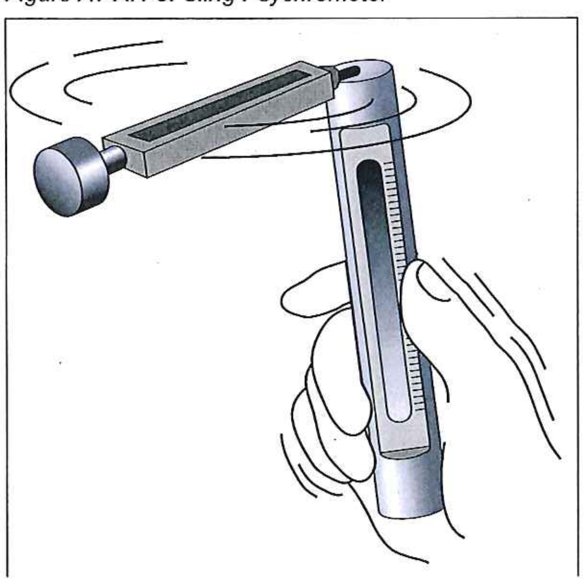
Can you find other GLOBE sites at your latitude which are closer to or further from large bodies of water? Do you see any systematic differences in relative humidity between your location and the others?

Does relative humidity affect any non-atmosphere parts of your local environment? How?

At what time of day will relative humidity normally be at a maximum? At a minimum?

Are your relative humidity and phrenology measurements related?

Figure AT-RH-3: Sling Psychrometer



Sling Psychrometer
Field Guide

Task

Find the relative humidity by measuring the temperatures of wet bulb and dry bulb thermometers.

What You Need

- ❑ Sling psychrometer
- ❑ A psychrometric chart or scale
- ❑ Watch or timer
- ❑ *Integrated 1-Day Data Sheet* OR *Ozone Data Sheet*

In the Field

1. Stand far enough away from other people and the instrument shelter so you will not hit them with the psychrometer. Stand in the shade if possible with your back to the sun. If there is no shade near the shelter, move to a shady spot nearby, but not too close to trees or buildings.
2. Keep the sling psychrometer as far away as possible from your body to prevent body heat from changing the temperature readings. This is very important in cold weather. Do not touch or breathe on the temperature-sensing parts of the thermometer as this, too, may affect the reading.
3. Open the sling psychrometer case by pulling out the slider, which contains the two thermometers.
4. Wait three minutes to allow the thermometer to read the current air temperature and then read the current dry bulb temperature to 0.5˚ C using the thermometer with no wick attached. Make sure your eyes are level with the instrument.
5. Record the dry bulb temperature.
6. Check to be sure that there is still distilled water in the reservoir, and that the wick is wet. If it is dry, add distilled water to the reservoir.
7. Sling the psychrometer for 3 minutes
8. Let the psychrometer stop whirling on its own! Do not stop it with your hand or other object.
9. Read the wet bulb temperature to 0.5˚ C (from the thermometer with the wick attached).
10. Record the wet bulb temperature.
11. Determine the relative humidity using a psychrometric chart or the sliding scale found on the cases of some psychrometers. You may also leave this blank as GLOBE can calculate relative humidity from your wet and dry bulb temperatures.
12. When you are done with the instrument, close it up and return it to the shelter properly.

Frequently Asked Questions

1. Why do you have two different methods of measuring relative humidity?

Two methods are used to try to provide an incentive for the teacher and student to make a determination about how much time is desired taking the observations. One is more complex (and fun) than the other. Observations from either method are equally valuable to the GLOBE program and scientists, in general.

2. Why do we need to take the hygrometer inside each day, and bring it out to the weather shelter 30 minutes before we make our local solar noon observations?

The sensitive electronics inside the hygrometer cannot be exposed to condensation for long periods of time, so it is best to avoid all situations when condensation may be expected. If fog or persistent rainfall is occurring at the time of observation, it is best not to take the hygrometer outside; rather, the observer should report a relative humidity of 100%, but also should make a comment in the metadata that the observation was inferred based on visible condensation in the air (rain or fog).

3. I see the definitions for wet-bulb and dry-bulb temperature; what is the dew point temperature?

The dew point temperature is the temperature to which air must be cooled to achieve saturation (relative humidity = 100%) given its current water content. Dew point is a measure of the actual water vapor content. On calm clear days followed by calm clear nights, the temperature will fall rapidly towards the dew point. Unless dew forms, if the air temperature reaches the dew point temperature, fog may form. Once dew or fog forms, the dew point temperature will fall, because there is less water vapor in the air.

4. Why can't we use the sling psychrometer below freezing?

The relationship between evaporation rate and temperature is more complicated below freezing than above freezing, so the sling psychrometer will not be as practical. More expensive models that have greater ranges are available, but are beyond the reach of the expected school budgets for instruments. We recommend the use of a hygrometer for locations that have frequent temperatures below freezing.

5. How accurate are these relative humidity readings, compared to those that might be taken with more expensive instruments?

The hygrometer will report relative humidity with an accuracy range of 2-4%, within the desired 5% figure. The sling psychrometer reports temperature to within an accuracy of approximately 0.5° C; provided the calibration on the thermometers is maintained, this also ensures accuracy better than 5% over the most common range of values of relative humidity, between 20-95%.

6. The reservoir on the left side of the instrument (holding the wick) is either broken or cracked (nearly broken); is there a way to still use it?

Yes. The plastic reservoir endcap that holds the wick inside can become weak. The instrument is still useable; however some simple repairs or precautionary effort must be done. Taping a piece of cardboard on the end will usually hold the wick inside and not affect the readings.

7. Is there a special way that we should store our sling psychrometer?

In order to prevent the liquid separating in the thermometers, it is suggesated that you store the sling psychrometer in a jar or other recepticle so that the thermometers are resting with the lower temperatures at the bottom.