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

Digital Hygrometer

Instrument shelter
Thermometer
Watch
Atmosphere Investigation Data Sheet

Sling Psychrometer

Instrument shelter
Calibration thermometer
Psychrometric chart
Watch or timer
Bottle of distilled water
Atmosphere Investigation Data Sheet

Prerequisites

None

Relative Humidity 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.

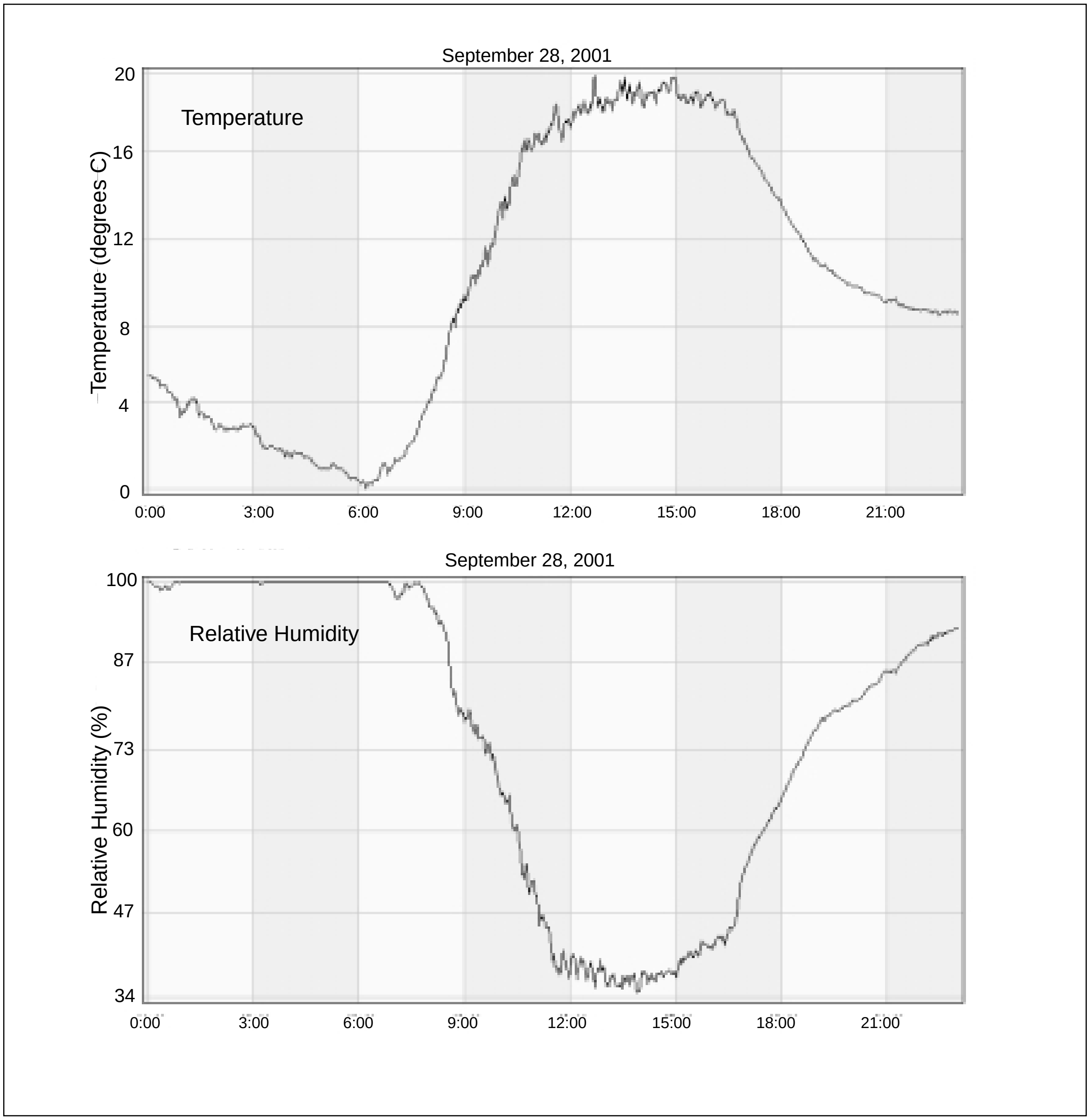
Water vapor in the atmosphere is an important part of the hydrologic cycle, and taking relative humidity measurements helps us to understand how rapidly water is moving from Earth's surface to the atmosphere and back again. By measuring water vapor in the atmosphere, the climate of a given location may 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/m^3)	Water Vapor Present at Saturation (g/m^3)	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



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Teacher Support

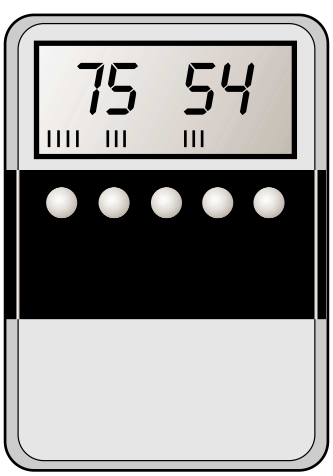
Digital Hygrometer

The hygrometer is a meteorological instrument with a long history. Initial hygrometers used human or other strands of hair, which when bundled, respond sensitively to moisture in the atmosphere (Perhaps some of you have experienced this yourself!) Using ceramic and metallic compounds, digital hygrometers which measure electrical resistance can also measure humidity over a wide range, thus making them ideal instruments for schools that cannot easily accommodate the difficulties of using the sling psychrometer for the humidity observations. No matter which instrument is used, the relative humidity observations will be useful to scientists.

Care must be taken to avoid exposure to condensation. If condensation occurs or is expected to occur during the time that the instrument will be exposed to the air in the instrument shelter, please do not place it outside. Rather, report a reading of 100% and enter comments "condensation occurring" in the metadata , which will indicate an inference, rather than a measurement, of relative humidity. An example of a digital hygrometer is shown in Figure AT-RH-2.

Most digital hygrometers may not be left in the instrument shelter during periods of condensation (precipitation or fog). Therefore, the instrument will have to be set out in the shelter at least 30 minutes before the local solar noon observations are begun. If you are also doing the ozone protocol, a convenient time to place the hygrometer in the shelter may be at the time you expose the ozone strip outside (which is one hour before your ozone observation is made).

Figure AT-RH-2: Digital Hygrometer



The hygrometer has a stand that can be used to place the instrument on the floor of the shelter. After the hygrometer has been in the shelter at least 30 minutes, read the value of relative humidity to the nearest 1% on the digital display. Be sure that the "max" or "min" indicators are not lit, as this will indicate that the instrument is set to show the maximum or minimum value, not the actual value. Enter the reading on the Data Entry Sheet while you also enter your cloud, temperature and precipitation observations, and report the data to GLOBE.

No calibration is necessary for the instrument, until the calibration certificate that comes with it expires. Please send the instrument back to the factory for recalibration at the interval that the manufacturer recommends (usually two years).

Measurement Logistics

The digital hygrometer can be ruined by condensation within the instrument. For this reason, it should not be left out in the instrument shelter except in extremely dry locations and seasons. It must be kept inside in dry conditions and left outside only long enough to obtain a good measurement. If your building is not climate controlled, store the instrument in an air tight container with rice, wheat berries, or some other item which readily absorbs water from the air and keeps the air in the container dry. Don't forget to change the absorbing substance periodically

The instrument takes some time (roughly 30 minutes) to adjust to outside conditions. This presents a logistics challenge. Generally, the daily measurements of temperature, precipitation, and clouds can all be accomplished within 15 minutes, so the hygrometer will need to be placed outside during one visit to the Atmosphere Study Site and read during a later visit.

If you are taking ozone measurements, you will have a similar situation in that students come to the Atmosphere Study Site and expose an ozone strip and then come to the site one hour later to read the strip. One approach is to put the hygrometer in the instrument shelter when the ozone strip is exposed and to read it when the ozone strip is read. A reading of current temperature must be taken when the digital hygrometer is read and is also required when the ozone strip is read, so with this approach one current temperature reading will serve to support the interpretation of both the ozone and relative humidity measurements.

If precipitation or fog is occurring or imminent, do not take the hygrometer outside. Instead, report a reading of 100% on your Data Entry Sheet, and enter comments stating that the air is saturated, so the relative humidity is approximated.

Storing the Hygrometer

The hygrometer observation can be taken every day, but if the instrument will not be used for an extended time (i.e., one week or more), it may be desirable to remove the batteries. Always be sure that the instrument does not remain in the instrument shelter or anyplace else where it will be exposed to condensation, or will get wet.

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?

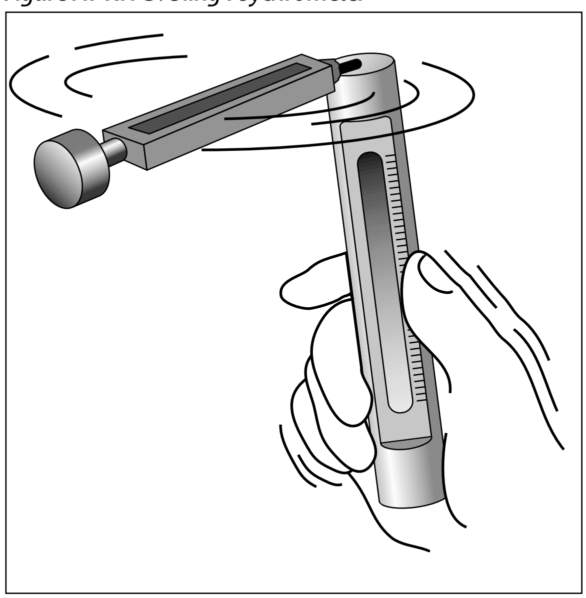
Can you find other GLOBE sites at your latitude which are closer to or further from large bodies of water? Do you see any systematic differences in relative humidity between your location and the others?

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



Digital Hygrometer
Field Guide

Task
Find the relative humidity using a digital hygrometer.

What You Need
- ❑ Digital hygrometer
- ❑ *Atmosphere Investigation Data Sheet* OR *Ozone Data Sheet*
- ❑ Watch or timer
- ❑ A thermometer properly installed in an Instrument Shelter

In the Field
1. Place the hygrometer in the instrument shelter. (Unless it is very dry, do not leave the hygrometer in the shelter overnight!)
2. After at least 30 minutes, read the relative humidity, and note the instrument used.
3. Read the current temperature (if your reading is not being taken at the same time as the daily reading of maximum, minimum, and current temperature).
4. Return the hygrometer to the classroom, and store it in a dry place.

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
- ❑ *Atmosphere Investigation 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. How come we have 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%.

Relative Humidity – Looking At Your Data

Are the data reasonable?

To determine if the relative humidity data you collect are reasonable, it is important that you know what to expect the values for relative humidity to be.

Relative humidity is inversely dependent on temperature. This means that for a given air mass, as temperature rises, relative humidity falls, as long as the amount of water vapor contained in the air remains the same. If your relative humidity observations are taken at local solar noon, near the warmest part of the day, you will be measuring relative humidity when it is likely to be near its minimum value for the day.

When relative humidity reaches 100%, the air is said to be *saturated*. For air at a given temperature and pressure, any additional water vapor added to the air will condense as rain drops (or freeze as ice particles if the air is cold enough). For clouds to form, the air must be saturated.

Dew point temperature is another measure of humidity. The dew point is the temperature at which condensation begins to occur for air with a given water vapor content at a given pressure. While the relative humidity changes with temperature, the dew point remains constant because the water vapor content is not changing. When you look at the dew point temperature, remember that it will always be less than the air temperature, unless the air is saturated, in which case they are equal. If you measure relative humidity several times during the same day, the dew point temperature should remain the same unless a weather front has moved through the area.

Determination of the dew point temperature from the air temperature and relative humidity is a complicated calculation that the GLOBE server will do automatically for you so that visualizations and tables of dew point temperatures may be examined.

These points are illustrated in figure AT-RH-4, which shows hourly values of air temperature, dew point temperature, and relative humidity for a three-day period at Tallahassee Florida, USA. The temperature scale is shown on the left hand axis.

These data were collected using a data logger and an automated weather station at Florida State University, a GLOBE school. Local solar noon at Tallahassee is very near 1800 UTC each day (near the time of maximum temperature). Note that the temperature (shown in red) has a maximum value slightly higher than the previous day, and that in each case, it corresponds to the same time that the relative humidity (shown in green) is at its minimum. The relative humidity is at its maximum in the early morning (near 1200 UTC), when the temperature is at its lowest. Note how the dew point temperature (shown in blue) and air temperature are very close to each other at this time. These observations all indicate that the data appear to be reasonable.

Your relative humidity data should always be provided as a percentage between 0 and 100%. Your dew point temperature should always be less than or equal to your current temperature observations. Most importantly, unless your observations are taken during fog or precipitation events, your relative humidity should be less than 100%.

What do scientists look for in these data?

Scientists look at trends in relative humidity over different time periods. For instance, changes during a day may be related to sea breezes in coastal areas. In GLOBE, relative humidity usually is taken only once per day, near local solar noon. So with GLOBE data scientists examine trends in relative humidity over periods of days.

Scientists use relative humidity changes to forecast the weather. For example, they might look at temperature, relative humidity, and dew point to predict the likelihood of showers on a given day. In Figure AT-RH-4, note that the local solar noon relative humidity value increased by a small amount each day. This indicates a gradually moistening environment. That observation is more clearly shown by the dew point temperature values that have an upward trend throughout the period. Note that unlike temperature and relative humidity, the dew point temperature does not exhibit a strong diurnal cycle.

Figure AT-RH-5 shows a graph of temperature and relative humidity data for Norfork Elementary School in Arkansas, USA. These data vary considerably from day to day. Let's try to understand the data better by first focusing on the axes. On the abscissa, or x-axis, time begins on 1 October 2000 and ends in September 2001, so nearly one year of data are plotted. Data are available for each day with few missing observations; even weekends are included! Now examine the ordinates, or y-axes (there are two of them). On the left, we find the scale for temperature, and on the right, we find the scale for relative humidity.

It is difficult to see that the temperature versus relative humidity relationship we described earlier exists here, but we can smooth such data to illustrate the relationship. The next figure (AT-RH-6) shows a smoothed graph using 5-day running averages of the data. To calculate a 5-day running average, you average the values for today, the two previous days, and the two following days.

Now the relationship can be seen more clearly. In the winter with cold mid-day temperatures, the relative humidity is often above 60%, but in summer the relative humidity is only rarely above 60%. This can also be used as a consistency check, to help to ensure your data are reasonable. These observations may also be used to examine the influence of temperature on relative humidity, when actual water vapor content does not change very much.

We can of course observe the progression of temperature throughout the year, with the coldest temperatures in December and January. Note how the relative humidity is a near maximum for many of these winter days! There can of course be dry days during winter months as well, and scientists use relative humidity monitoring to classify air masses. These air mass identifications help meteorologists identify and monitor frontal systems and provide useful weather forecasts. Climatologists also use relative humidity to classify climates for various locations.

One of the main climatic controls that scientists recognize is how close a location is to a large body of water, such as a sea or ocean. Let's look at two GLOBE schools' humidity data to see if we recognize such a relationship. We will use the dew point temperature rather than the relative humidity here, to examine only the affect of water vapor content. Relative humidity, remember, includes both water vapor effects, and temperature effects.

Figure AT-RH-7 illustrates observations from two schools in Europe, the Istituto Tecnico Industriale Fermi, in Naples, Italy, and the Hermann Lietz-Schule Haubinda in Germany. Remember that the dew point temperature will illustrate only how the water vapor content of the air at a weather station changes over time. The graph illustrates a plot of three months of observations from winter 2001 (January through March), and on every day for which observations were taken from these two schools, you can see how the dew point temperature at Naples, located on the Mediterranean Sea, was much higher than the dew point at Haubinda, located far inland.

Although elevation, latitude, and air motion (the other major climatic controls) may help to explain some of these differences, how close a station is to large bodies of water will play a large role, in general, due to the large amount of evaporation that takes place in coastal regions. A useful project for GLOBE coastal schools is to compare the dew point values calculated from their data with those from a school at roughly the same latitude and elevation that is well inland from the same body of water. Is the relationship similar?

It is interesting to see how relative humidity is related to other meteorological variables. Naturally, as evaporation increases, relative humidity increases. So, we would expect to find a relationship with cloud cover, since clouds require a relative humidity at their altitudes of 100%. We measure relative humidity near the ground, not at the cloud base, but in general, relative humidity increases with altitude up to 100% at the base of the clouds. This is true for low clouds, in particular. Figure AT-RH-8 shows a plot of relative humidity and cloud cover from Gladstone High School in South Australia for July and August of

Figure AT-RH-4

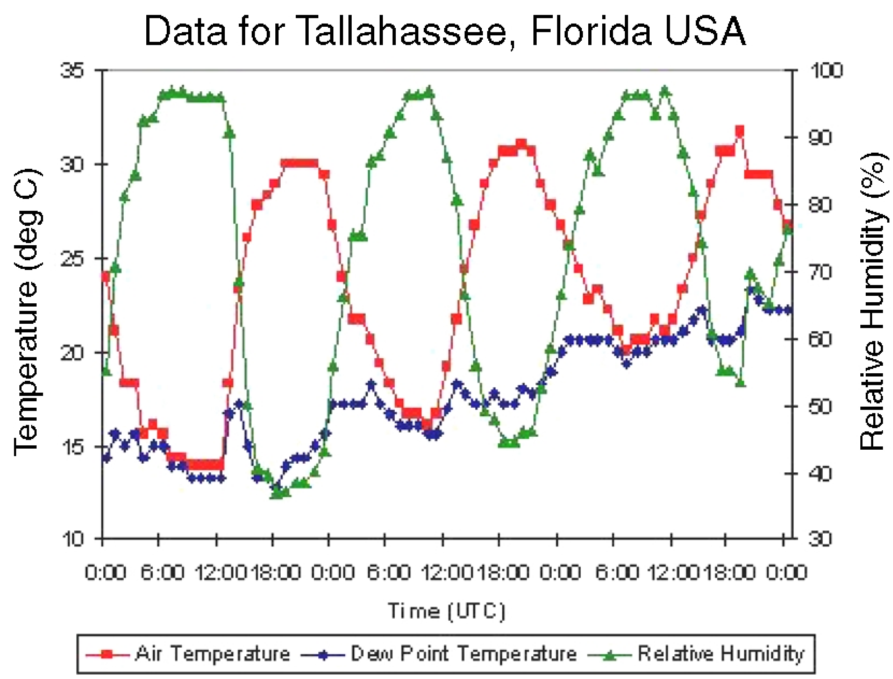


Figure AT-RH-5

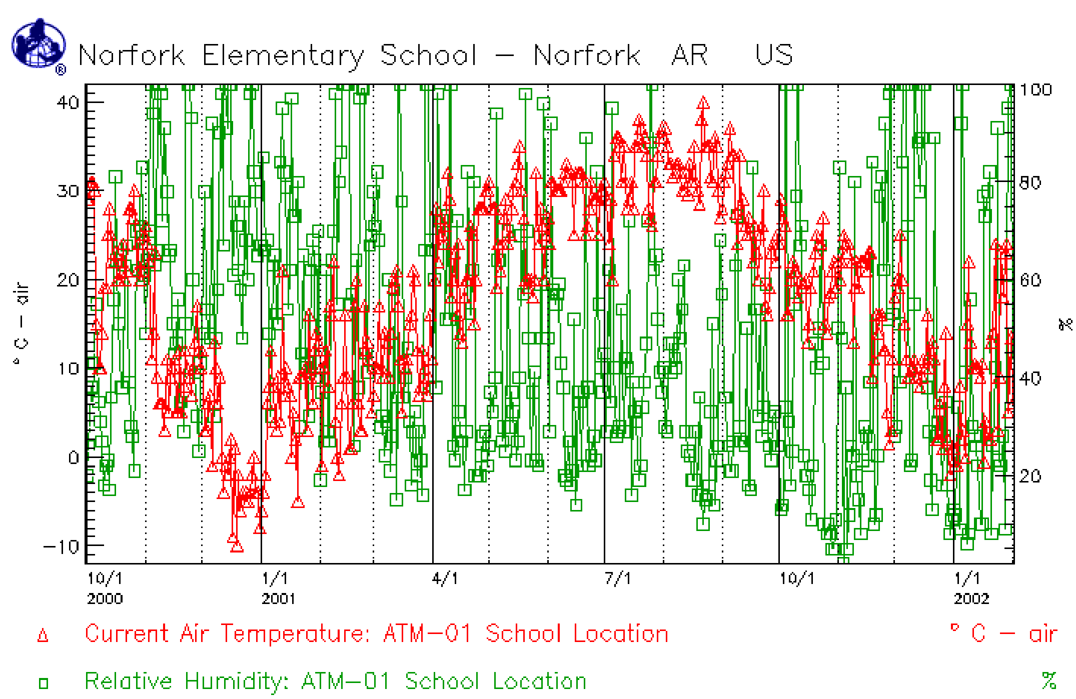


Figure AT-RH-6

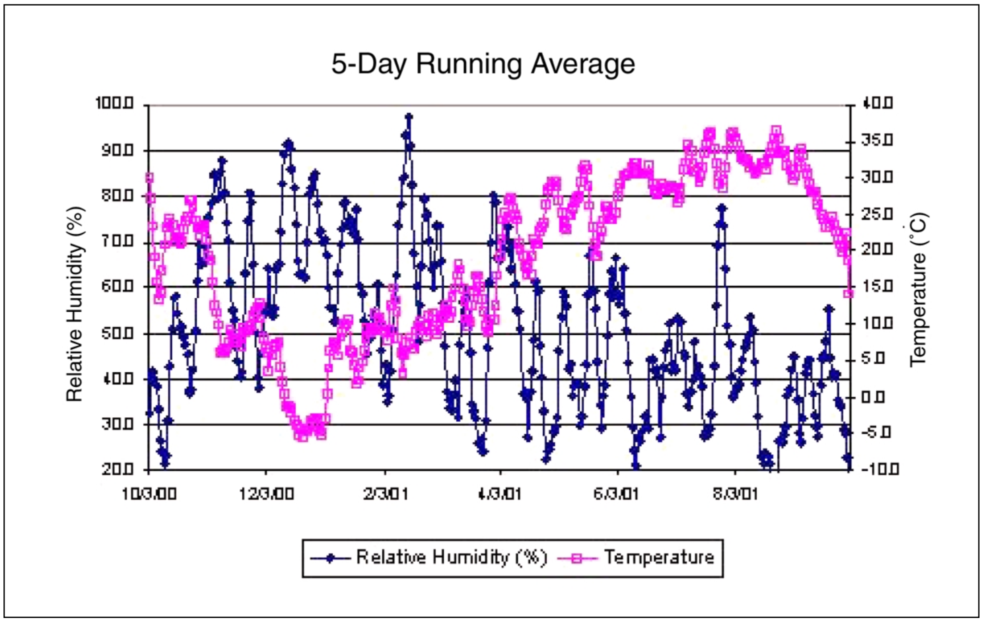


Figure AT-RH-7

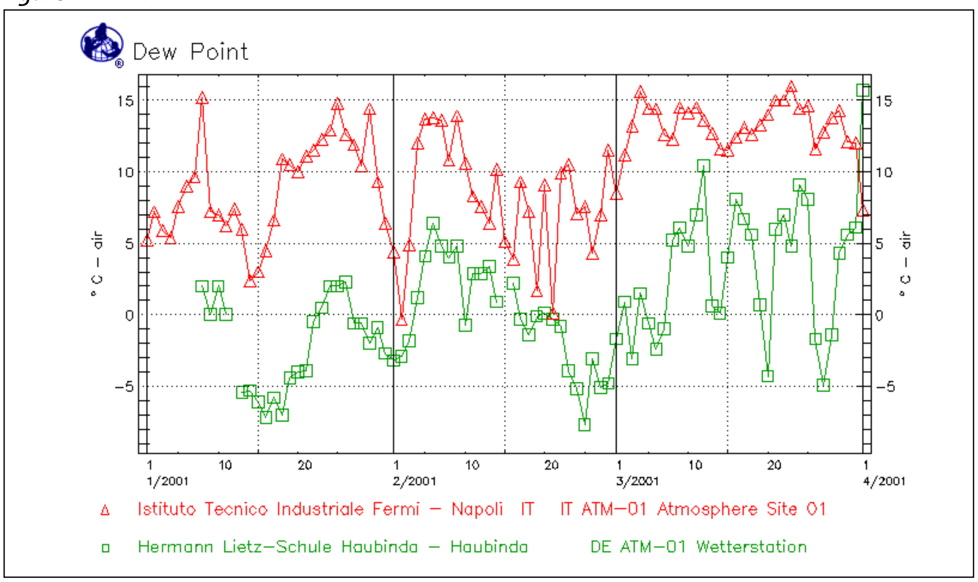
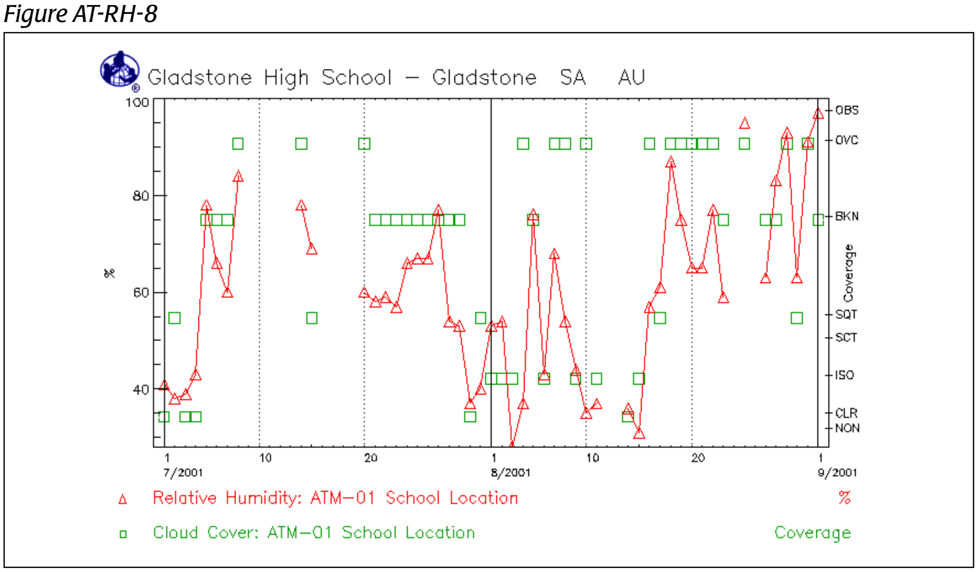


Figure AT-RH-8



2001 (during winter). Note that on this graph relative humidity is shown as a red graph with connected lines, and the cloud cover is indicated as a single square for each day's cloud cover observation. There are several days when the relative humidity is at or below 50%, and on each of these days, the cloud cover was clear or isolated. Only when the relative humidity approaches 60% was scattered cloud cover observed in these two months. Broken and overcast skies occurred only when the relative humidity was greater than 50%. The relationship is not perfect, but for most days it is clear that when relative humidity is high, cloud cover is more likely to be high than not.

You can test the hypothesis that there is a relationship between cloud cover and relative humidity for a school like Gladstone by averaging the relative humidity for all days for various cloud covers. Let's test the hypothesis that on average as relative humidity increases, cloud cover also increases. Using data from Gladstone as an example, let's compute the average relative humidity for the scattered cloud cover days and the isolated cloud cover days. These calculations are shown in the box below.

Based on these limited observations, our hypothesis has been supported. In general scientists would want to use equal numbers of days for such tests and comparisons, and also would want to use at least 30 observations for each. You could do this for all your cloud cover and relative humidity observations to see how well this relationship holds for your location.

An Example of a Student Research Investigation

Designing an Investigation

Heikki, a student at Juuan Lukio/Poikolan Koulu in Juuka, Finland has been taking relative humidity measurements along with other students at his school. In studying climate, his teacher mentioned the moderating effect on air temperature of nearby large water bodies. When he asks questions about how this works, his teacher mentions that evaporation from the water causes higher levels of relative humidity and that it takes more energy to heat or cool moist air than dry air.

Heikki decides that this would make a good investigation. He wonders if relative humidity values from inland schools will be lower on average than the values from a coastal school. After looking at the GLOBE archive he selects three inland schools and one coastal school. He also decides to only look at data from late spring and early summer when ice will not be covering the water body. Table AT-RH-2 shows the data he found for these four schools.

Scattered Cloud Cover

$$\frac{38 + 68 + 41 + 62 + 64}{5} = 54.6\%$$ average relative humidity for scattered cloud cover days

Isolated Cloud Cover

$$\frac{54 + 55 + 27 + 42 + 43 + 36 + 31}{7} = 41.1\%$$ average relative humidity for isolated cloud cover days

Table AT-RH-2. Relative Humidity at GLOBE Schools from Heikki's Sample

Date	Juuka Inland	Ammansaari Inland	Utajarvi Inland	02600 Espoo Coastal
5/10/01	32	77	49	39
5/11/01	39	57	39	32
5/12/01	46	57	50	32
5/13/01	68	94	65	48
5/14/01	77	80	42	35
5/15/01	33	78	61	49
5/16/01	30	53	33	33
5/17/01	30	45	38	97
5/18/01	46	98	83	96
5/19/01	56	97	87	83
5/20/01	56	98	89	71
5/21/01	54	85	81	81
5/22/01	41	70	54	39
5/23/01	95	100	74	78
5/24/01	39	65	58	41
5/25/01	39	80	50	46
5/26/01	41	66	49	37
5/27/01	43	74	50	52
5/28/01	51	88	74	38
5/29/01	50	73	63	50
5/30/01	53	52	40	45
5/31/01	32	45	33	38
6/1/01	23	35	29	42
6/2/01	28	33	32	52
6/3/01	—	38	31	58
6/4/01	33	46	70	36
6/5/01	51	88	85	53
6/6/01	25	48	49	38
6/7/01	30	51	44	38
6/8/01	46	60	71	73
6/9/01	57	97	63	97
6/10/01	90	92	84	70
6/11/01	41	62	67	65
6/12/01	72	63	77	96
6/13/01	84	87	89	97
6/14/01	48	92	67	90
6/15/01	32	74	47	56
6/16/01	43	77	63	52
6/17/01	39	67	42	97
6/18/01	49	74	50	63
6/19/01	47	57	41	97
6/20/01	39	44	29	97
6/21/01	85	61	52	97
6/22/01	78	59	64	90
6/23/01	41	35	39	58
6/24/01	29	39	33	46
6/25/01	34	55	34	—
6/26/01	46	57	46	48
6/27/01	39	55	38	66
6/28/01	33	60	37	56
6/29/01	39	53	36	63
6/30/01	37	76	66	65
7/1/01	33	51	58	76
7/2/01	65	85	65	61
7/3/01	41	60	65	47
7/4/01	38	53	49	44
7/5/01	39	99	89	41
7/6/01	35	62	47	58
7/7/01	46	—	56	47
7/8/01	51	70	52	60
7/9/01	41	59	59	48
7/10/01	51	92	63	58
7/11/01	62	89	75	69
7/12/01	54	70	62	60
7/13/01	82	68	65	53
Avg. RH	47.3	67.6	56.0	60.0
Days highest	2	35	5	21

Collecting and Analyzing Data

Heikki calculates the average relative humidity for each of these schools by adding up all values reported for this time period from each school and dividing the sum by the number of days for which data were reported. His results are given on the next-to-last line of Table AT-RH-2.

Heikki asks a younger student if she would figure out whether the coastal school has higher relative humidity than the inland schools. She decides to look at which school reported the largest value for relative humidity each day and to count how many days each school's value was highest. She noticed that some days, only three schools reported data, so she skipped those days. Her results are given on the last line of Table 1.

Heikki is quite surprised to find that both the younger student's approach and his found that one of the inland schools had the *highest* relative humidity overall for this time period. The coastal school was only second highest.

Heikki concludes that there are clearly exceptions to the general rule about how relative humidity varies between coastal and inland schools. His teacher asks what more he could do to investigate the. The teacher tells Heikki that he could look for more schools in Finland with the relevant data, look for sets of inland and coastal schools from another country, or try to learn more about the geography of the school which had higher relative humidity than the coastal school in his study.

The teacher points out that Heikki's investigation did not examine the moderating effect of relative humidity on air temperature, nor did his investigation include the effects of altitude. They agree that Heikki will do a study of this as part of a group investigation with several of his classmates. The group discusses the concept they are going to study and decides that they will compare the difference between maximum and minimum air temperature for each day with the relative humidity data. Since the maximum and minimum air temperatures cover a 24-hour period that begins one day and ends the next, the group concludes that they will compare with the average relative humidity for each two-day pair. These data comparisons are shown in Table AT-RH-3.

Table AT-RH-3

Date (2001)	Juuka		Ammansaari		Utajarvi		02600 Espoo	
	Average 2-day RH (%)	Temp. Range (°C)	Average 2-day RH (%)	Temp. Range (°C)	Average 2-day RH (%)	Temp. Range (°C)	Average 2-day RH (%)	Temp. Range (°C)
10-May		17.0		10.5		0.7		
11-May	35.5	9.0	67.0	9.0	44.0	8.8	35.5	15.1
12-May	42.5	5.1	57.0	4.0	44.5	2.2	32.0	18.0
13-May	57.0	5.0	75.5	6.0	57.5	1.5	40.0	8.5
14-May	72.5	5.0	87.0	5.5	53.5		41.5	18.3
15-May	55.0	10.2	79.0	6.0	51.5		42.0	16.6
16-May	31.5	14.9	65.5	10.0	47.0	1.7	41.0	19.9
17-May	30.0	18.1	49.0	14.0	35.5		65.0	12.5
18-May	38.0	8.0	71.5	12.5	60.5	12.2	96.5	10.5
19-May	51.0	5.5	97.5	2.5	85.0	5.1	89.5	8.7
20-May	56.0	5.5	97.5	6.0	88.0	7.0	77.0	7.5
21-May	55.0	9.0	91.5	4.0	85.0	3.6	76.0	5.6
22-May	47.5	4.0	77.5	3.5	67.5	6.9	60.0	14.9
23-May	68.0	10.0	85.0	6.0	64.0	7.4	58.5	16.9
24-May	67.0	9.6	82.5	7.5	66.0	9.0	59.5	12.3
25-May	39.0	7.2	72.5	7.5	54.0	5.8	43.5	9.6
26-May	40.0	6.2	73.0	4.5	49.5	3.5	41.5	15.7
27-May	42.0	8.1	70.0	4.0	49.5	8.5	44.5	14.5
28-May	47.0	9.6	81.0	4.5	62.0	7.8	45.0	12.2
29-May	50.5	4.9	80.5	4.0	68.5	3.4	44.0	8.1
30-May	51.5	6.3	62.5	4.0	51.5	8.9	47.5	12.0
31-May	42.5	12.0	48.5	10.5	36.5	14.0	41.5	14.4
1-Jun	27.5	15.4	40.0	8.0	31.0	15.3	40.0	19.3
2-Jun	25.5	16.3	34.0	12.0	30.5	11.4	47.0	17.4
3-Jun			35.5	9.0	31.5	16.8	55.0	9.9
4-Jun		14.9	42.0	10.0	50.5	9.7	47.0	17.5
5-Jun	42.0	10.4	67.0	10.5	77.5	7.4	44.5	17.2
6-Jun	38.0	16.8	68.0	14.5	67.0	13.6	45.5	16.8
7-Jun	27.5	12.4	49.5	8.5	46.5	7.2	38.0	16.8
8-Jun	38.0	9.8	55.5	6.5	57.5	10.0	55.5	
9-Jun	51.5	8.0	78.5	7.0	67.0	7.0	85.0	5.3
10-Jun	73.5	10.1	94.5	7.5	73.5	6.1	83.5	10.9

Date (2001)	Juuka Average 2-day RH (%)	Juuka Temp. Range (°C)	Ammansaari Average 2-day RH (%)	Ammansaari Temp. Range (°C)	Utajarvi Average 2-day RH (%)	Utajarvi Temp. Range (°C)	02600 Espoo Average 2-day RH (%)	02600 Espoo Temp. Range (°C)
11-Jun	65.5	9.6	77.0	9.5	75.5	10.6	67.5	11.0
12-Jun	56.5	6.1	62.5	6.0	72.0	5.2	80.5	6.7
13-Jun	78.0	5.6	75.0	8.5	83.0	6.8	96.5	5.0
14-Jun	66.0	12.5	89.5	8.5	78.0	6.8	93.5	4.7
15-Jun	40.0	15.5	83.0	8.5	57.0	11.5	73.0	16.8
16-Jun	37.5	13.5	75.5	7.0	55.0	12.0	54.0	18.2
17-Jun	41.0	12.8	72.0	9.0	52.5	14.0	74.5	12.3
18-Jun	44.0	6.7	70.5	8.5	46.0	8.4	80.0	12.3
19-Jun	48.0	8.2	65.5	9.0	45.5	8.8	80.0	2.4
20-Jun	43.0	9.6	50.5	9.5	35.0	10.5	97.0	2.5
21-Jun	62.0	7.3	52.5	9.0	40.5	7.9	97.0	3.7
22-Jun	81.5	4.1	60.0	7.0	58.0	3.2	93.5	10.7
23-Jun	59.5	9.2	47.0	8.0	51.5	6.7	74.0	
24-Jun	35.0	14.8	37.0	10.5	36.0	14.5	52.0	
25-Jun	31.5	13.0	47.0	7.5	33.5	16.6		
26-Jun	40.0	15.5	56.0	12.0	40.0	14.5		
27-Jun	42.5	15.2	56.0	9.5	42.0	13.1	57.0	14.7
28-Jun	36.0	12.9	57.5	6.5	37.5	11.5	61.0	13.8
29-Jun	36.0	9.7	56.5	9.0	36.5	10.3	59.5	14.4
30-Jun	38.0	9.0	64.5	9.0	51.0	5.2	64.0	9.5
1-Jul	35.0	14.6	63.5	10.5	62.0	8.2	70.5	10.8
2-Jul	49.0	11.2	68.0	9.0	61.5	7.8	68.5	6.3
3-Jul	53.0	10.4	72.5	7.5	65.0	11.3	54.0	14.1
4-Jul	39.5	8.0	56.5	6.5	57.0	7.1	45.5	15.4
5-Jul	38.5	16.0	76.0	10.5	69.0	7.2	42.5	10.5
6-Jul	37.0	13.2	80.5	9.0	68.0	13.1	49.5	14.0
7-Jul	40.5	18.8			51.5	14.2		
8-Jul	48.5	10.1		8.5	54.0	15.7		
9-Jul	46.0	12.4	64.5	8.5	55.5	13.2	54.0	12.0
10-Jul	46.0	15.1	75.5	9.5	61.0	9.9	53.0	2.5
11-Jul	56.5	5.7	90.5	7.5	69.0	6.5	63.5	6.3
12-Jul	58.0	9.0	79.5	6.5	68.5	8.3	64.5	5.0
13-Jul	68.0	12.3	69.0	10.0	63.5	8.4	56.5	7.9

Figure AT-RH-9: Average Temperature Range Plotted as a Function of Average Relative Humidity for Schools in the Study Sample

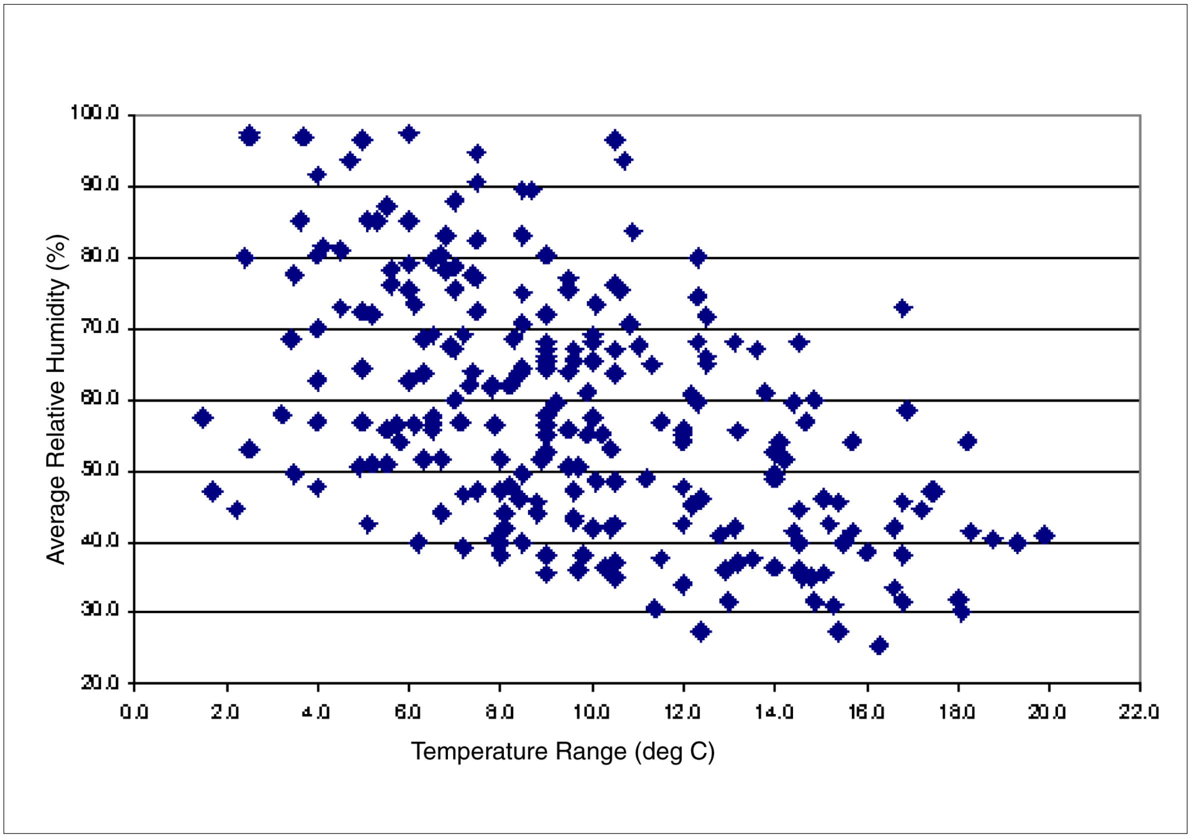
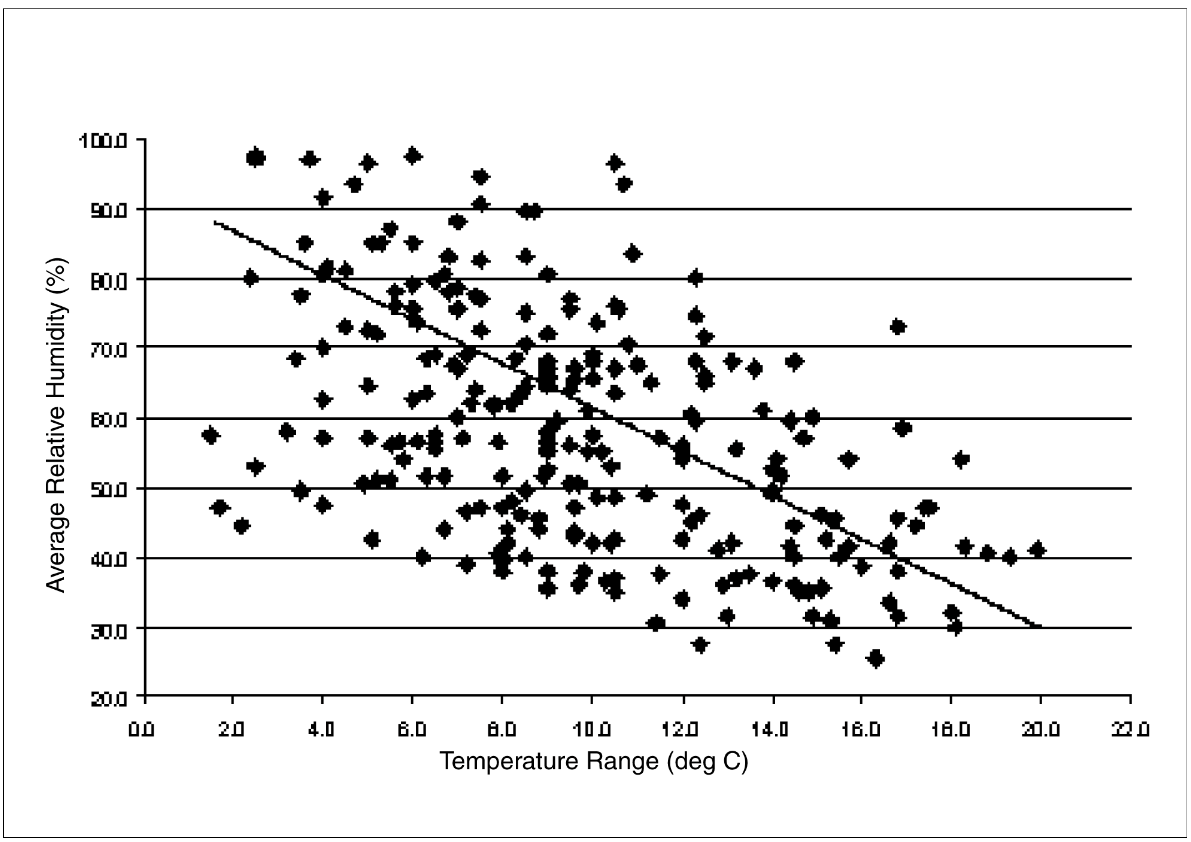


Figure AT-RH-10



Communicating Results

The students calculate temperature range for each day for each school and then graph all the points together with temperature range on the y-axis and relative humidity on the x-axis. Figure AT-RH-9 shows the result.

The students can see that for low temperature ranges (for example, less than about 4˚C), the average relative humidity reported is generally above 45%, and as the temperature ranges get larger, lower relative humidity values are reported. In fact, for high temperature ranges (greater than 16˚C), only one observation of relative humidity greater than 70% is reported, all the remaining observations are less than 60%. So, there indeed does appear to be a good relationship between these datasets.

This relationship is an inverse relationship, because as one variable increases, the other variable tends to decrease. If we tried to develop a line that best fits the data points, which might be used to try to forecast relative humidity from the temperature range, it might look like the line shown in Figure AT-RH-10. This line is called a least squares fit line, and it measures the best "straight-line" representation of the data that are plotted.

Future Research

The results are so encouraging that Heikki decides next to investigate the effects of altitude to see if he can explain his surprising results from the first experiment, and to look further at other geographic areas to see if the conclusions here are the same as his findings. He looks forward to the results from these investigations and the possible international collaborations to which they may lead.