Cloud Protocols

Draft 8/31/00

Cloud Protocols

Purpose

To observe cloud type and cover

Educational Outcomes

Students learn how to make estimates from observations and how to categorize specific clouds following general descriptions for the categories.

Students learn the meteorological concepts of cloud heights, types, and cloud cover and learn the ten basic cloud types.

Overview

Students observe which of ten types of clouds are visible and how much of the sky is cloud covered.

Time

10 minutes

Level

All

Frequency

Daily within one hour of local solar noon
In support of ozone and haze measurements
Additional times are welcome

Key Concepts

Cloud formation
Composition of the atmosphere
Three-dimensional nature of the atmosphere
Cooling and warming effects of clouds
Condensation and evaporation
Weather phenomena which can obscure the sky

Skills

Identifying cloud type
Estimating cloud cover
Using fractions
Interpreting definitions
Comparing pictures with what you see
Recording data
Determining present weather types

Processes

Materials and Tools

Atmosphere Investigation Data Work Sheet or *Cloud Data Work Sheet*
GLOBE Cloud Chart
Observing Cloud Type (in the appendix)

Prerequisites

None

Teacher Support

Every one looks at clouds. Children often stare up and imagine that they see the shapes of various objects in the sky. In GLOBE, students will be shifting what they look for in the sky to some specific, scientifically meaningful properties – cloud type and cover. A great habit to develop is looking up at the sky every time you go outdoors. Pay attention to what is going on in the atmosphere. You might be surprised at how much is happening!

Students take cloud observations with their eyes. The only equipment needed is the GLOBE Cloud Chart, so these protocols are easy to get started, but identifying cloud cover and cloud types is a skill. Students will get better with practice; so, the more frequently you and your students take cloud observations, the more comfortable you will become with these measurements, and the better will be the quality of your data.

With the advent of automated weather stations which only have instruments capable of viewing clouds at heights up to 3,000 to 4,000 meters, many middle and high clouds are no longer observable. The GLOBE cloud observations will provide a useful data set, continuing visual observations that have been collected for over 100 years that are now being replaced with automated observations.

Good questions to help students start determining the best place to take their measurements would be:

Where on the school grounds would you see the most clouds? Where would you see the least?

As you walk around the school grounds, have the students draw a map of the area. The youngest students could just sketch the main features, such as the school building(s), parking lots, playgrounds, etc. Older students should fill in more detail, such as what the playground surface is (e.g. paved, grassy, or bare ground). Have them note any streams or ponds and indicate areas of trees. They could measure how much of the sky is hidden by buildings and trees using the clinometer and techniques given in *Documenting Your Atmosphere Study Site*. The goal is to have a drawing of the school grounds so that students understand why the site for cloud observations was chosen. Each year, the new class of students can repeat this mapping to gain this understanding.

Key Science Concepts

Water is present in the atmosphere in the form of gas (water vapor), liquid (rain drops or water droplets), and solid (ice crystals or frozen rain). Like most other gases that make up the atmosphere, water vapor is invisible to the human eye. However, unlike most other gases in our atmosphere, under the right conditions water vapor can change from a gas into solid particles or liquid drops. If temperatures are above freezing, the water vapor will condense into water droplets. If temperatures are below freezing, as they always are high in the atmosphere, tiny ice crystals will form instead. Clouds are simply the visible accumulations of these crystals or droplets.

Which types of clouds you see often depends on the weather conditions you are experiencing or will soon experience. Some clouds form only in fair weather, while others bring showers or thunderstorms. The types of clouds present provide important information about vertical movement of the atmosphere at different heights. By paying attention to the clouds, soon you will be able to use cloud formation to forecast the weather!

Everyone is aware of clouds, but not everyone is aware of their importance to weather and climate. Clouds play a complex role in the climate system. They are the source of precipitation, affect the amount of energy from the sun that Earth absorbs, and insulate the Earth's surface and lower atmosphere. At any given time, about half of Earth's surface is shadowed by clouds. Clouds reflect some of the sunlight away from Earth, thus keeping the planet cooler than it would be otherwise. At the same time, clouds also absorb some of the heat energy given off by Earth's surface and release some of this back toward the ground, thus keeping the surface warmer than it would be otherwise. Satellite measurements have shown that, on average, the cooling effect of clouds dominates over their warming effect. Scientists calculate that if clouds never formed in Earth's atmosphere, our planet would be nearly 30˚ C warmer on average.

Question for discussion: Find out the average number of sunny days in each month for your area, as well as the average temperature for each month (consult an almanac or similar reference book, or conduct a search on the World Wide Web; after the first year, use your GLOBE data as well). How do students think the temperature of your area would be affected if the number of sunny days increased or decreased?

Measurement Hints

Cloud Cover

Cloud cover is a subjective estimate, but never the less, it is an important scientific one. Meteorologists and climate scientists must have accurate cloud cover observations to correctly account for the amount of solar radiation which is reflected or absorbed, before sunlight reaches Earth's surface and the amount of radiation coming up from Earth's surface and lower atmosphere which is reflected or absorbed before it can escape to space.

As the Learning Activity *Estimating Cloud Cover: A Simulation* makes clear, the human eye tends to overestimate the percentage of the sky covered by clouds. Having students do this activity is the best first step to taking accurate measurements. The other key to accuracy for cloud cover is to have students observe the entire sky that is visible from your Atmosphere Study Site.

Once students begin to take cloud cover observations, it is important that the observations be done by small groups in which some consensus can be achieved. One useful way to do the observation is to divide the sky into four quadrants, estimate the fractional coverage in each quadrant, and then find the average. This can be done using decimal values, or fractions, depending on students' mathematical abilities. The biggest discrepancies will usually occur for borderline situations, where one category is close to another. Keep in mind these break points:

Percentage	If less than	If greater or equal to
10%	Clear	Isolated
25%	Isolated	Scattered
50%	Scattered	Broken
90%	Broken	Overcast

As students become more expert in this measurement, they will begin to realize that clouds are three dimensional and have thickness. As one looks toward the horizon, the sky can look more cloud covered than it really is because the spaces between clouds are hidden from view. This effect is more pronounced for low clouds than for middle and high clouds (these categories are discussed under *Cloud Type*). It is also more of an issue for cumulus clouds than for stratus clouds. If directly overhead students see a pattern of cloud cover with individual puffs or long rolls of cloud separated by clear areas and the general appearance of the clouds is similar looking toward the horizon, it is reasonable to infer that there are spaces between these clouds as well and the cloud cover is not 100% toward the horizon.

The protocol includes a category of "No Clouds" which should be reported whenever there are no clouds visible in the sky. In addition, a new category for this version of the Teacher's Guide is "Obscured Sky". This condition is to be reported when weather phenomena restrict the observer's ability to clearly see and identify the clouds in the sky. There are ten possible reportable obscurations. If your students have difficulty seeing the clouds in the sky, they will not report cloud cover using one of the normal categories, rather, they should report that the sky is Obscured, and then report one (or more) of the obscuring phenomena which are responsible for the limited visibility of the sky. These are defined below.

- **Fog**
  Fog is a collection of small water droplets which is based at the ground, and restricts visibility along the ground and above it. Stratus clouds are often associated with fog. In coastal areas, mountains, and valleys, fog may be prevalent during the midday GLOBE observations. This category will include ice fog or diamond dust which is so prevalent in cloud-free weather at high latitudes.
- **Smoke**
  Smoke particles, from forest fires or others sources, often severely restrict visibility along and above the ground. If smoke is present, there will be a distinct odor of smoke which will distinguish it from haze or fog.
- **Haze**
  Haze is caused when a collection of very small water droplets, or aerosols (which may be water droplets, pollutants or natural dust particles suspended in the atmosphere), which collectively give the sky a reddish, brown, yellowish, or white tint. Smog would be placed in this category. GLOBE has a new *Haze Protocol* for teachers who wish to learn more about haze and its causes. Most times there will be measurable haze present, but clouds will still be observable. This category is only checked when the haze is so extreme that clouds cannot be seen.

- **Volcanic Ash**
  One of the greatest natural sources of aerosols in the atmosphere occurs when a volcano erupts. In such cases, it is conceivable that schools may have ash falling, or other restrictions to visibility (perhaps a plume overhead).
- **Dust**
  Wind will often pick up dust (small soil particles – clay and silt) and transport them thousands of kilometers. If the sky cannot be discerned because of dust falling or blowing, please report this category. Severe duststorms may restrict visibility at some locations, and they would be reported in this category as well, for example, if students cannot go outdoors because of a severe duststorm, the sky would be reported as obscured and dust would be the reason.
- **Sand**
  Blowing or suspended sand, or sandstorms, generally require stronger winds than dust events, but they can make it just as difficult for observers to see the sky.
- **Spray –** (also called sea spray)
  Near large bodies of water, strong winds may suspend drops of water which will be sufficient to reduce the visibility so that the sky cannot be clearly discerned. This category generally is restricted to the area immediately adjacent to the coast, once inland, salt particles may be suspended after the water drops evaporate, leaving haze particles behind.
- **Heavy Rain**
  If rain is falling at excessive rates at the time of the observation, the sky may not be visible. Even though it may seem overcast, if you cannot see the entire sky, you should report the sky as obscured, and heavy rain being the cause.
- **Heavy Snow**
  Snow may also fall at rates sufficient to prevent the observer's clear view of the sky and cloud cover.
- **Blowing Snow –** In the event snow is no longer falling, but the wind is blowing sufficiently strong to lift newly fallen snow off the ground, it may be sufficient to prevent an observation of the sky. If blizzard conditions are occurring (strong winds and snow is still falling), both of these last two categories should be reported.

Cloud Type

Cloud type is a qualitative measurement. The GLOBE Cloud Chart, the cloud quiz on the GLOBE Web site, and other cloud information attainable in textbooks and from online sources may be useful in helping students learn the many different ways clouds can appear. However, two-dimensional images look quite different compared to actual sky observations, which are three-dimensional, and there is no substitute for experience in taking cloud observations.

The cloud type system is organized into 3 categories depending on the height or altitude of the cloud bottoms. High clouds (cirro- or cirrus) are universally composed of ice crystals, and hence are more delicate in appearance. Because they are farther from the observer, they will also appear smaller than other cloud types, in general. The wispy trails often seen in high clouds are ice crystals falling and subliming (turning from a solid into a gas). Generally, the sun can be seen through high clouds and the ice particles in cirrostratus clouds scatter the sunlight to form a bright ring around the sun. Middle clouds always begin with the prefix *alto-* and are predominantly comprised of water droplets. They may contain some ice. Sometimes the sun can be seen through these clouds as well, but without a ring. Low clouds are closest to the observer, and they will often be quite large in comparison to higher clouds. They may be much darker, appearing more gray than high or middle clouds. Low clouds may extend to much higher altitudes which can be seen when there are clear gaps between the clouds.

Once you have this basic distinction down (high/middle/low), the next thing to decide is the shape or form of the cloud. If the cloud feature is a fairly uniform layer, it will be a stratiform, stratus-type cloud. Most clouds which have shape or forms such as puffs, rolls, bands, or tufts, are cumuliform, from the cumulus family. Finally, if a cloud is producing precipitation (which the observer can see), it must have nimbus in its name. The wispy shapes produced by ice clouds almost always occur at high altitudes and so they are called by the same name as high clouds – cirro- or cirrus. By performing the *Cloud Watch Learning Activity* from time to time with your students, you (and they) will gain more confidence in their ability to identify the cloud types in a complex sky!

Student Preparation

The estimates of cloud type and cloud cover are *subjective* measurements, so involving several students in this task is good. Each student should take his or her own readings; then, students should come to an agreement as a group. Do not be surprised if your students initially have difficulty with these estimates. Even seasoned weather observers debate which type of cloud they are seeing, or exactly how much of the sky is covered by clouds. As your students get used to these observations, they will begin to recognize the subtle differences in cloud types.

The *Cloud Cover Simulation* will help students gain confidence in their ability to distinguish the various cloud cover categories from each other. Practicing such simulations with classmates will help build this confidence. Be sure to check the entire sky. One of the best ways to do this is with groups of four students, standing back-to-back. Stand with your back to each other, one facing north, one east, one south, and one west. Now, you are responsible for estimating the amount of cloud from the horizon to directly overhead in your quadrant. Make sure that you are all defining your quadrant the same way. Once you each have your estimate (use 10% increments, or fractions like 1/8s or 1/10s), take the average of the four estimates by adding them up and then dividing by 4. This method will be particularly useful when you have a difficult sky that leads to different estimates among group members.

The following tip may help you determine the heights of cumulus clouds. Extend your arm away from your shoulder parallel to the ground, and align your fingers with the cloud feature you are observing. A good rule of thumb to use is that if the individual puffs, rolls, waves, etc., of the clouds are smaller than one finger width, they are cirrocumulus. If they are not as wide as two fingers, but wider than one finger, it is most likely an altocumulus. If wider than two fingers, it will be cumulus (look for isolated puffs), stratocumulus (clouds are wider than tall, and there are many, perhaps elongated in bands), or cumulonimbus (with precipitation).

For distinguishing the different heights of stratus clouds, remember the following. Cirrostratus is the only cloud type which can produce a halo around the sun or moon. The halo will have all the rainbow colors in it. Altostratus will produce a thinly veiled sun or moon, and will often be darker in appearance, a medium gray color. Stratus will usually be very gray and often very low to the ground. Fog is actually a stratus cloud at zero altitude.

Overview of Educational Activities

Student Learning Goals

Within GLOBE, students can enhance their education through involvement in hands-on, scientifically valid research. Student learning goals for this module are:

- to observe and measure weather and climate-related phenomena accurately and objectively,
- to design and test students' own weather instruments as a way of understanding how standard instruments work,
- to classify objects and events based on similarities, differences, and interrelationships,
- to solve problems by experimentation,
- to interpret collected data and come to sound conclusions,
- to explore and understand the uncertainties inherent in any scientific measurement,
- to communicate information learned through their scientific investigations, and
- to develop models from data, patterns, or relationships.

Concepts

The concepts which are covered in the protocols and learning activities of this investigation are:

Composition of the atmosphere
Cloud formation
Condensation
Cooling and warming effects of clouds
Clouds are identified by their shape, altitude, and precipitation characteristics
Relationship of clouds and changes in clouds to weather
Effects of wind on precipitation measurement
Change of state
Density of snow
Factors affecting the pH of precipitation
Temperature
Heat
Convection
Conduction
Radiation
Heat transfer through radiation, conduction, and convection
Conduction and convection are two key forms of heat transfer
Different substances, such as soil, water, and air, transfer energy and heat at different rates
Heat capacity
Substances expand and contract as the temperature changes
Liquid-in-glass thermometers work on the basis of thermal expansion and contraction
Using a simulation to explore the accuracy of observations
Meniscus reading

Student Assessment

Students should be assessed using formative and summative evaluation methods, which may be either qualitative or quantitative in nature. Such methods should reflect the development level of your students. Various tools should be used to assess the growth of students in the following areas:

- concept mastery
- use of science process skills
- attitudes toward science, science classes, and science careers
- higher level skills, including questioning, identifying cause and effect, and predicting
- applying concepts and process skills in new situations

One way to assess students' understanding of the content and processes within the Atmosphere Investigation is to monitor the daily data that students record and submit. Is the maximum temperature recorded always greater than the minimum temperature? Is the current temperature recorded equal to or between the maximum and minimum for the past 24 hours? In both instances, the answer should be yes. If it is not, you should suspect that either the students do not know how to read the maximum/minimum thermometer or they are unsure of what they are reading.

Another way to assess students' understanding of the protocols is to ask them to choose the optimum placement for instruments when presented with a variety of situations. What if your school were in a city? What if it were in a heavily wooded area?

The learning activities in this module are designed to help students understand the protocols and the instruments used to implement the protocols. They also allow you to assess students' understanding of key concepts and skills. Students may keep a log of their activities, give oral reports to the class (or maybe even weather reports to the school!), and write papers that could be reviewed by other students.

Skills

The skills covered in the protocols and learning activities of this investigation are as follows:

Broadly Applicable Science Skills

Observing carefully

Observing systematically over a period of time

Measuring

Reading a scale accurately

Collecting and *recording* data

Conducting an experiment

Constructing an apparatus for an experiment

Hypothesizing and *predicting*

Designing experiments

Organizing data in tables

Analyzing data

Graphing

Correlating one observed phenomenon with another

Communicating experimental results orally and in writing

Communicating mathematically

Working effectively in a group

Specific Skills Associated with the Atmosphere Investigation

Estimating simulated cloud cover

Estimating cloud cover

Observing and *describing* the appearance of clouds

Estimating cloud height

Identifying the ten major cloud types

Recording and *organizing* cloud data in the GLOBE Science Notebook

Using a rain gauge

Using a thermometer

Using pH measuring equipment

Student Support

Scientific Justification

Cloud types often indicate a trend in the weather pattern. For example, altocumulus clouds are often the first indicator that showers may occur later in the day. For over two hundred years, meteorologists have been foretelling the weather using cloud types, and more generally, sequences of cloud types.

In middle latitudes, one can often tell the advance of a warm front by watching the sky change from cirrus to cirrostratus. Later on, as the front gets closer, the clouds thicken and lower, becoming altostratus. As precipitation begins, the altostratus clouds become nimbostratus, immediately before the front passes your location.

Cloud types are an important sign of the processes that are occurring in the atmosphere. Clouds indicate that moist air is ascending, and precipitation can only occur when this occurs. Clouds often provide the first signal that adverse weather is about to occur, although not all clouds are associated with bad weather.

Many official sources of weather observations are now using automated equipment. These automated measurement systems do not take cloud type observations. This makes cloud observations by GLOBE students and other amateur weather observers unique as a data source.

In the absence of cloud type observations from official sources, professional meteorologists are increasingly relying on weather satellites for these observations. They are working hard to develop automated methods to infer cloud types from visible and infrared weather satellite images. This task is hard, and observations from the ground are needed for comparison. Your accurate cloud type observations may be just the data the professional meteorologists need.

Many scientists have found that their initial interest in scientific careers began with careful observation of their surroundings. In many cases, it has come by experiencing a severe storm of some sort, or observing an interesting optical phenomenon, such as a rainbow or mirage. But many report that their initial interest comes from observing the sky and watching interesting cloud patterns evolve.

Synthesis Questions

Do cloud patterns change during the year? How?

Does the amount of cloud cover affect the local temperature?

How reliable are local weather forecasts based on cloud type observations alone? Can they be improved by using other GLOBE measurements?

Do cloud conditions and phenomena that block our view of the sky influence the types of vegetation and soil in our area? If so, how?

How do our cloud observations compare with satellite images of clouds?

Cloud Cover Protocol

Student Field Guide

Task:

Observe how much of the sky is covered by clouds.

What You Need

❑ *Atmosphere Investigation Data Work Sheet* OR
Cloud Data Work Sheet OR
Ozone Data Work Sheet OR
Atmospheric Haze/Aerosols Data Work Sheet

In the Field

1. Complete the top section of your *Data Work Sheet*.
2. Look at the sky in every direction.
3. Estimate how much of the sky is covered by clouds.
4. Decide which classification best matches what you see.

Cloud Cover Classifications

No Clouds
The sky is cloudless; there are no clouds visible

Clear
Clouds are present but cover less than one-tenth (or 10%) of the sky.

Isolated Clouds (New category for 2000)
Clouds cover between one-tenth (10%) and one-fourth (25%) of the sky.

Scattered Clouds (Modified instructions for 2000)
Clouds cover between one-fourth (25%) and one-half (50%) of the sky.

Broken Clouds
Clouds cover between one-half (50%) and nine-tenths (90%) of the sky.

Overcast
Clouds cover more than nine-tenths (90%) of the sky.

Obscured (New category for 2000)
Clouds cannot be observed because the sky cannot be seen clearly.

5. If the sky is Obscured, report what is blocking your view of the sky. Report as many of the following as you observe.
   - Fog • Smoke • Haze • Volcanic Ash • Dust
   - Sand • Spray • Heavy Rain • Heavy Snow • Blowing Snow
6. Record your observations on your *Data Work Sheet*.

Cloud Type Protocol
Student Field Guide

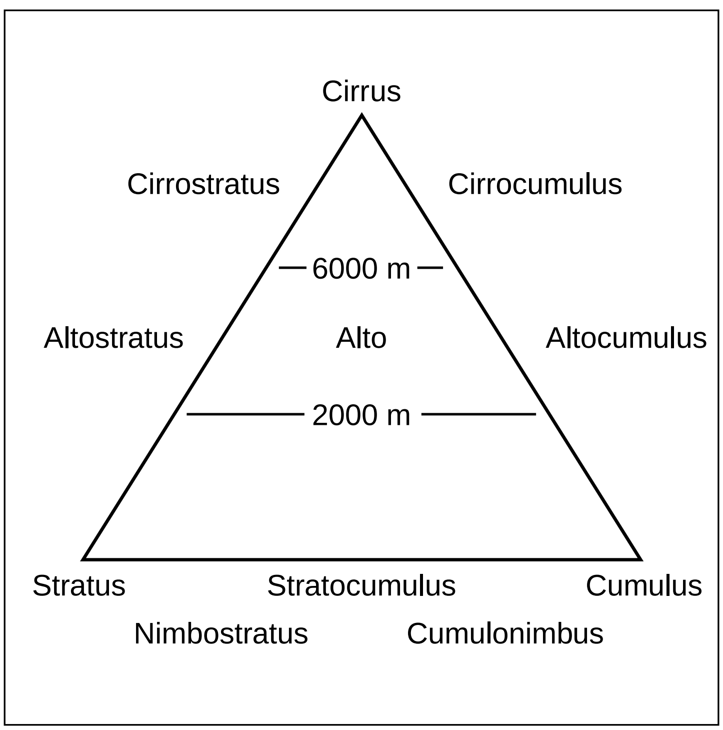
Task
See which of the ten types of clouds are visible.

What You Need
❑ *Atmosphere Investigation Data Work Sheet* OR
Cloud Data Work Sheet OR
Ozone Data Work Sheet OR
Atmospheric Haze/Aerosols Data Work Sheet

❑ GLOBE Cloud Chart

❑ *Observing Cloud Type* (from the *Appendix*)

In the Field
1. Look at all the clouds in the sky, look in all directions, including directly overhead
2. Identify the types of clouds that you see using the GLOBE Cloud Chart and the definitions found in *Observing Cloud Type*
3. Check the box on your *Data Work Sheet* for each and every cloud type you see.



Frequently Asked Questions

1. We have been taking cloud cover observations for GLOBE for several years; why has the *Cloud Cover Protocol* changed to include new categories?

The addition of the **isolated** category was made necessary by a change in the way that scientists and trained meteorological observers take their cloud observations. The old **scattered** category was divided up into two categories. This is important, particularly for pilots, because they need to know when clouds first form and also when they begin to cover more than 50% of the sky. The old scattered category simply covered too wide a range of values (10-50%) to be of great use to pilots, so observation standards changed. We are changing the GLOBE protocol to better match these standards, and in this way, make the GLOBE cloud cover observations of more use to scientists. The addition of the **obscured** category was done to account for the very real possibility that the clouds may not be seen on some days due to natural weather obstructions. In the past, fog was lumped with stratus clouds and there was no clear guidance as to what to report if the sky was obscured for other reasons.

2. How come we have to report cloud cover observations even if there are no clouds?

It is just as important for scientists to know when there are no clouds in the sky as when there are clouds. Please always report the cloud cover, even on a beautiful day with blue sky! How could you accurately calculate average cloud cover if data were always missing for completely clear days?

3. Can't an instrument be designed to measure cloud cover?

Yes, in fact, lasers are used to measure this and the instrument is called a ceilometer. Ceilometers measure the portion of the sky covered by clouds, but they are very expensive. Furthermore, the ceilometers in use today only provide accurate estimates of cloud cover up to heights of about 3.5 kilometers, which makes them useless for most middle clouds and all high clouds. Cloud cover is an aggregate of all clouds at all levels, and human observations are still the best way to measure this at this time.

4. Is there any way to make sure that our observations are accurate, since there is no instrument to calibrate?

These data are very important, and practice will help you to become proficient in estimating cloud cover. You can compare your own observations with nearby neighbors' observations, and compare them with "official" observations, too, to learn about how accurate your own observations are, but remember that on some days the cloud conditions will be different even over short distances and they may change in minutes. If you do them diligently every day, you should become very comfortable with your efforts!

5. We have real trouble figuring out if we are correct when we call a certain cloud one of the ten types. How do we know if we are correct?

You can't know for sure. The most important thing to do is to practice identifying cloud types as often as you can. If you have access to the World Wide Web, you can take the Interactive GLOBE cloud quiz, which you will find online as part of the GLOBE Web site. Also, you may wish to obtain another copy of the GLOBE Cloud Chart, cut it up, and make flash cards to help quiz your classmates.

6. Is this cloud type observation system in GLOBE unique or new in some way?

This system is the same one that meteorologists have been using for two hundred years. Many scientists report becoming interested in science because they started to observe the sky and note how it was different (in terms of cloud types) from one day to another. The scientific basis of this cloud type observing system has not changed substantially since it was first devised. The systematic breakdown of clouds into ten basic types was motivated at least in part by the classification of species of living things into the Animal and Plant Kingdoms by biologists. In fact, meteorologists often further divide the cloud types into other specific variations within each cloud type. *Castellanus* refers to castle-like turrets in a cloud formation, an indicator that the atmosphere is becoming unstable, perhaps foretelling precipitation. *Lenticularis* means lens-shaped, a cloud often formed over high mountains. And cumulus are often separated into *humilis* (fair weather, puffy) or *congestus* (towering, heaped like cauliflower, very tall).