Cloud Protocols

Purpose

To observe the type and cover of clouds including contrails

Overview

Students observe which of ten types of clouds and how many of three types of contrails are visible and how much of the sky is covered by clouds (other than contrails) and how much is covered by contrails.

Student 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.

Science Concepts

Earth and Space Science

- Weather can be described by qualitative observations.
- Weather changes from day to day and over the seasons.
- Weather varies on local, regional, and global spatial scales.
- Clouds form by condensation of water vapor in the atmosphere.
- Clouds affect weather and climate.
- The atmosphere has different properties at different altitudes.
- Water vapor is added to the atmosphere by evaporation from Earth's surface and transpiration from plants.

Physical Science

- Materials exist in different states – solid, liquid, and gas.

Geography

- The nature and extent of cloud cover affects the characteristics of the physical geographic system.

Scientific Inquiry Abilities

- Use a Cloud Chart to classify cloud types.
- Estimate cloud cover.
- Identify answerable questions.
- Design and conduct scientific investigations.
- Use appropriate mathematics to analyze data.
- Develop descriptions and predictions using evidence.
- Recognize and analyze alternative explanations.
- Communicate procedures, descriptions, and predictions.

Time

10 minutes

Level

All

Frequency

Daily within one hour of local solar noon

In support of ozone and aerosol measurements

At the time of a satellite overpass

Additional times are welcome.

Materials and Tools

- *Atmosphere Investigation Data Sheet* or *Cloud Data Sheet*
- GLOBE Cloud Chart
- *Observing Cloud Type* (in the *Appendix*)

Prerequisites

None

Cloud Protocols – Introduction

Clouds and the Atmosphere

Water in the environment can be a solid (ice and snow), a liquid, or a gas (water vapor). As water moves from place to place it can melt, freeze, evaporate, or condense. These changes happen as the water is warmed or cooled.

Water in the atmosphere exists in all three phases (solid, liquid, gas) and changes phase depending on temperature and pressure. 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 may form instead. When a large number of water droplets or ice crystals are present, they block light enough for us to see them – they form clouds. So, clouds tell us something about air temperature and water up in the sky. They also affect the amount of sunlight reaching the ground and how far we can see.

In the troposphere, the lowest part of the atmosphere, temperature decreases with increasing altitude. As ice crystals form at high altitudes, they are often blown away from the region where they formed by the strong winds of the jet streams. Through this process of formation and movement ice crystals often merge into larger crystals and then begin to fall. These falling or windblown crystals create streaks, which we see as wispy clouds. These streaks are often curved by the wind, which can blow at different velocities at different altitudes.

Other types of clouds are blown about by the wind, too. Updrafts help form towering clouds; downdrafts tend to create clear spaces between clouds. Horizontal winds move clouds from place to place. Clouds that form over lakes and oceans are blown over the dryer land, bringing precipitation. Strong winds high in the atmosphere sometimes blow the tops off clouds creating anvil shapes or carrying ice crystals far downwind to clear areas.

Ice crystals and water drops scatter light differently. Thick clouds absorb more sunlight than thin ones. The types of clouds, phases of water, and amount of clouds, ice, and water drops all affect the amount of sunlight that comes through the atmosphere to warm Earth's surface. Clouds also affect how easily heat from the surface can escape through the atmosphere back to space.

By observing clouds, we can get information about temperature, moisture, and wind conditions in different places in the atmosphere. This information helps in predicting the weather. Observations of clouds also help us know how much sunlight is reaching the ground and how easily heat from the ground and lower atmosphere can escape, and this information is important in understanding climate.

Clouds and Weather

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 at different heights in the atmosphere. By paying attention to the clouds, soon you will be able to use cloud formation to forecast the weather!

Cloud types may indicate a trend in the weather pattern. For example, altocumulus clouds are often the first indicator that showers may occur later in the day. In middle latitudes, one can often see the advance of a warm front by watching the cloud types 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 moving upward, and precipitation can only happen when this occurs. Clouds often provide the first signal that bad weather is coming, although not all clouds are associated with bad weather.

Clouds and Climate

Clouds play a complex role in climate. They are the source of precipitation, affect the amount of energy from the sun that reaches Earth's surface, and insulate Earth's surface and lower atmosphere.

At any given time, over half of Earth's surface is shadowed by clouds. Clouds reflect some of the sunlight away from Earth, keeping the planet cooler than it would be otherwise. At the same time, clouds absorb some of the heat energy given off by Earth's surface and release some of this heat back toward the ground, keeping Earth's surface warmer than it would be otherwise. Satellite measurements have shown that, on average, the cooling effect of clouds is larger than their warming effect. Scientists calculate that if clouds never formed in Earth's atmosphere, our planet would be over 20˚ C warmer on average.

Conditions on Earth affect the amount and types of clouds that form overhead. This helps to shape local climate. For example, in rain forests, the trees release large amounts of water vapor. As daily heating causes the air to rise, clouds form and intense rainstorms occur. Over three-quarters of the water in tropical rain forests is recycled in this way and cloud cover is almost complete for most of the year. In contrast, in a desert there is no surface source of moisture and clear conditions are typical. These clear conditions allow for more heating by sunlight and larger maximum temperatures. In both cases, the local climate – precipitation and temperature – is tied to cloud conditions.

Human activities also can affect cloud conditions. One specific and obvious example is the formation of contrails, or condensation trails. These are the linear clouds formed when a jet aircraft passes through a portion of the atmosphere having the right combination of moisture and temperature. The jet exhaust contains some water vapor as well as small particles – aerosols – that provide condensation nuclei that help ice crystals begin to form. In some areas, jet traffic is causing a noticeable change in cloudiness, which may affect both weather and climate.

How will cloud conditions change if Earth's surface becomes warmer on average? If the surface water of oceans and lakes warms, more water will evaporate. This should increase the total amount of water in the atmosphere and the amount of cloud cover, but what type of clouds will form? Will the increase in clouds happen mostly at high altitudes or low altitudes? Clouds at all altitudes reflect sunlight helping to cool Earth's surface, but high clouds release less heat to space and thus warm the surface more than low clouds. So, the changes in surface temperatures may depend on how cloud conditions change.

Many official sources of weather observations are now using automated equipment to observe clouds. 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. Since 1960, scientists have also used satellites to observe clouds. These observations began with simple pictures of clouds, but more advanced techniques are always being added. Scientists are working 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. Contrail detection from space is especially challenging, since many contrails are too narrow to see in satellite images. Accurate cloud type observations from GLOBE students are an important source of these ground-based observations.

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; 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, including contrails, 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.

Measurement Hints

Cloud Cover

Cloud cover is a subjective estimate, but 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* 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 a 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. Cloud cover categories are given in Table AT-CL-1.

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 appear to be 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 when

Table AT-CL-1

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

looking 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.

This protocol includes a category of "No Clouds" which should be reported whenever there are no clouds visible in the sky and a category "Obscured Sky". This condition is to be reported when weather phenomena restrict the observer's ability to clearly see and identify the clouds and contrails in the sky. There are ten possible reportable obscurations. If your students have difficulty seeing the clouds and contrails in more than one-quarter of the sky, they will not report cloud or contrail 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 that are responsible for the limited visibility of the sky. Metadata should be reported for cloud and contrail cover for the part of the sky that is visible if the sky is only partially obscured. The obscuring phenomena 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 prevalent in cloud-free weather at high latitudes.
- **Smoke**
  Smoke particles, from forest fires or other sources, often severely restrict visibility along and above the ground. If smoke is present, there will be a distinct odor of smoke, distinguishing it from haze or fog.
- **Haze**
  Haze is caused by 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 *Aerosols Protocol* for teachers who wish to learn more about haze and its causes. Most of the time measurable haze is present, 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 aerosols behind.
- **Heavy Rain**
  If rain is falling intensely 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 the wind is blowing with sufficient strength to lift fallen snow off the ground, it may prevent observation of the sky. If blizzard conditions are occurring (strong winds and snow is still falling intensely), both of these last two categories should be reported.

Contrail Cover

The same technique of dividing the sky into four quadrants described above for cloud cover can also be used in the estimate of contrail cover. One single persistent contrail crossing the sky covers less than 1% of the sky (see *Estimating Cloud Cover Learning Activity*). Therefore, counting contrails can also be a good tool in the estimation. When the sky is obscured, as described above, contrail cover measurements cannot be taken.

Remember contrail cover is measured separately from cloud cover. So when you estimate cloud cover, you should not include contrails. When you observe contrails that overlap with clouds, you should report this in the metadata.

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 base of the cloud. 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, called a halo, 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 appear to 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 this basic distinction is clear to you (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 that 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!

Contrail Type

Contrails generally occur at high levels like cirro- or cirrus clouds. However, as human-induced clouds, contrails are reported in a separate category. There are three types of contrails for students to classify. These are:

- *Short-lived* – contrails that disappear shortly and form short line segments in the sky that fade out as the distance away from the airplane that created them increases.
- *Persistent Non-Spreading* – these contrails remain long after the airplane that made them has left the area. They form long, generally straight, lines of approximately constant width across the sky. These contrails are no wider then your index finger held at arm's length.
- *Persistent Spreading* – these contrails also remain long after the airplane that made them has left the area. They form long streaks that have widened with time since the plane passed. These contrails are wider than your index finger held at arm's length. This type is the only type that can currently be seen in satellite imagery; and only when they are wider than four fingers held at arm's length. Therefore, noting the equivalent finger width of these contrails in the metadata will be very useful for the scientists.

Refer to the Web site of the contrail team for additional pictures of the various contrail types.

Short-lived contrails form when the air at the elevation of the airplane is somewhat moist. Persistent contrails form when the air at the elevation of the airplane is very moist, and are more likely to affect climate than short-lived contrails are.

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.

Here are two effective ways to help train your students to take the most accurate cloud observations possible:

1. Practice cloud type observing by taking the GLOBE cloud quiz, available from the Resource Room of the GLOBE Web server, or by spending a lot of time looking at and identifying examples of the predominant cloud types for your location;
2. Do the following Learning Activities from the GLOBE *Atmosphere Teacher's Guide*
   - *Estimating Cloud Cover*
   - *Observing, Describing and Identifying Clouds*
   - *Cloud Watch*

These activities are designed to give students plenty of opportunities to gain proficiency in identifying cloud type and cloud cover.

Sometimes there may be disagreement among students taking observations of clouds, and the process of students coming to a consensus is an important part of the scientific discovery process. However, it may be useful to include some commentary in the Metadata section of your *Data Sheet.*

Practicing simulations with classmates will help build students' confidence. Be sure to have them check the entire sky. One of the best ways to do this is with groups of four students, standing back-to-back, one facing north, one east, one south, and one west. Now, each student is responsible for estimating the amount of cloud from the horizon to directly overhead in their quadrant.

Make sure they are all defining their quadrant in the same way. Once each student has an estimate (use 10% increments, or fractions like eighths or tenths), take the average of the four estimates by summing them and 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 your students determine the heights of cumulus clouds. Have them extend their arm away from their shoulder parallel to the ground, and align their fingers with the cloud feature they 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.

Here are some questions that students may be thinking about (or asking) as they take cloud observations:

What kind of sky do I see?
What kind of sky do other students from nearby schools see?
Should they be the same?

Cloud cover in particular can be a very local phenomenon, and therefore cloud type may vary significantly from one place to another nearby. When viewed as an aggregate for a large grouping of GLOBE schools, cloud observations become more useful. Also, local cloud observations are important to several other GLOBE protocols.

Questions for Further Discussion

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?

Are contrails often seen in the local area? Why or why not?

Are the types of clouds and contrails you observe related?

How do the clouds you see relate to nearby mountains, lakes, large rivers, bays, or the ocean?

Cloud Cover and Contrail Cover Protocol

Field Guide

Task

Observe how much of the sky is covered by clouds and contrails.

What You Need

❑ *Atmosphere Investigation Data Sheet* OR *Cloud Data Sheet* OR *Ozone Data Sheet* OR *Aerosol Data Sheet*

In the Field

1. Complete the top section of your *Data Sheet*.
2. Look at the sky in every direction.
3. Estimate how much of the sky is covered by clouds that are not contrails.
4. Record which cloud classification best matches what you see.
5. Record which contrail classification best matches how much of the sky is covered by contrails.

Cloud Cover Classifications	***Contrail Classifications***
No Clouds The sky is cloudless; there are no clouds visible.	**None** There are no contrails visible.
Clear Clouds are present but cover less than one-tenth (or 10%) of the sky.	**0-10 %** Contrails are present but cover less than one-tenth (or 10%) of the sky.
Isolated Clouds Clouds cover between one-tenth (10%) and one-fourth (25%) of the sky.	**10-25 %** Contrails cover between one-tenth (10%) and one-fourth (25%) of the sky.
Scattered Clouds Clouds cover between one-fourth (25%) and one-half (50%) of the sky.	**25-50%** Contrails 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.	**> 50%** Contrails cover more than one-half (50%) of the sky.
Overcast Clouds cover more than nine-tenths (90%) of the sky.	
Obscured Clouds and contrails cannot be observed because more than one-fourth (25%) of the sky cannot be seen clearly.	

6. If the sky is Obscured, record 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

Cloud Type and Contrail Type Protocol

Field Guide

Task

To see which of the ten types of clouds and how many of each of the three types of contrails are visible

What You Need

❑ *Atmosphere Investigation Data Sheet* OR
Cloud Data Sheet OR
Ozone Data Sheet OR
Aerosol Data Sheet

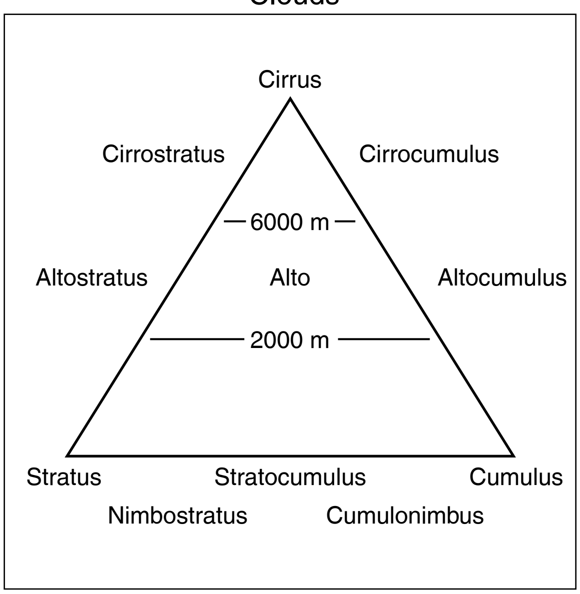
❑ *Observing Cloud Type* (in *Appendix*)

❑ GLOBE Cloud Chart

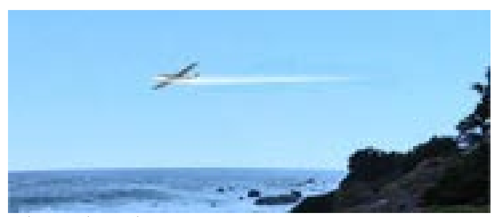
In the Field

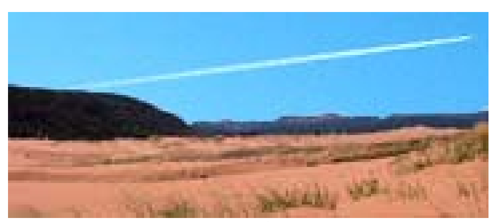
1. Look at all the clouds in the sky, look in all directions, including directly overhead. Be careful not to look directly at the sun.
2. Identify the types of clouds that you see using the GLOBE cloud chart and the definitions found in *Observing Cloud Type.*
3. Check the box on your *Data Sheet* for each and every cloud type you see.
4. There are three types of contrails. Record the number of each type you see.

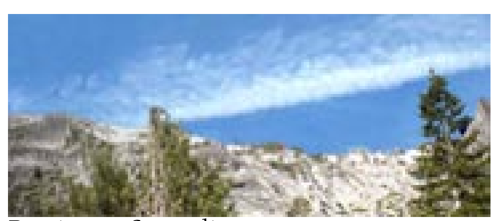
Clouds



Contrails


Short-lived


Persistent Non-Spreading


Persistent Spreading

Frequently Asked Questions

1. Why do 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? Also be aware that clear sky is the easiest measurement from the ground, but the hardest to determine with confidence from satellite imagery.

2. 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, many of 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 from the ground. Also, ceilometers take only a single point or profile measurement that may not be representative of the overall cloud cover.

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

These data are 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 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!

4. We have 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.

5. 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).

6. What do I report if only part of the sky is obscured, but I can determine cloud types for part of the sky?

If more than one-quarter of the total sky is obscured, report 'obscured', and report the cloud types that you see in metadata. If less than one-quarter of the total sky is obscured, record the cloud cover and cloud types and state in the metadata how much of the sky is obscured.

7. I am not sure whether what I see is cirrus or old, spreading contrails?

At some point the distinction between the two cannot be made. In this situation, please report cirrus, but also note in your comments that the cirrus looks like it may have started from a contrail.

Cloud Protocol – Looking At Your Data

Are the data reasonable?

Given the subjective nature of cloud observations, it can be very difficult to determine if they are reasonable.

The internal consistency of the observations can be used to determine whether cloud type and cover data are reasonable. For instance, if there is overcast cloud cover with stratus, stratocumulus, or nimbostratus clouds, reports of alto or cirro cloud types would be unlikely as observers on the ground would not be able to see higher altitude clouds through the thick lower cloud cover. Another example would be reports of only cirrus clouds with overcast skies; cirrus clouds are only very rarely present in the amounts needed to cover 90% of the sky. The same is true for cumulus clouds as there must be breaks between the clouds for them to be cumulus (rather than stratocumulus).

What do scientists look for in these data?

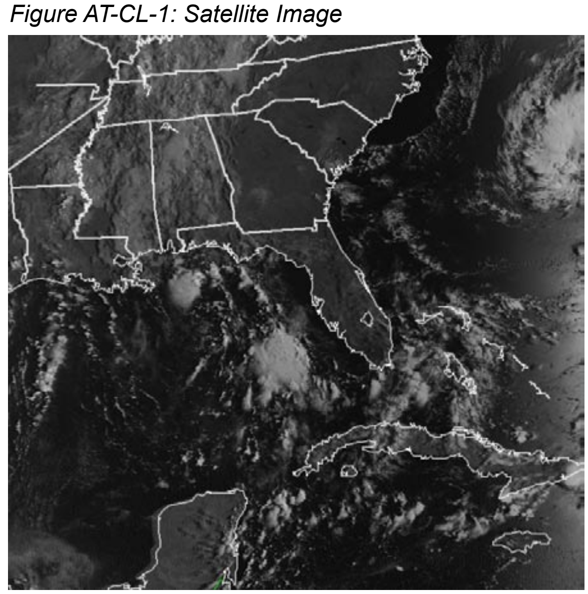
Many official weather observing stations across the world have effectively stopped taking cloud observations. National meteorological organizations have two primary reasons for this change. First, weather satellites are constantly monitoring Earth's surface and atmosphere, and we have become much better at determining cloud cover from satellite pictures in recent years. Second, many weather stations are taking their observations using automated instruments. These instruments cannot determine cloud type, and are often limited in their ability to distinguish middle and high cloud layers. The automated instruments can only sense clouds up to about 3.6 km in altitude and many cloud types are too high for most of these *ceilometers* to see them. So, they can only see half of the cloud types (cumulus, cumulonimbus, stratus, stratocumulus, and nimbostratus).

Clouds have been observed and associated with weather changes for centuries; in fact our cloud classification system is over 200 years old. The changes that you observe in the clouds help meteorologists to forecast the weather. By watching a clear sky change to a sky with isolated cumulus clouds, which may grow to scattered cumulus and broken cumulonimbus clouds, you can expect that thundershowers may begin soon. When an overcast stratus cloud thins out to stratocumulus, you might expect clearer weather to follow. Climate scientists like to watch cloud changes over long periods of time, to see if there is an increase or decrease in cloud cover or a change in type.

Since the early 1960's, meteorologists have had weather satellite pictures that can be used to see clouds (generally shown as white areas on satellite pictures), such as Figure AT-CL-1, a visible photograph from the NOAA 15 polar-orbiting weather satellite of the Gulf of Mexico, near the southeastern United States. Clouds are seen over the waters to the west of Florida, in the Bahamas and on the eastern edge of the picture, off the coast of North Carolina. The land areas of the southeastern United States are fairly clear along the Atlantic Ocean, but further to the west we see some clouds that are not as bright. This tells meteorologists that these clouds are probably lower and/or not as thick as the bright white ones in this mid-afternoon picture.

Scientists who work with satellite data need good surface observations of clouds to provide what is called ground truth for their satellite observations. These observations are important because they help meteorologists to understand

Figure AT-CL-1: Satellite Image



how accurate their satellite observations continue to be. In general, the more GLOBE schools that produce cloud observations, the better for scientists who wish to use these data, because they can assess how accurate and consistent the observations are by making such comparisons.

Satellite photographs do not always give scientists a clear idea of which cloud types are present. This is particularly true for contrails, which are often too narrow to be seen from space. For this reason, it is important for scientists to be able to find areas of low, middle, and high clouds, since each cloud layer will have different abilities to block sunlight and trap infrared radiation.

Let's look at some maps to see how we might proceed with such investigations. Figure AT-CL-2 shows some cloud cover observations for a spring day in 2001 over part of the United States and Canada, near the Great Lakes. The Great Lakes are large bodies of water that provide ample moisture to the atmosphere through evaporation. High levels of water vapor often lead to cloudy skies. The weather map for that day will also be useful to understand what type of cloud systems were present for that day since, in general, air must be rising to produce clouds and low pressure systems and fronts are the most likely areas for clouds to form.

Note the large number of gray boxes near the center of the state of Ohio in the map above. From the map legend, we see that these indicate areas of overcast skies. There are a few stations nearby that are not overcast, including one observation of an obscured sky, one broken, and one scattered. Perhaps a storm system is affecting a fairly large area of northern Ohio and western Pennsylvania. To the west of this area, the observations are mostly of clear skies. The same is true on the far eastern edge of the map, where skies are also mostly clear. Note how similar the cloud type observations are to each other within a region.

Each cloud cover observation also contains a cloud type observation, where students identify each of the ten possible cloud types present. Making a map of such observations would be very complicated, since there are so many possible combinations. GLOBE maps of cloud cover are drawn by dividing all cloud types into their height categories – low, middle, and high – and combinations of these. See Figure AT-CL-3.

Let's concentrate on eastern Ohio once again. Note that almost all of the observations are red, with a couple of green squares, a couple of blue squares, and one purple square. The map legend shows that red squares are low clouds (L), green squares are middle clouds (M), and blue squares are high clouds (H). The purple square is for an observation of low and high clouds (L+H) combined. Once again, the cloud observations are generally similar to each other, with most GLOBE schools reporting that low clouds were present.

If you look to the eastern edge of the map, there are many schools reporting high clouds, middle and high clouds, or low and high clouds. Perhaps these schools are in the path of a storm system that is moving their way from eastern Ohio.

An Example of a Student Research Investigation

Designing an Investigation

Natalie has always been interested in clouds. She is always drawing them and making shapes out of them in her mind. Natalie is one of the students in her class who volunteers to take GLOBE Atmosphere measurements and really likes to observe the clouds. Natalie decides to make her own cloud chart for the class, using cotton balls, white paper, blue construction paper, and glue. Her teacher decides to make that a class project, and they make a beautiful display board with cloud cover examples on it (from the *Estimating Cloud Cover Learning Activity*), and pictures of each of the ten cloud types.

Natalie wonders if the sky that she sees is the same sky that others see at nearby schools. The class decides to compare their cloud observations each day to those of two other schools in their area, another elementary school and a middle school. Some of the children think that it is a game that has to be won by finding the most cloud types, but that is quickly corrected by the teacher. She tells the students that they are collecting data that scientists will be using in research work, and that it is important that they do this job well. It does not take long for the students to all pitch in and do a good job collecting their observations.

Collecting and Analyzing Data

After they have made their cloud observations for about three weeks, the students use the GLOBE visualization tool to find other nearby schools with many cloud observations. They decide to limit their search to schools within 50 km of their school and they find 7 other schools. One of the students has a big sister that goes to a middle school they found, and another attended a different elementary school last year, so they choose those two schools.

The students decide to compare data first by printing out maps for each day for cloud cover and cloud type. Using these maps, they make an observation that the cloud cover observations at the nearby schools are not always the same as theirs.. In particular, the other elementary school, which is near the mountains, seems to have more cloud cover and more observations of cumulus clouds than Natalie's school. They decide that this will be a good investigation. The middle school reports cloud observations similar to theirs.

The students read about mountain weather and discover that in mountain areas there usually are more clouds, because as the air is blown across the mountains it has to rise, and rising air often leads to cloud formation. Because strong upward motions form the clouds, they tend to be cumulus and even cumulonimbus clouds. This seems to explain what they are seeing, and Mrs. Jones suggests that they test this explanation.

The students expect to find that GLOBE schools near the mountains have more cloud cover and more observations of cumulus clouds than other nearby schools farther away from the mountains.

After examining data for an entire year, the students find the following data for 240 observations:

	Natalie's school	Mountain View school
No clouds	15	10
Clear	33	27
Isolated	18	14
Scattered	32	35
Broken	64	66
Overcast	71	79
Obscured Sky	7	9

It is clear indeed that the Mountain View school has more overcast days and fewer clear days (or days with no clouds) than Natalie's school. The students are happy that they have been able to test their explanation with observations.

Future Research

Another curiosity they observe, with their teacher's help, is the larger number of observations of low cloud (23 more days with low cloud types at Mountain View School than Natalie's school), and they wonder if they are cumulonimbus or cumulus clouds? They also wonder if the Mountain View school has more precipitation than Natalie's school, if they have more cumulonimbus clouds. The students are eager to begin their next investigation!

Figure AT-CL-2

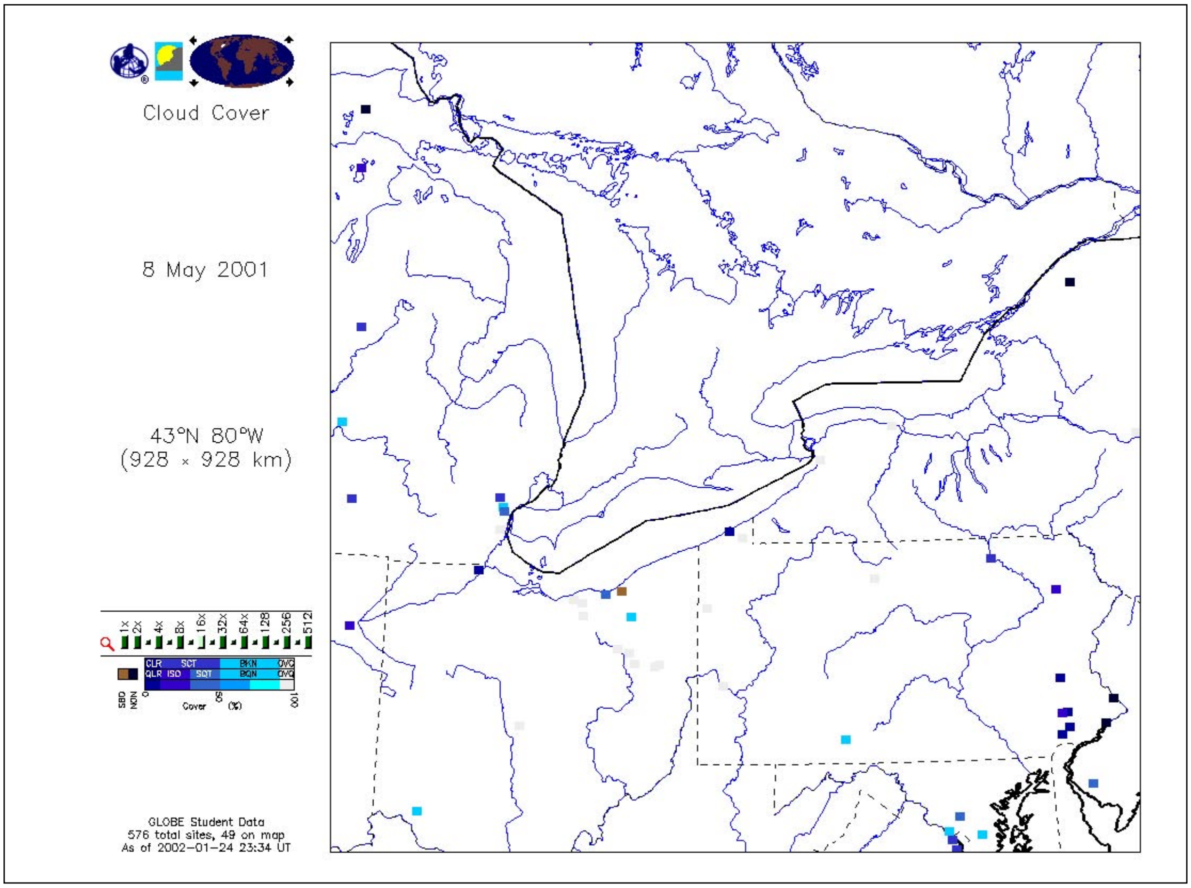


Figure AT-CL-3