ARM Climate Research Facility

Climate Education Update

NEWS AND INFORMATION ABOUT CLIMATE CHANGE STUDIES FOR TEACHERS AND STUDENTS

May 2005

The Department of Energy's Atmospheric Radiation Measurement (ARM) Climate Research Facility supports education and outreach efforts for communities and schools located near its sites. The mission of the Education and Outreach Program is to promote basic science education and community awareness of climate change research by focusing on three goals: student enrichment, teacher support, and community outreach.

http://education.arm.gov/

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Point Reyes National Seashore:

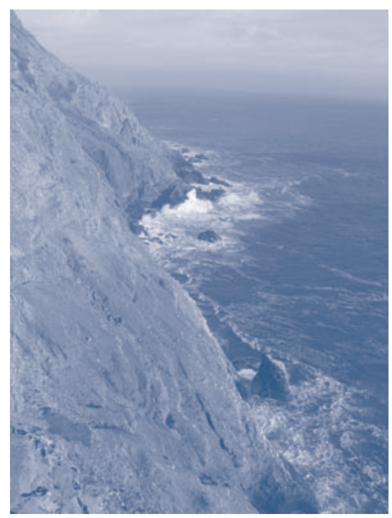
ARM's new hotspot for climate research

by Mary Jane Bartholomew, AMF Associate Site Scientist

Point Reyes National Seashore, California, USA, is perfectly situated for the formation of stratus and stratocumulus clouds. The ARM Mobile Facility (AMF) is making its first stop at Point Reyes for a six-month research initiative that will focus on the study of the stratus and stratocumulus clouds that form over the northern coast of California. These clouds are some of the most prevalent on Earth, but remain an under-sampled component of the Earth's climate system. The scientific instruments at the AMF site will collect data intended to improve our understanding of the role of stratus and stratocumulus clouds in global climate change.

Point Reyes is located at the edge of an abrupt and steep continental margin where cold ocean currents rise up from the ocean bottom. The ocean provides the moisture, and cold ocean currents provide some of the refrigeration needed to condense water droplets in the air above. Often, the refrigerated air near the surface is trapped by a layer of warm, descending air from above.

As the cool upwelling air meets the warmer descending air, they mix and form clouds. They will, occasionally, contain ice crystals and can persist for a long time, depending on how stable the top layer is. When these clouds hug the ground, we call it fog. The uniform top and bottom of the clouds gives them a blanket-like appearance, although rifts or long narrow patches where the stratus appear to be thinner, do occur. In many circumstances, you can hike to elevations above the stratus to take in the sunshine. There you might see the sun "burn off" the clouds, especially around noon or just after. During the warmest part of the day, the heating of the cloud by sunlight causes some of the droplets to evaporate and, in addition, creates a warm non-moving layer of air below the cloud,



Point Reyes National Seashore

shutting down the competition between upwelling and down welling forces critical to the formation of cloud droplets. In some cases, all of the cloud evaporates; other times, there is hardly any cloud thinning at all. (More information about the AMF can be found on page five.)

No Dust, No Clouds

Clouds are made of water droplets right? Well, yes, but without dust, sea salt particles, pollution or other tiny particles, clouds would be a rare occurrence! The general term for small particles in the atmosphere is *aerosols*. Those aerosols that give rise to cloud droplets are called *cloud condensation nuclei*. Aerosols can be water loving (hygroscopic), or when they have no chemical affinity for water, hygrophobic. Imagine air without aerosols, only water vapor. Would we ever see clouds? In natural settings, no aerosols means no clouds. A water molecule is 4×10^{-8} cm in diameter. In addition, the molecules are not chemically attracted to each other. The air must be extremely supersaturated to force these very tiny molecules to come together. For this to happen, the concentration of water vapor must be equivalent to relative humidity of 400% or greater; a condition that never happens in natural settings on Earth. However, when hygroscopic aerosols like sea salt are present, chemical interactions can take place between the aerosols and the water vapor in the air. This interaction favors the condensation of water and the formation of droplets.

A similar process happens with salt in a table salt shaker as it scavenges water vapor from the air in the room. When hygrophobic aerosols are present, the surfaces of the solid particles are wetted by water vapor. This is another circumstance that favors condensation. Aerosols, or cloud condensation nuclei, come from many sources. Sea salt particles arise from sea spray and the bursting of ocean water bubbles. Mineral dust aerosols come from wind blown dirt areas, volcanoes and remnants of meteorites. Pollen grains and bacteria are examples of organic aerosols. Other biologic sources include partially decomposed plant matter from wind blown areas and carbon-rich soot from bush fires or biomass burning. Furthermore, there are man-made aerosols. The incomplete burning of gasoline and other petrochemical products produces additional soot aerosols. Sulfate and nitrate compounds also occur as cloud condensation nuclei.

Clouds in Our Future

Our climate is changing and the clouds will change as well. As the Earth warms, clouds may become more or less frequent, higher, lower, thicker, or thinner. Furthermore, these changes may slow climate change or speed it up. We might experience more severe storms or fewer. While scientists have some ideas about the future of clouds, they just don't know for sure. Because these changes are so profound and because cloudiness plays such a significant part of understanding global warming and cooling, clouds are extensively studied by the ARM Program.

Some studies focus on the broad aspects of clouds like: What is the fraction of the sky covered by clouds? How does this change throughout the day, from day to day, and from season to season? A number of instruments are used at the ARM Mobile Facility site to make these measurements. The most familiar is a radar instrument similar to weather radar used to track precipitation. Of particular interest is the millimeter cloud radar (MMCR). This instrument can provide information about the height of both the bottom and top of the clouds, and hence, its thickness. Radars transmit radio waves that reflect off the droplets or ice crystals higher in the cloud. The reflected radar waves from the top most droplets/ice crystals show the upper boundary of the cloud. Laser devices that transmit and receive reflected electromagnetic energy at visible and near infrared wavelengths provide much of the same information and often times complementary information. For instance, another instrument, the ceilometer, can be used to determine the properties of aerosols below clouds but cannot determine the top of thick clouds.

Another important area of cloud research concerns the microphysical properties of clouds. The microscopic world of aerosol-water vapor interaction that leads to the formation of water drops, rain, ice crystals, and snow is a complicated one. For instance, if more condensation nuclei are present, a stratus cloud will tend to have more, smaller droplets than one with fewer condensation nuclei. Clouds are almost never made up of droplets of a single size, nor are they made up of ice crystals of a single size. The MMCR allows ARM scientists to determine the various diameters of the droplets and ice crystals present. Sometimes both water droplets and ice crystals are present within the same clouds. The number and size of droplets and ice crystals are important because these factors have an impact on how much sunlight reaches the Earth's surface below the cloud. Our weather and climate are driven by heat from the sun.

The overall challenge for cloud-climate research is a quantitative understanding of the exchange of heat between Earth and atmosphere during day and night for all cloud types and for the variations within cloud types.

by Mary Jane Bartholomew

Teacher's Notes

High Clouds: Cirrus

Cirrus clouds are thin, wispy clouds blown by high winds into long streamers. They are considered "high clouds" forming above 6000 m (18,000 ft). Cirrus clouds usually move across the sky from west to east. They generally mean fair to pleasant weather.

Cirrocumulus clouds appear as small, rounded white puffs. The small ripples in the cirrocumulus sometimes resemble the scales of a fish.

Middle Clouds: Altostratus

Altostratus clouds are gray or blue-gray middle level clouds composed of ice crystals and water droplets. These clouds usually cover the entire sky. In the thinner areas of the cloud, the sun may be dimly visible as a round disk. Altostratus clouds often form ahead of storms that will produce steady precipitation.

Altocumulus clouds are middle level clouds that form between 1,829 and 6,096 m (6000-20,000 ft). They are made of water droplets and appear as gray, puffy masses, sometimes rolled out in parallel waves or bands. The appearance of these clouds on a warm, humid summer morning often means thunderstorms may occur by late afternoon.

Low Clouds: Stratus

Forming below 1,829 m (6,000 ft), stratus clouds are uniform grayish clouds that often cover the entire sky. They resemble fog that does not reach the ground. Usually no precipitation falls from stratus clouds, but sometimes they may drizzle. When a thick fog "lifts," the resulting clouds are low stratus.

Stratocumulus clouds generally appear as a low, lumpy layer of clouds that is sometimes accompanied by weak precipitation. Stratucumulus vary in color from dark to gray to light gray and may appear as rounded masses or rolls with breaks of clear sky in between.

Vertically Developed Clouds: Cumulus

Cumulus clouds are puffy clouds that sometimes look like pieces of floating cotton. The base of each cloud is often flat and may be only 1000 m (330 ft) above the ground. The top of the cloud has rounded towers.

When the top of the cumulus resembles the head of a cauliflower, it is called cumulus congestus or towering cumulus. These clouds grow upward, and they can develop into a giant cumulonimbus, which is a thunderstorm cloud.

Hands-on Activity: Students can make their own cloud charts using poster board, cotton, colored pencils, paper and other materials. Hang the cloud charts in the classroom, school library, community building, or arrange for the students to present their charts to younger students at their school.

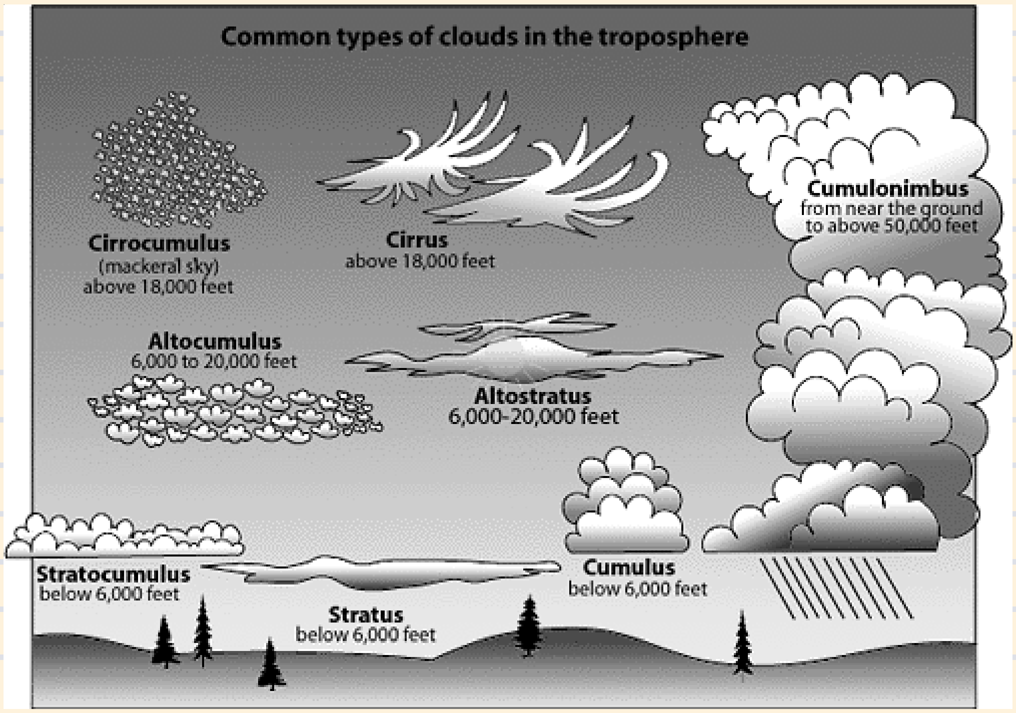


Chart and cloud descriptions can be found at http://www.ucar.edu/educ_outreach/webweather/

Cloud Craze!

Principle

Clouds are masses of condensed water vapor which are visible signs of atmospheric processes at work. Clouds help regulate Earth's energy balance by reflecting and scattering solar radiation and by absorbing the Earth's infrared radiation. In addition, clouds help redistribute surplus heat from the equator toward the poles and return water (in the form of precipitation) to the oceans and land masses across the globe.

The importance of clouds

Clouds are essential to the earth-atmosphere system. Clouds complete the following functions:

1. On Earth we get energy from the sun's light. As you know, it gets hot outside if the sun is shining brightly on a summer day. The reason it warms up is because the Earth is absorbing some of that solar energy. However, not all the energy is absorbed. Some energy is reflected back into space in the form of light. Clouds help regulate the Earth's energy balance by reflecting and scattering solar radiation and by absorbing Earth's infrared energy.

2. Clouds are required for precipitation to occur and hence are an essential part of the hydrologic cycle. The hydrologic cycle is the description of the transport of water substance between the Earth, atmosphere, and seas. The stages of the hydrologic cycle are: evaporation, condensation, precipitation, and collection.

3. Clouds indicate what type of atmospheric processes are occurring (e.g., cumulus clouds indicate surface heating and atmospheric turbulence).

4. Clouds help redistribute extra heat from the equator toward the poles.

Making a Cloud

Clouds are formed when water vapor is condensed into liquid water (water droplets). There are three requirements for clouds to occur:

1. Water vapor must be present in sufficient amounts so that saturation can be reached by some means.

2. Cloud condensation nuclei (CCN) must be present to provide a surface on which water will condense. Examples of CCN include dust in the air from Earth's surface, salt particles from the sea, combustion products, and volcanic or meteorite dust.

3. A cooling mechanism is required to cool the air temperature to the dew point temperature. The requirements for sufficient water vapor and CCN are rarely the limiting factors for cloud development. Typically, the limiting factor is a cooling mechanism. Thus, the air temperature needs to be lowered to the dewpoint temperature for a cloud to form. If a cooling mechanism is not present, clouds will not form.

Critical Thinking Questions

How do you find out what the weather will be like tomorrow? Do you listen to the radio, watch the news on television, or ask somebody in your community?

Challenge students to making their own weather predictions based strictly on cloud observations. Students will research the kind of weather each cloud type typically signals and use this information to guide their weather predictions. A weather journal can be created to keep track of observations.

What do the shape and color of clouds tell you about the weather?

Ask students to observe cloud types every day for a one or two week period. Students will use the scientific names to identify clouds and record their observations in a weather journal. Daily entries will include the cloud type and description of weather, as well as the date and time of the observation. If possible, students can make two or three observations daily, especially if weather conditions change throughout the day.

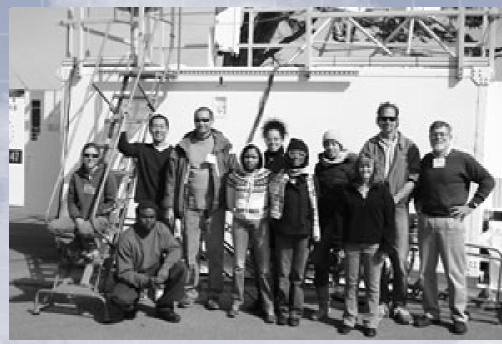
What instruments do scientists use to study cloud properties?

Students can visit the ARM web site at www.arm.gov for a list of instruments used to study clouds at the ARM sites. Students can choose one instrument and write to Ask a Scientist, at the ARM Education Center web page, to find out how scientists use that instrument. Encourage students to share their answers with the class, along with a picture of the instrument they chose.

ARM Mobile Facility: Science on the Go

The Atmospheric Radiation Measurement Program (ARM) Climate Research Facility maintains research sites in Oklahoma, Alaska, and the Tropical Western Pacific to obtain measurements of cloud and radiative properties, which are used to improve climate models.

In addition to these fixed sites, the **ARM Mobile Facility** (AMF) will now enable ARM scientists to collect data from other locations around the world. The AMF is a flexible instrument platform for conducting atmospheric experiments lasting from 6 to 18 months in any environment, from the cold of the Arctic to the heat of the Tropics.



AMF observers and training instructors pause for a group picture at the Point Reyes site.

You and your students can track the AMF as it travels to new and exciting locations. Each deployment of the AMF will provide opportunities to learn about different regions of the Earth's climate system.

On March 12, 2005, full-time operations of the AMF site commenced at Point Reyes, California. Following a week long training session led by ARM's Amon Haruta and Barry Lesht, nine newly appointed observers began maintaining site operations 24 hours a day, seven days a week, working in teams of two. Their duties include launching four weather balloons and monitoring site instruments daily.

In 2006, the AMF heads to West Africa to join the African Monsoon Multidisciplinary Analysis (AMMA) experiment. Stay tuned for more news about AMF adventures!

Make a Portable Cloud

The purpose of this experiment is to observe how moisture, cooling, temperature and condensation nuclei play a role in cloud formation.

Materials

Gallon jar; hot and cold water; food coloring; rubber glove, matches, lamp, rubber band

Make it happen

1. Pour 100 ml of cold water into the jar. Add food coloring to the water.
2. Swirl the water in the jar for one minute to allow some water to evaporate.
3. Stretch the open end of a rubber glove over the mouth of the jar, with the glove fingers hanging down into the jar.
4. Place a rubber band around the mouth of the jar to secure the glove.
5. Turn on the lamp so it shines through the jar.
6. Insert your hand into the glove. Pull quickly outward without disturbing the jar's seal. Record your observations.
7. Quickly push your hand back down into the jar.
8. Carefully remove the glove from the jar.
9. Drop a lit match into the jar and quickly seal it again with the rubber glove as before.
10. Insert your hand into the glove. Pull quickly outward without disburbing the jar's seal. Record your observations.
11. Repeat the entire process using hot tap water instead of cold.

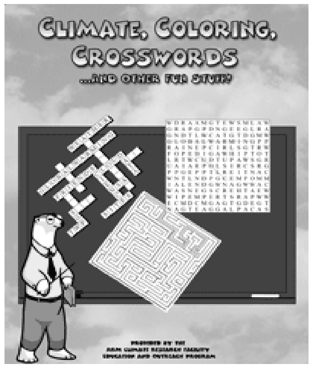
What do you see happening inside the jar?

Water vapor is created as water heats under the lamp. Swirling the water also helps water molecules to move into the air from the water's surface. When you pull the glove out of the jar, the air pressure is lowered inside the jar. The jar contains the same number of air molecules, but they have more space between them (they are less dense). Molecules collide with each other less frequently and slow down, causing the air temperature to go down. When you press the rubber glove into the jar, you are increasing the air pressure. The air becomes denser as the molecules are crowded together. This also causes the air to heat up as molecules collide with each other more often. The smoke particles provide tiny nuclei on which water vapor molecules condense, when the air temperature cools. This forms a little cloud.

This activity is courtesy of the Web Weather for Kids web site at http://www.ucar.edu/educ_outreach/webweather/

ACRF Activity Book Wins Award of Distinction

The *Climate, Coloring, Crosswords…and Other Fun Stuff* activity book was recently honored with an Award of Distinction in the 2005 international Communicator Awards competition. Since its debut in January 2005, the activity book has been a huge success among students and teachers.



Professor Polar Bear, Teacher Turtle and PI Prairie Dog are mascots that represent the ARM research facilities at the North Slope of Alaska, Tropical Western Pacific and Southern Great Plains, respectively. These mascots are the stars of the activity book, which gives students an introduction to the ARM Program as well as basic information about climate studies. Students are challenged with tricky word searches and puzzles, focused on a variety of topics such as cloud types and climate patterns. Additional activities include coloring pages, mazes, and dot to dot. The entire book can be downloaded from the Education Center web page (http://education.arm.gov).

The Communicator Awards recognize outstanding work in the communication field. More than 5,000 entries from throughout the United States and several foreign countries were submitted to the competition in various categories. Approximately 19 percent of the entries received an Award of Distinction, given for work that exceeds industry standards in communicating a message or idea.

Archive a New Learning Tool for Arctic Community

As an extension of the *Climate Change: Science and Traditional Knowledge* kiosk developed by ACRF Education and Outreach, a DVD archive of kiosk interviews is now available to students, teachers, and the community of Barrow, Alaska. Footage from the filming process for the North Slope of Alaska (NSA) kiosk has been integrated into an archive of 305 video clips from 28 interviewees. Designed to run on a personal computer, users can search the archive for video clips by an interviewee's name or a topic of interest.

During the first week of May, NSA site manager Bernie Zak and ACRF Education and Outreach staff will present the archive to the Iñupiat Heritage Center (IHC) in Barrow. The IHC was a collaborator on the kiosk project by facilitating discussions between ACRF Education and Outreach and community elders, leaders, educators and students. The interactive kiosk, in place at the IHC since October 2003, is a tool to help the public learn about climate change from both scientific and indigenous perspectives.

Because not all the interviews taken during the filming process could be included in the kiosk, the *Climate Change: Science and Traditional Knowledge* ***Archive*** was developed to make the valuable information easily accessible to teachers, students, and the public. The archive is an excellent resource for teaching basic climate concepts as well as history, cultural studies, and social studies.

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