Atmospheric Radiation Measurement
Climate Research Facility
U.S. Department of Energy

Climate Education Update

NEWS AND INFORMATION ABOUT CLIMATE CHANGE FOR TEACHERS AND STUDENTS

IN A FOG

H. Michael Mogil, Certified Consulting Meteorologist

In April 2008, scientists from the Atmospheric Radiation Measurement (ARM) Program conducted an experiment using an airplane that flew over Barrow, Alaska, where the North Slope Alaska ARM Climate Research Facility is located. Throughout the experiment, they were based out of Fairbanks, about 500 miles inland from Barrow. Instruments on the aircraft and at Barrow allowed the scientists to obtain various measurements from the sky, including atmospheric conditions that create **fog**.

On their return, some of the ARM team members participated in *Science Potpourri*, an annual science fair held at the University of Alaska at Fairbanks that features hands-on demonstrations of various earth sciences. They showed kids how to measure raindrops using flour and a squirt bottle, and how to create a "cloud in a cup" using salt and soda pop.

Greg McFarquhar explains precipitation and other weather phenomena to students at the science fair in Fairbanks, Alaska. Photo by Lynne Roeder, Pacific Northwest National Laboratory.

SO WHAT IS FOG?

Fog is simply a cloud in contact with the ground. Fog forms most often at night when the Earth radiates energy out into space, allowing the ground to chill.

Any object not at **Absolute Zero** radiates energy. Radiation given off by the Earth is primarily in the form of infrared energy; the Sun, at a much hotter temperature, radiates most of its energy in the visible part of **electromagnetic spectrum** (http://science.hq.nasa.gov/kids/imagers/ems/index.html).

The air near the ground is then cooled by **conduction,** or heat transfer by contact. As a result, the air near the ground may cool to its **dew point,** causing water droplets to form on ground-based objects (dew) or on small, solid particles in the air near the ground (fog). This process, known as **condensation,** involves water changing from its gaseous state into its liquid state.

Radiation loss is greatest when nights are long, skies are clear, and the air is very dry. These conditions often are present in interior Alaska, especially during the snowy winter months.

Fog lies across suburban Boston, MA, on an early fall morning. The fog is already beginning to dissipate thanks to solar heating at the time of this image. Photo by H. Michael Mogil

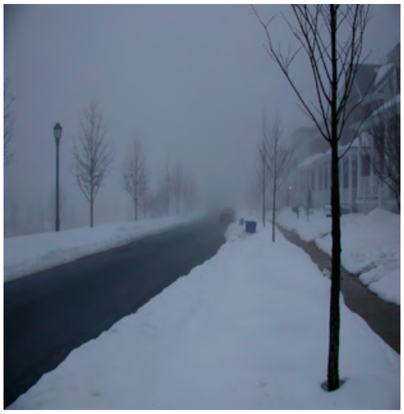
Snow is an effective radiator of energy. Temperatures often plummet when the ground is snow covered and the conditions mentioned above also are present.

Fog also can form when warm air moves over cold ground, water, or snow cover (**advection fog**) and when cold rain falls into warm air, chilling and moistening the air. Sometimes fog forms when cold air moves across warm water. The air becomes moistened and heated from below, much like what happens when a pot of water is heated to boiling.

A similar effect happens when chilly rain or hail falls on hot pavement during a summer thunderstorm. Both allow streamers of clouds to rise from the surface in what is commonly referred to as **steam fog**.

ICE FOG

A special type of fog, called **ice fog,** forms when temperatures are very cold (as low as about -35° F). Instead of liquid cloud droplets forming, the water vapor in the air transforms immediately into ice crystals, a process known as **deposition.**



Advection fog (warm air moving over cold snow cover) created this foggy scene. Photo by H. Michael Mogil

INVERSIONS

Fog often forms in a layer, with warmer temperatures overlying the colder temperatures closest to the ground. This vertical temperature profile is known as an **inversion** because temperatures usually get colder as one goes up into the lower atmosphere, called the troposphere. This "inverted" temperature profile is also considered to be stable because vertical air motions are inhibited.

Sometimes the fog layer can be very thin, maybe not even as high as an average person standing. This is called **ground fog.** As the fog thickens, it is simply called fog.

This thin layer of ground fog was barely 5 ft thick. With solar heating, this fog will evaporate in minutes. Photo by H. Michael Mogil

When the sun rises, it starts heating the outer edges and top of the fog area, eventually evaporating it. However, in places like interior Alaska, where sunlight may be limited or even non-existent for long periods, fog can last for days.

In California's Central Valley, winter can bring extended periods of fog, too. When a storm system moves eastward from the coast, rain-cooled air can remain trapped between mountain ranges as a high-pressure system with warmer air aloft moves in.

Dense fog fills the western part of California's Central Valley in November 2002. Fog has either dissipated or not formed elsewhere in the area. The snow-covered peaks of the Sierra Nevada Mountains lie to the east of the fog area. Photo by NASA

Fog can persist for days. Even though the fog may evaporate partially during daylight, it often reforms at dusk. Another storm system is often necessary to dissipate the long-lasting fog.

DEFINITIONS

Absolute Zero: the lowest possible temperature where nothing could be colder and no heat energy remains in a substance.

advection fog: occurs when moist air passes over a cool surface by advection (wind) and is cooled.

condensation: when water vapor in the air transforms into liquid water.

conduction: the transmission of heat directly across or through matter.

deposition: when water vapor in the air transforms immediately into ice crystals.

dew point: the temperature to which a given parcel of air must be cooled, at constant barometric pressure, for water vapor to condense into water.

electromagnetic spectrum: the complete range of frequencies of electromagnetic waves including radio, infrared, visible light, ultraviolet, X-ray, gamma ray, and cosmic rays.

fog: a cloud in contact with the ground.

ground fog: fog that obscures less than 60% of the sky and does not extend to the base of any overhead clouds.

ice fog: any kind of fog where the water vapor in the air has frozen into extremely tiny crystals of ice.

inversion: air temperature increasing with height.

steam fog: the most localized form of fog, created when moisture evaporates from heated land or water into cooler air.

For more information:

Edward Lorusso, PhD
ARM Education Outreach Director
Los Alamos National Laboratory
505-665-3618
lorusso@lanl.gov

LA-UR-08-04898

UNDERSTANDING INVERSIONS

Background

When placing any two fluids (either two liquids or two gases) in proximity, the fluids will want to stratify or layer according to their densities (mass per volume). The variation in density can be linked to either what is dissolved in each liquid or the temperature of the two liquids or gases. The denser fluid will settle to the bottom; the warmer fluid will rise to the top, creating an inversion because it is opposite or inverted from what a typical temperature profile looks like in the lower atmosphere.

Creating an Inversion (Demonstration)

Objective

The objective is to create an inversion and show that it is stable (up and down motion is inhibited).

Materials

- ❑ A clear container at least 3 inches tall
- ❑ Tea or coffee at room temperature (any other type of colored water, including water with food coloring, will do)
- ❑ Cold milk (small amount)

Important Points to Understand

The milk in this demonstration is both colder and denser than the colored liquid into which it is being poured.

Procedure

1. Fill the container about two-thirds full with the colored liquid.

2. Gently pour some milk into the colored fluid (near the edge of the container) and allow it to settle.

Questions

1. Before pouring the milk into the colored fluid, ask students what they think will happen and why.

2. After observing the results of the pour, what do students notice? Can they explain how the fluid Layering replicates an atmospheric inversion?

Rain Falls on the Ocean (Activity)

Objective

The objective is to demonstrate what happens when fresh rainwater falls on salty ocean water. This activity presumes that the temperature of both liquids is about the same and that waves are not present to mix the fluids.

Materials

- ❑ Small clear containers (preferably taller than wider)
- ❑ Salt water (either from the ocean or mixed up by teacher)
- ❑ Colored fresh water (use food coloring, coffee, or tea to color)
- ❑ Pipettes or spoons

Important Points to Understand

The rainwater in this demonstration is less dense than ocean salt water. Less dense fluids will remain on top of more dense fluids.

Procedure

1. Fill the container two-thirds full with the salt water.

2. Gently drip some colored water onto the salt water. Students can also gently push small drops of colored water off a spoon into the salt water. Have students watch from the side of the container. The fresh water should sink into the salt water and then rise to the top of the salt water.

3. Continue for several minutes until a well-defined layer of colored water sits on top of the salt water.

Questions

1. Before dripping the colored fluid into the salt water, ask students what they think will happen.

2. What do students notice? Can they again explain how the fluid layering replicates an atmospheric inversion?

3. Why did the fresh water drops first sink into the salt water and then rise?

Extension Activity

Repeat the student activity. Change variables, making the salt water warmer than the fresh water. Observe what happens and compare to the classroom activity.