The Atmosphere
Teachers Guide
National Weather Service Shreveport

Slide 1: Introduction

Slide 2: Course outline

Slide 3: The atmosphere is a cloud of gas and suspended solids extending from the Earth's surface out many thousands of miles, becoming increasingly thinner with distance but always held by the Earth's gravitational pull. The atmosphere is made up of layers surrounding the earth that holds the air we breath, protects us from outer space, and holds moisture (clouds), gases, and tiny particles. In short, the atmosphere is the protective bubble we live in.

This protective bubble consists of several gases (below) with the top four making up 99.998% of all gases. By far, the most common, **nitrogen**, dilutes oxygen and prevents rapid burning at the earth's surface. Living things need it to make proteins. **Oxygen** is used by all living things and is essential for respiration. It is also necessary for combustion or burning. **Argon** is used in light bulbs. Plants use **carbon dioxide** to make oxygen. Carbon dioxide also acts as a blanket and prevents the escape of heat into outer space.

Slide 4: The envelope of gas surrounding the Earth changes from the ground up. Five distinct layers have been identified using thermal characteristics (temperature changes), chemical composition, movement, and density. Each of the layers are bounded by "pauses" where the maximum changes in thermal characteristics, chemical composition, movement, and density occur.

Troposphere
The troposphere begins at the Earth's surface and extends up to 4-12 miles (6-20 km) high. This is where we live. As the gases in this layer decrease with height, the air becomes thinner. Therefore, the temperature in the troposphere also decreases with height. As you climb higher, the temperature drops from about 62°F (17°C) to -60°F (-51°C). Almost all weather occurs in this region.

The height of the troposphere varies from the equator to the poles. At the equator it is around 11-12 miles (18-20 km) high, at 50°N and 50°S, 5½ miles and at the poles just under four miles high. The transition boundary between the troposphere and the layer above is called the tropopause. Both the tropopause and the troposphere are known as the lower atmosphere.

Stratosphere
The Stratosphere extends from the tropopause up to 31 miles above the Earth's surface. This layer holds 19 percent of the atmosphere's gases but very little water vapor.

Temperature increases with height as radiation is increasingly absorbed by oxygen molecules which leads to the formation of Ozone. The temperature rises from an average -76°F (-60°C) at tropopause to a maximum of about 5°F (-15°C) at the stratopause due to this absorption of ultraviolet radiation. The increasing temperature also makes it a calm layer with movements of the gases slow.

The regions of the stratosphere and the mesosphere, along with the stratopause and mesopause, are called the middle atmosphere by scientists. The transition boundary which separates the stratosphere from the mesosphere is called the stratopause.

Mesosphere
The mesosphere extends from the stratopause to about 53 miles (85 km) above the earth. The gases, including the oxygen molecules, continue to become thinner and thinner with height. As such, the effect of the warming by ultraviolet radiation also becomes less and less, leading to a decrease in temperature with height. On average, temperature decreases from about 5°F (-15°C) to as low as -184°F (-120°C) at the mesopause. However, the gases in the mesosphere are thick enough to slow down meteorites hurtling into the atmosphere, where they burn up, leaving fiery trails in the night sky.

Thermosphere
The Thermosphere extends from the mesopause to 430 miles (690 km) above the earth. This layer is known as the upper atmosphere. The gases of the thermosphere are increasingly thinner than in the mesosphere. As such, only the higher energy ultraviolet and x-ray radiation from the sun is absorbed. But because of this absorption, the temperature increases with height and can reach as high as 3,600°F (2000°C) near the top of this layer.

However, despite the high temperature, this layer of the atmosphere would still feel very cold to our skin because of the extremely thin air. The total amount of energy from the very few molecules in this layer is not sufficient enough to heat our skin.

Slide 5: In order to measure the conditions of the lower atmosphere, the National Weather Service utilizes an upper air network across the country. Pictured here is an upper air site in Shreveport where weather balloons are release twice a day, in the morning and in the evening. The instruments pictured above measure temperature, relative humidity, pressure, and wind speed/direction at various levels from the ground up to over 50 thousand feet.

The data collected at each upper air site is used with other data sources in numerical weather models to help predict future weather patterns.

Slide 6: The balloons are filled with hydrogen and measure about 6 feet wide by 6 feet tall when released. When a balloon reaches nearly 50 thousand feet, the balloon has significantly increased in size. Sometimes when a widespread severe weather is expected or a hurricane is approaching the Gulf Coast, a special release may occur at select upper air sites in between the regularl scheduled times.

Slide 7: The atoms and molecules that make up the various layers in the atmosphere, despite their tiny size, actually exert some weight on us. We feel this weight as pressure. Air pressure is simply the weight of air *above* an object. The weight of air is directly related to the number of air molecules in a given volume. So, air pressure depends on the number of air molecules in a given volume *above* an object and how fast the molecules are moving.

From sea-level to the top of the atmosphere, the weight of all molecules *above* each square inch of any object (for example, a one inch by one inch piece of paper), is about 14.7 pounds.

That is a lot of weight considering it is just molecules. However, it is also a lot of molecules. Near sea-level, a box with a volume of one cubic inch (1 inch x 1 inch x 1 inch) contains around 400 sextillion air molecules (400 followed by 21 zeros).
As elevation increases, the number of molecules decreases and the weight of air therefore is less, meaning a decrease in air pressure. In fact, while the atmosphere extends more than 15 miles (24 km) up, one half of the air molecules in the atmosphere are contained within the first 18,000 feet (5.6 km).

Because of this decrease in pressure with height, it makes it very hard to compare the air pressure at one location to another, especially when the elevations of each site differ. Therefore, to give meaning to the pressure values observed at each station, we need to convert the station air pressures reading to a value with a common dominator. The common dominator we use is the sea-level. At observation stations around the world, through a series of calculations, the air pressure reading, regardless of the station elevation, is converted a value that *would* be observed if that instrument were located at sea level.

The two most common units in the United States to measure the pressure are "Inches of Mercury" and "Millibars". Inches of mercury refers to the height of a column of mercury measured in hundredths of inches.

Millibars comes from the original term for pressure "bar". Bar is from the Greek "báros" meaning weight. A millibar is 1/1000th of a bar and is the amount of force it takes to move an object weighing a gram, one centimeter, in one second. Millibar values used in meteorology range from about 100 to 1050. At sea level, standard air pressure in millibars is 1013.2. Weather maps showing the pressure at the surface are drawn using millibars.

Slide 8: The amount of air over us is constantly changing. As a result, the weight of that air, called pressure, is constantly changing. These changes in air pressure are indications of changes in our weather. We measure this change using a device called barometer (bar-meter or measurer).

This first barometer was created by Evangelista Torricelli in 1643. Torricelli was actually trying to discover the reason that water would rise no more than 33 feet up a tube though the use of a suction pump. He had first built a water barometer, but it required a glass tube 60 feet long. Aware that mercury was 14 times heavier than water, he constructed a tube only 35 inches long. Filing the tube with mercury and inverting the tube into a bowl of mercury caused mercury in the tube to drop to a level around 30 inches and creating a vacuum at the top of the tube.

The top of the mercury column was observed to fluctuate by a few percent, due mainly to what we now know to be fluctuations in atmospheric pressure. This is because as the column of air directly above the barometer pushes on a dish containing mercury, it is forced up a tube. The stronger the downward push, the higher the pressure and therefore the higher the mercury rises in the tube. This is where the unit "Inches of Mercury" comes from.
The aneroid barometer is the most common type of barometer for home use. The aneroid cell volume is very sensitive to changes in atmospheric pressure as it expands and contracts as air pressure decreases or increases. Attached to the aneroid cell is a lever indicating the air pressure.
In this barometer, high pressure in the atmosphere will weigh more the pressure inside the can at the time the barometer was constructed. That added weight will force the plastic wrap into the can, causing the straw tip to rise, indicating higher pressure.

The opposite will occur when low pressure is in the area. The decrease in weight of air on top of the can will help cause the plastic wrap to rise, therefore lowering the straw tip.

Slide 9: The scientific unit of pressure is the Pascal (Pa) named after after Blaise Pascal (1623-1662). One pascal equals 0.01 millibar or 0.00001 bar. Meteorology has used the millibar for air pressure since 1929. When the change to scientific unit occurred in the 1960's many meteorologists preferred to keep using the magnitude they are used to and use a prefix "hecto" (h), meaning 100.

Therefore, 1 hectopascal (hPa) equals 100 Pa which equals 1 millibar. 100,000 Pa equals 1000 hPa which equals 1000 millibars. The end result is although the units we refer to in meteorology may be different, there value remains the same. For example the standard pressure at sea-level is 1013.25 millibars and 1013.25 hPa.

Slide 10: The most basic change in pressure is the twice daily rise and fall in due to the heating from the sun. Each day, around 4 a.m./p.m. the pressure is at its lowest and near its peak around 10 a.m./p.m. The magnitude of the daily cycle are greatest near the equator decreasing toward the poles.

On top of the daily fluctuations are the larger pressure changes as a result of the migrating weather systems. These weather systems are identified by the blue H's and red L's seen on weather maps. The H's represent the location of the area of highest pressure. The L's represent the position of the lowest pressure.

Slide 11: Experiments

Slide 12: Capped Bottle eventually collapsed. WHY?
Answer: Air inside that bottle cooled off. Cooling takes place because the atoms inside the bottle loose energy as they collide with the bottle side that is exposed to the cooler surrounding air.

But why did it collapse?
Answer: As atoms loose energy…their velocity decreases resulting in a decrease of pressure in the bottle. Since the pressure inside the bottle is less than outside…the bottle is crushed.

The uncapped bottle remains unchanged. WHY?
Answer: As air cools inside the bottle, outside air moves into the bottle to equalize the pressure on both sides.

Slide 13: Air flows from high to low pressure. The air blown between the cans created an area of low pressure between the cans and induced high pressure surrounding the cans. This caused the cans to move from high to low pressure. This is known as Bernoulli's Principle**.**

Slide 14: The heat source for our planet is the sun. Energy from the sun is transferred through space and through the earth's atmosphere to the earth's surface. Since this energy warms the earth's surface and atmosphere, some of it is or becomes heat energy. There are three ways heat is transferred, into the atmosphere, radiation, conduction, and Convection.

Slide 15: If you have stood in front of a fireplace or near a campfire, you have felt the heat transfer known as radiation. The side of you nearest the fire warms, while your other side remains unaffected by the heat. Although you are surrounded by air, the air has nothing to do with this transfer of heat. Heat lamps, that keep food warm, work in the same way. Radiation is the transfer of heat energy by electromagnetic radiation.

Most of the electromagnetic radiation that comes to the earth from the sun is in the form of visible light. Light is made of waves of different frequencies. The frequency is the number of instances that a repeated event occurs, over a set time. In electromagnetic radiation, the frequency is the number of times an electromagnetic wave moves past a point each second.

Our brain interprets these different frequencies into colors, including red, orange, yellow, green, blue, indigo, and violet. When the eye views all these different colors at the same time, it is interpreted as white. Waves from the sun which we cannot see are infrared, which have lower frequencies than red, and ultraviolet, which have higher frequencies than violet light.
Most of the solar radiation is absorbed by the atmosphere and much of what reaches the earth's surface is radiated back into the atmosphere to become heat energy. Dark colored

objects such as asphalt absorb more of the radiant energy and warm faster that light colored objects. Dark objects also radiate their energy faster than lighter colored objects.

Slide 16: Conduction is the transfer of heat energy from one substance to another or within a substance. Have you ever left a metal spoon in a pot of soup being heated on a stove? After a short time the handle of the spoon will become hot. This is due to transfer of heat energy from molecule to molecule or from atom to atom. Also, when objects are welded together, the metal becomes hot (the orange-red glow) by the transfer of heat from an arc. This is called conduction and is a very effective method of heat transfer in metals. However, air conducts heat poorly.

Slide 17: Convection is the transfer of heat energy in a fluid. This type of heating is most commonly seen in the kitchen when you see liquid boiling.

Air in the atmosphere acts as a fluid. The sun's radiation strikes the ground, thus warming the rocks. As the rock's temperature rises due to conduction, heat energy is released into the atmosphere, forming a bubble of air which is warmer than the surrounding air. This bubble of air rises into the atmosphere. As it rises, the bubble cools with the heat contained in the bubble moving into the atmosphere.

As the hot air mass rises, the air is replaced by the surrounding cooler, more dense air, what we feel as wind. These movements of air masses can be small in a certain region, such as local cumulus clouds, or large cycles in the troposphere, covering large sections of the earth. Convection currents are responsible for many weather patterns in the troposphere.

Slide 18: Short pop quiz

Slide 19: We measure the transfer of heat through thermometers, that is how hot or cold is it. The Cotton Region Shelter (CRS) houses a max/min thermometer. A CRS is typically a wooden structure with louvered sides, a slotted bottom and solid top. It is usually made of pine, painted white, and sits atop a wooden or metal base, 5 to 6 feet above the ground. The slates allow for air ventilation and protection from the sun so as to provide an accurate reading.

Slide 20: There are different scales of temperature measurement.

Fahrenheit temperature scale - The scale in which the temperature difference between two reference temperatures, the melting and boiling points of water, is divided into 180 equal intervals called degrees. The freezing point is taken as 32°F and the boiling point as 212°F.

Kelvin temperature scale - The scale having an absolute zero below which temperatures do not exist. Absolute zero, is the temperature at which molecular energy is a minimum, and it corresponds to a temperature of -273.15° on the Celsius temperature scale is the same size as the Celsius degree; hence the two reference temperatures for Celsius, the freezing point of water (0°C), and the boiling point of water (100°C), correspond to 273.15K and 373.15K, respectively.

Celsius temperature scale - The scale according to which the temperature difference between the reference temperatures of the freezing and boiling points of water is divided into 100 degrees. The freezing point is taken as 0 degrees Celsius and the boiling point as 100 degrees Celsius. The Celsius scale is widely known as the centigrade scale because it is divided into 100 degrees.

Slide 21: The earth-atmosphere energy balance is the balance between incoming energy from the Sun and outgoing energy from the Earth. Energy released from the Sun is emitted as shortwave light and ultraviolet energy. When it reaches the Earth, some is reflected back to space by clouds, some is absorbed by the atmosphere, and some is absorbed at the Earth's surface.
However, since the Earth is much cooler than the Sun, its radiating energy is much weaker (long wavelength) infrared energy. We can indirectly see this energy radiation into the atmosphere as heat, rising from a hot road, creating shimmers on hot sunny days. The earth-atmosphere energy balance is achieved as the energy received from the Sun *balances* the energy lost by the Earth back into space. In this way, the Earth maintains a stable average temperature and therefore a stable climate.

The absorption of infrared radiation trying to escape from the Earth back to space is particularly important to the global energy balance. Energy absorption by the atmosphere stores more energy near its surface than it would if there was no atmosphere. The average surface temperature of the moon, which has no atmosphere, is 0°F (-18°C). By contrast, the average surface temperature of the Earth is 59°F (15°C). This heating effect is called the greenhouse effect.

Slide 22: Greenhouse warming is enhanced during nights when the sky is overcast. Heat energy from the earth can be trapped by clouds leading to higher temperatures as compared to nights with clear skies. The air is not allowed to cool as much with overcast skies. Under partly cloudy skies, some heat is allowed to escape and some remains trapped. Clear skies allow for the most cooling to take place.

Slide 23: The greenhouse effect is the rise in temperature that the Earth experiences because certain gases in the atmosphere (water vapor, carbon dioxide, nitrous oxide, and methane, for example) trap energy from the sun. Without these gases, heat would escape back into space and Earth's average temperature would be about 60ºF colder. Because of how they warm our world, these gases are referred to as greenhouse gases.

The Green House Effect prevents heat loss mainly from convection (air movement carrying away the heat).

Slide 24: The Hydrologic Cycle involves the continuous circulation of water in the Earth-atmosphere system.

Of the many processes involved in the hydrologic cycle, the most important are evaporation, transpiration, condensation, precipitation, and runoff.

Evaporation

Evaporation is the change of state in a substance from a liquid to a gas. In meteorology, the substance we are concerned about the most is water. For evaporation to take place, energy is required. The energy can come from any source; the sun, the atmosphere, the earth, or objects on the earth such as humans.

Everyone has experienced evaporation personally. When the body heats up due to the air temperature or through exercise, the body sweats, secreting water onto the skin. The purpose is to cause the body to use its heat to evaporate the liquid, thereby removing heat and cooling the body. It is the same effect that can be seen when you step out of a shower or swimming pool. The coolness you feel is from the removing of bodily heat to evaporate the water on your skin.

Transpiration

Transpiration is the evaporation of water from plants through stomata. Stomata are small openings found on the underside of leaves that are connected to vascular plant tissues. In most plants, transpiration is a passive process largely controlled by the humidity of the atmosphere and the moisture content of the soil. *Of the transpired water passing through a plant only 1% is used in the growth process of the plant. The remaining 99% is passed into the atmosphere.*

Condensation

Condensation is the process whereby water vapor in the atmosphere is returned to its original liquid state. In the atmosphere, condensation may appear as clouds, fog, mist, dew or frost, depending upon the physical conditions of the atmosphere. Condensation is not a matter of one particular temperature but of a difference between two temperatures; the air temperature and the dewpoint temperature.

Slide 25: Hydrologic Cycle

Slide 26: Experiment

Slide 27 – 33: Questions

Slide 34: Acknowledgments