UNITED STATES MARINE CORPS

LESSON PLAN

CLOUD FORMATION

INTRODUCTION:

1. Gain Attention. Have you ever wondered what makes clouds or how they cover the whole sky? How they get so high in the sky and they look so far away? Well with the knowledge of this class you will soon know why and how.

2. Overview. During this period of instruction, the student(s) shall learn the different types of cloud formations and the process in which takes place to form a cloud.

3. Introduce Learning Objectives.

a. Terminal Learning Objective. Without the aid of reference, but in accordance with the instruction, the student(s) shall define and discuss the various ways in which clouds are formed.

b. Enabling Learning Objective(s). Without the aid of reference, but in accordance with the instruction, the student(s) shall:

(1) Define and discuss the ingredients necessary for the formation of cloud particles.

(2) State the three (3) lifting mechanisms that aid to cloud development.

(3) Define and discuss how radiational cooling enhances cloud development.

4. Method/Media. This period of instruction will be taught using the lecture method with the aid of a Macromedia Flash presentation "QMMPH1-Introduction to the Dynamics of the Atmosphere".

5. Evaluation. The student(s) shall not be evaluated at the conclusion of this period of instruction.

TRANSITION. Clouds are the visible portion of the sky and provide much of the day-to-day character of a region. When analyzing and forecasting the weather, understanding the microphysics of cloud formation, or how clouds form, is crucial. The following section discusses the necessary requirements that clouds need in order to develop.

1. Formation of Cloud Particles. Air is comprised mainly of nitrogen and oxygen, but also contains a small amount of water vapor. Clouds form when a parcel of air is cooled until the water vapor that it contains condenses to liquid form. Another way of saying this is that condensation, or clouds, occur when an air parcel is saturated with water vapor.

a. Saturation of the Air. The amount of moisture in a parcel of air is expressed in a variety of ways. The standard scientific measure is the partial pressure of water vapor.

(1) *Partial pressure* refers to the pressure exerted by only the water vapor part of the air parcel. The standard unit of measure is millibars (mb) and is typically a small fraction of total atmospheric pressure.

(2) The water vapor content can also be expressed as a mass *mixing-ratio*, that is, the mass of water vapor per total mass of air. Mixing ratio is usually expressed as grams water vapor per kilograms of air.

(3) The partial pressure of water vapor at the point of condensation is termed the *saturation pressure* (e_s). The saturation pressure of any air parcel is proportional to temperature and is described by the Clausius-Clapeyron equation, the figure below.

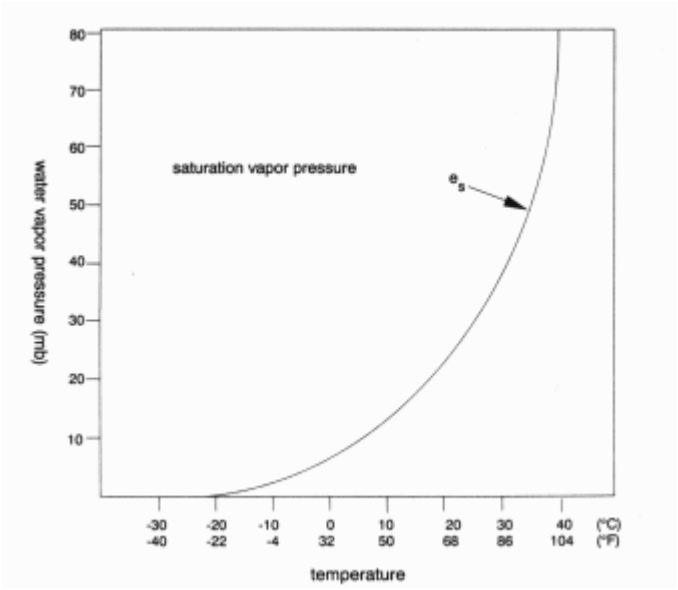


Figure 1 - Derived from the First Law of Thermodynamics, the Clausius-Clapeyron Equation states the dependence of saturation vapor pressure on temperature.

b. Cloud Condensation Nuclei (CCN). In the atmosphere, clouds can form at relative humidities of less than 100%. This is due to the presence of minute (0.1 - 2 micrometers in radius) water-seeking (hygroscopic) particles. Water vapor will stick to, and condense on, these particles to form clouds; hence the particles are termed cloud condensation nuclei (CCN).

(1) CCN occur naturally in the atmosphere. Sources of CCN include volcanoes that produce ash (dust) and sulfate particles, the oceans produce airborne sea salt particles, phytoplankton produce sulfate particles and wild fires contribute ash, soot, and dust.

(2) CCN can also result from human activities. In particular, CCN form as a byproduct of any combustion process. This includes motor vehicles emissions, industrial activities, and controlled fires.

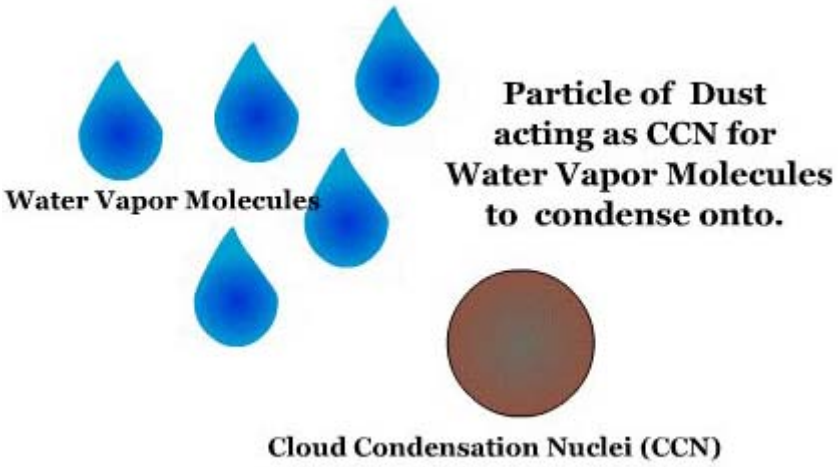


Figure 2 – Particles of dust, ash, or pollutants act as a solid for water vapor molecules to condense onto.

TRANSITION. Clouds may occur when air is cooled to near its dew point. The next section focuses on the three (3) ways that air-cools to the dew point temperature.

2. Cloud Formation Processes. Cooling the air at the surface may reduce the temperature to the dew point to form dew, frost, of fog, but in most cases, this occurs in a relatively thin layer at the surface resulting in a limited amount of condensation. The only way that a thick layer of air can be cooled enough to produce an extensive layer of clouds or precipitation is by adiabatic lifting and cooling. No matter how dry the air at the surface is, if it can be lifted to a level high enough, the temperature will eventually be dropped below the dew point and the condensation level will be reached. Once the air is lifted to this height, liquids water droplet become visible as clouds. Lifting the air can occur in one of four (4) ways: orographic (topographic) lifting, convective lifting, convergent lifting, or frontal lifting (*also call forced or cyclonic lifting*).

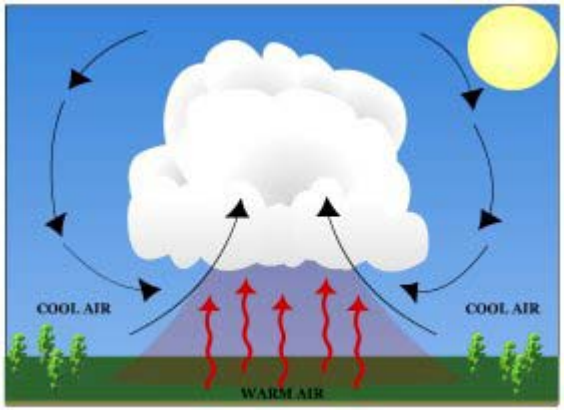
a. Types of Lifts.

(1) Orographic Lifting. Orographic uplift occurs when air is forced to rise because of the physical presence of elevated land. As the parcel rises it cools as a result of adiabatic expansion at a rate of approximately 10° Celsius per 1000 meters until saturation. The development of clouds and resulting heavy quantities of precipitation along the west coast of Canada are mainly due to this process.

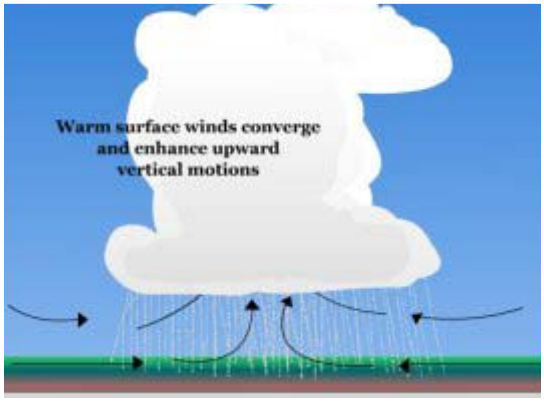
(2) Convectional Lifting. Convectional lifting is associated with surface heating of the air at the ground surface. If enough heating occurs, the mass of air becomes warmer and lighter than the air in the surrounding environment, and just like a hot air balloon it begins to rise, expand, and cool. When sufficient cooling has taken place saturation occurs forming clouds. This process is active in the interior of continents and near the equator forming cumulus clouds and or cumulonimbus clouds (thunderstorms). The rain that is associated with the development of thunderstorm clouds is delivered in large amounts over short periods of time in extremely localized areas.)

(3) Convergent Lifting. When winds at a particular level come together, or converge, the result is usually rising air due to the net gain in mass. The forced uplift cause instability and is likely to produce showery precipitation. Convergent lifting is frequently associated with cyclonic storms, particularly in the low latitudes such as the Intertropical Convergence Zone (ITCZ).

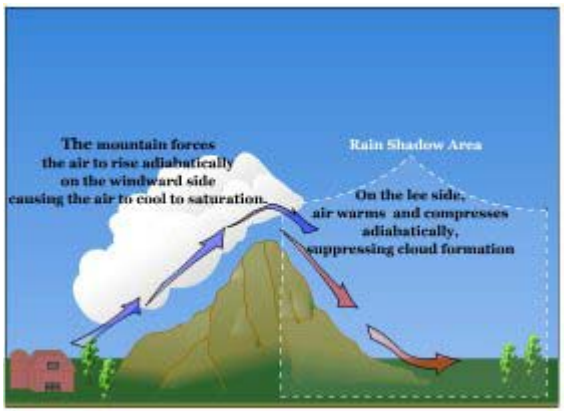
(4) Frontal Lifting. Convergence or frontal lifting takes place when two masses of air come together. In most cases, the two air masses have different temperature and moisture characteristics. One of the air masses is usually warm and moist, while the other is cold and dry. The leading edge of the latter air mass acts as an inclined wall or front causing the moist warm air to be lifted. Of course the lifting causes the warm moist air mass to cool due to expansion resulting in saturation. This cloud formation mechanism is common at the mid-latitudes where cyclones form along the polar front and near the equator where the trade winds meet at the intertropical convergence zone.



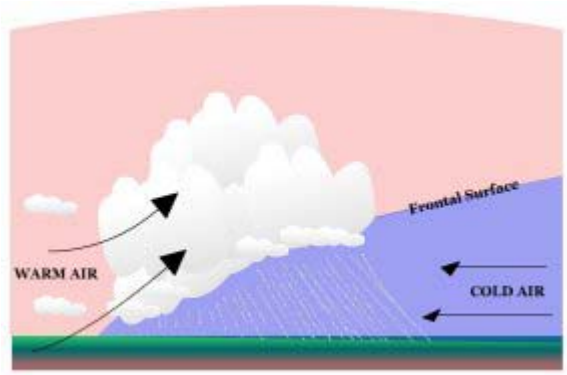
(a) Convective lifting.



(b) Convergent lifting.



(c) Orographic lifting.



(d) Frontal lifting (wedging).

Figure 2 – Illustration of the four (4) different types of lifting mechanism that aid in the cloud formation process.

b. Nocturnal Cooling. Radiative or nocturnal cooling occurs once the sun is no longer supplying the ground and overlying air with its solar energy. Instead, the surface of the Earth now begins to lose energy in the form of longwave radiation, which causes the ground and air immediately above it to cool faster than the air at higher altitudes. The clouds that result from this type of cooling take the form of surface fog (radiation fog) or low-level stratus.

TRANSITION. Lifting mechanisms are a main ingredient for cloud formation, as they aid air parcels in cooling to the dew point.

OPPORTUNITY FOR QUESTIONS:

1. Questions from the Class. At this time, are there any questions pertaining to the material that has just been presented to you?

2. Questions to the Class.

a. QUESTION. Name four (4) of the types of lifts for cloud formation?

b. ANSWER. Orographic, Convergence, Frontal, and Convectional lifting.

c. QUESTION. State the equation for determining relative humidity.

d. ANSWER. Vapor Pressure divided by Saturation Vapor Pressure.

e. QUESTION. Define Cloud Condensation Nuclei.

f. ANSWER. Minute (0.1 - 2 micrometers in radius) water- seeking (hygroscopic) particles.

SUMMARY: This period of instruction covered the ingredients and processes that are necessary for cloud formation. A solid understanding of how clouds form is needed in order to understand how clouds grow and to forecast the type of cloud the particles will grow into.

REFERENCE:

Cloud Formation Processes, Chapter 8 Introduction to the Hydrosphere. Dr. Michael Pidwirny. Department of Geography, Okanagan University College 1999-2004. Last updated 2/16/2004. Last accessed 8/9/2004. http://www.physicalgeography.net/fundamentals/8e.html

Clouds. Atmospheric Sciences Competency Activity Plans. Arlene S. Levine, Educational Director, Atmospheric Sciences Competency. Last updated 9/30/2002. Last accessed 8/9/2004. http://asd-www.larc.nasa.gov/edu_act/clouds.html.

Lydolph, Paul E. The Climate of the Earth. Rowman & Allanheld, 1985.