UNITED STATES MARINE CORPS

LESSON PLAN

TEMPERATURE BASICS

INTRODUCTION:

1. Gain Attention. Have you ever wondered wondered why it is cold at the North Pole year round, but extremely warm at the Equator year round?

2. Overview. In this class we will discuss the standard atmospheric temperature profile, the different types of inversions, temperature controls, and diurnal temperature changes.

3. Introduce Learning Objectives.

   a. Terminal Learning Objectives. With the aid of and in accordance with the references, discuss temperature as it relates to standard atmosphere, define an inversion, discuss the three types of inversions, discuss temperature controls, and state the effects of diurnal temperature changes.

   b. Enabling Learning Objectives. Without the aid of, but in accordance with the references:

      1) Utilize a Skew-T Log P Diagram to determine if there are any inversions. If inversions exist identify which type(s) of inversion(s) they are.

4. Method/Media. This period of instruction will be taught using the lecture method with aid of QMMCBT-001 "Introduction to the Dynamics of the Atmosphere".

5. Evaluation. You will be evaluated by a question and answer period upon completion of the lesson plan.

TRANSITION. Are there any questions over the material that will be covered, TLO's, ELO's, method/media, or how you will be evaluated upon completion of this period of instruction.

BODY:

1. Standard Atmosphere. Temperature, as it relates to the Standard Atmosphere, assumes a mean sea level temperature of 15°C, and an environmental lapse rate of 6.5°C per kilometer up to 11 kilometers in the atmosphere. (See figure 1 below)

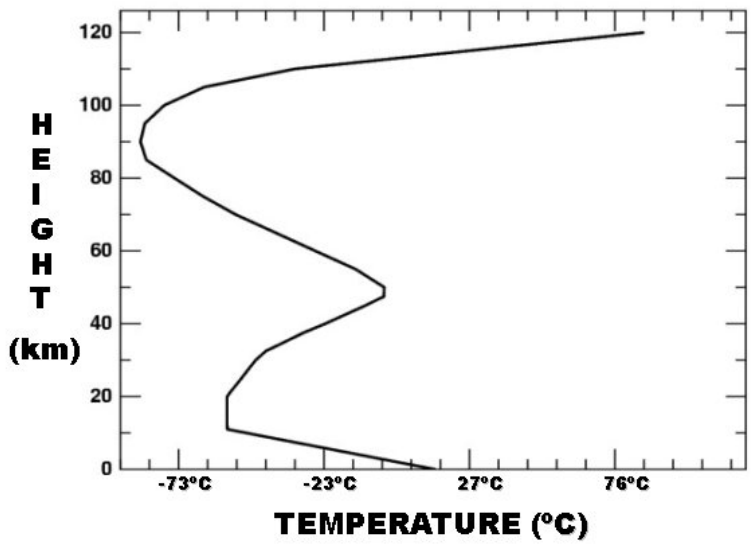

Figure 1 - Standard Atmospheric Profile.

TRANSITION. Remember that the Standard Atmospheric temperature profile is what the temperature would be under ideal conditions, it will almost never actually occur.

2. Inversions. In the troposphere, temperature normally decreases with height. An inversion is when temperature increases with height. The lapse rate in an inversion is negative which represents a stable layer. The base, or bottom, of the inversion is where the temperature begins to increase with height. The top of the inversion is where the temperature begins to decrease with height again. There are three basic types of inversions: radiation, subsidence, and frontal.

a. Radiation Inversion. Figure 2 is an example of a surface based radiation inversion.

(1) This type of inversion that forms by rapid cooling of air in contact with the surface and is frequently associated with fog.

(2) Radiation inversions occur only during times of maximum radiational cooling (nighttime effect), but may persist for several hours after sunrise.

(3) The temperature at the top of the inversion is called the inversion break temperature; fog will usually persist until the surface temperature reaches the inversion break temperature.

(4) Clear skies and light winds, typically caused by stable high-pressure systems, are characteristics conducive to the formation of radiation inversions.

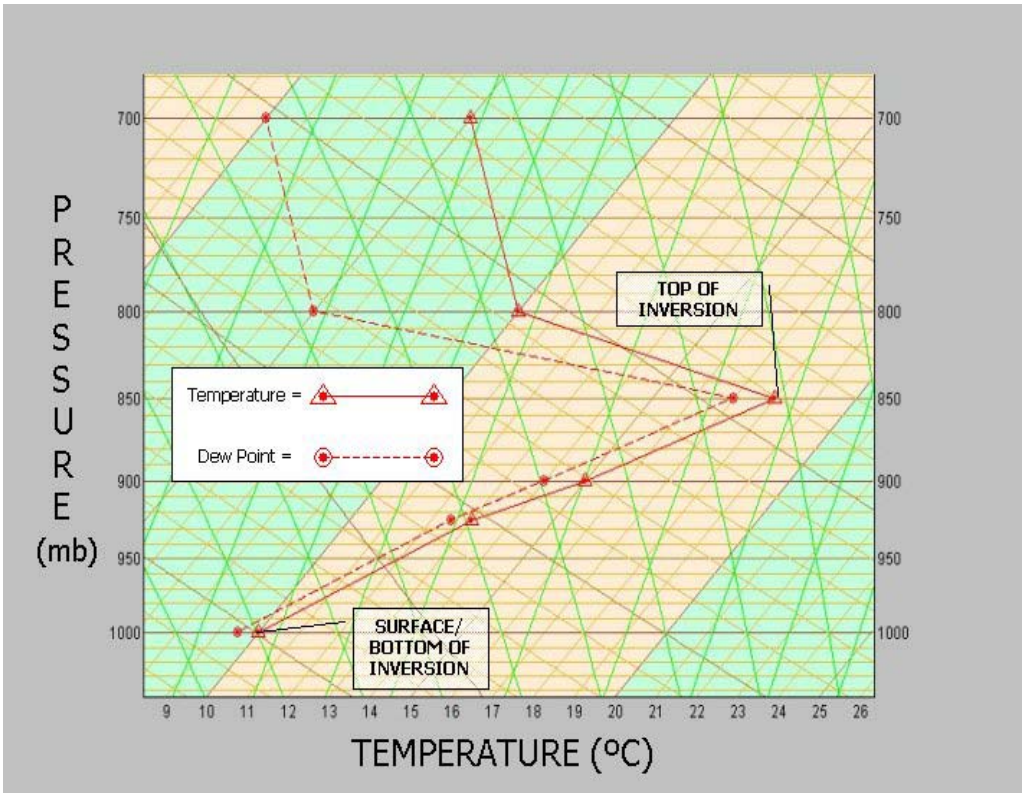

Figure 2 - Radiation Inversion.

b. Subsidence Inversion. A mechanically produced inversion formed by adiabatic warming of sinking air (shown by figure 3) is called a subsidence inversion.

(1) Usually seen as an elevated inversion where the dew point rapidly decreases at the base of the inversion as the sinking air dries out, but may also occur at the surface.

(2) Occurring in areas affected by high pressure, subsidence inversions act as a cap or lid that stabilizes the atmosphere and suppresses convective activity.

(3) Hazy/smoggy days are typically associated with these types of inversions because they trap dust and other pollutants near the surface.

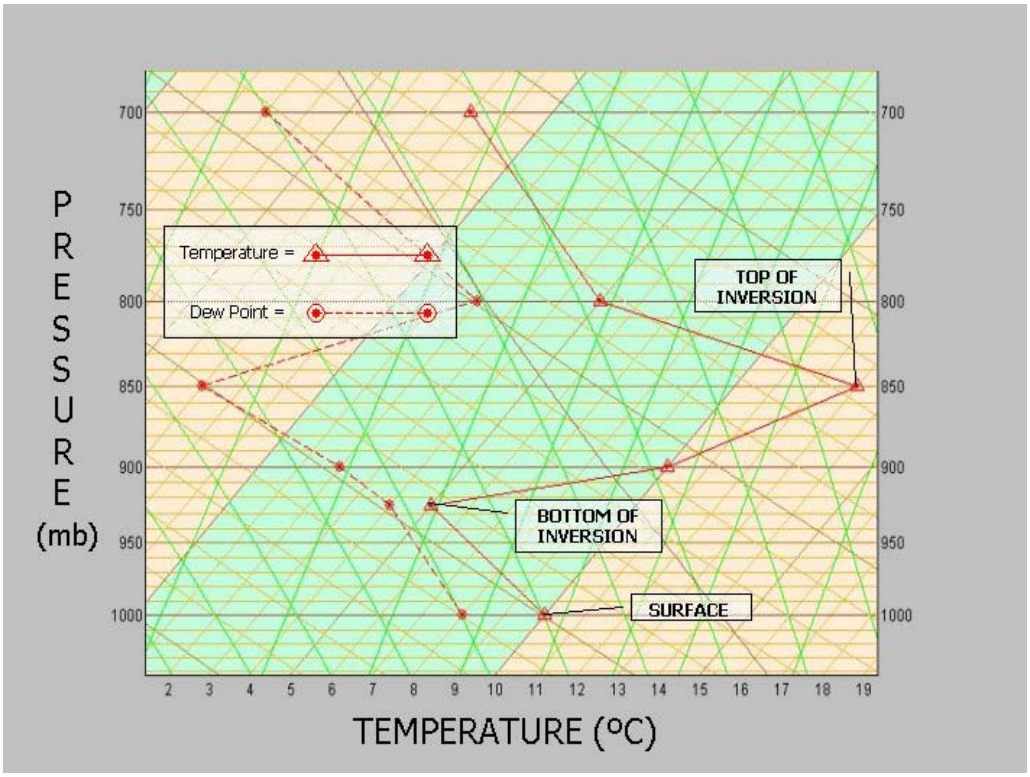

Figure 3 - Subsidence Inversion.

c. Frontal Inversion. This type of inversion (figure 4) depicts the transition zone between a cold air mass and the warmer air mass above it.

(1) Usually seen as an elevated inversion where the dew point increases through the inversion.

(2) The type of front can be determined by looking at the vertical wind profile through the inversion.

(3) A cold front would have backing winds with height and a warm front would have veering winds with

height.

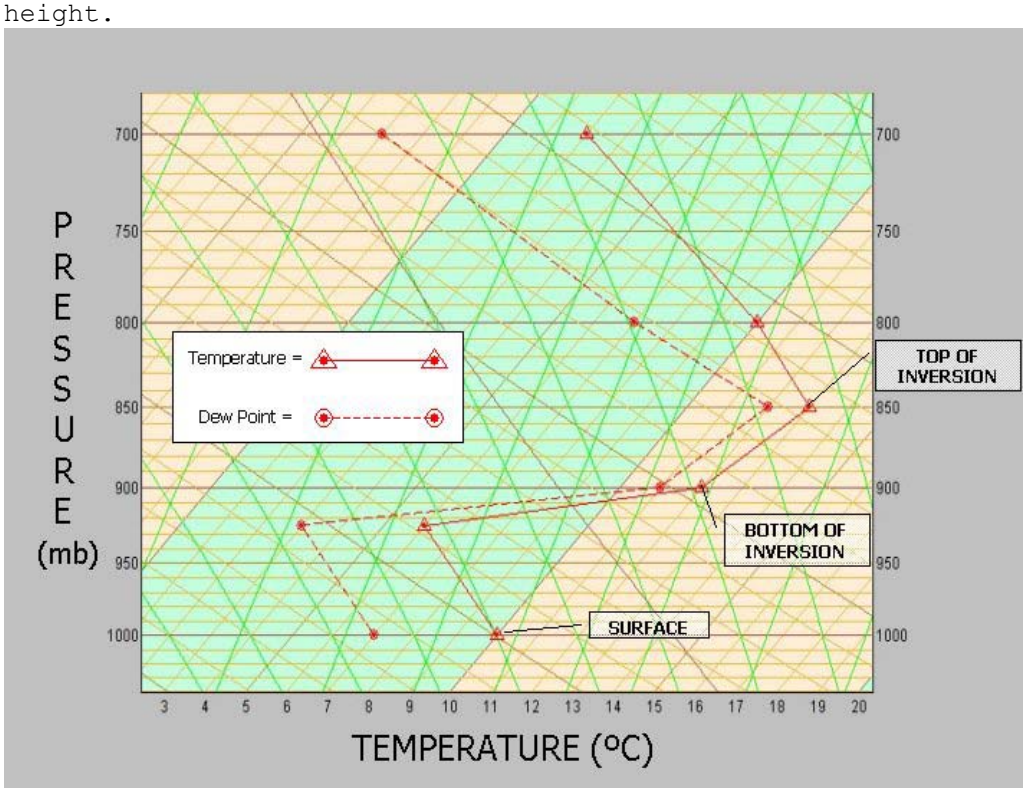

Figure 4 - Frontal Inversion.

TRANSITION. Inversions are very important in determining what type of weather a station may be experiencing as for they can limit upward vertical motions. There are several other factors that play an important role in temperature patterns for a given region.

3. Temperature Controls. Temperature controls are the factors that cause variations in temperatures from one place to another. These factors include: (1) latitude, (2) land and water distribution, (3) ocean currents, and (4) elevation.

a. Latitude. Latitude is by far the most significant temperature control. Temperature is most significantly impacted by the amount of solar radiation that reaches the surface. This is determined by the length of daylight hours and the intensity of the incoming solar radiation, which are both controlled by latitude.

b. Land and Water Distribution. Temperature is also controlled by land and water distribution.

(2) Land heats up faster than water, but also cools off more rapidly than water due to their respective specific heat capacities.

(3) Daily temperature changes over large bodies of water, such as oceans, are not very great. There are several reasons as to why this is true.

(a) One reason for this is because water is highly mobile. As water is heated, convection distributes the heat through a considerably larger mass than that of land.

(b) Daily temperature changes occur to depths of up to 20 feet below the water's surface. Yearly variations occur through a layer between 650 and 2,000 feet thick in oceans and deep lakes.

(c) Heat does not penetrate rock or soil very deep, and no mixing can occur on land because land is not fluid. Heat is transferred by conduction rather than convection.

(d) Daily temperature changes on land are very slow below a depth of 4 inches, slight changes up to 3 feet can occur. Yearly variations usually only reach depths of 50 feet or less. The result of the mobility of water and lack thereof in land is that, during the summer, a relatively thick layer of water is heated to moderate temperatures where in comparison a thin layer of land is heated but to much higher temperatures. During the winter, the thin layer of land that was heated in the summer cools rapidly.

(e) Water bodies cool slowly because they draw on the reserve heat stored at greater depths. Vertical motions are established as water cools. The cooled surface water, which is dense, sinks and is replaced by warmer water, which is less dense.

(f) Another reason why water warms more slowly than land is because land surfaces are opaque. Because of this heat is only transferred to shallow depths. An example of this is a hot and sunny day at the beach; the top of the sand is unbearably hot but push your feet just under the surface sand and it is much cooler there. Water, being more transparent than land, allows solar radiation to penetrate depths of several meters.

(g) Specific heat also plays a role in why land heats up more quickly than water. Specific heat is the amount of heat needed to raise the temperature of 1 gram of a substance 1°C. The specific heat of water is three times greater than that of land. Thus water requires considerably more heat to raise its temperature to the same amount as an equal quantity of land. Where daily temperature ranges over land of 20°-30°F are not uncommon, daily temperature ranges over bodies of water usually range from 5°-10°F.

(h) This small temperature range has a moderating effect on temperatures near bodies of water. Generally, during the summer daily temperatures in coastal cities are a few degrees cooler during the day than inland

cities, and vice versa, they tend to be a few degrees warmer during the night than inland cities. During the winter, however, the opposite is true. In winter, coastal cities are generally a few degrees warmer than inland cities.

c. Ocean Currents.

(1) Ocean currents are set in motion by the surface wind. At the water surface, where the ocean and the atmosphere meet, energy is passed from the surface wind to the water by friction. The result of this transfer of energy is that the water near the ocean's surface moves in the direction the surface wind is blowing to. Thus, ocean currents are affected by the circulation of the atmosphere, which is determined by the location of semi-permanent pressure systems.

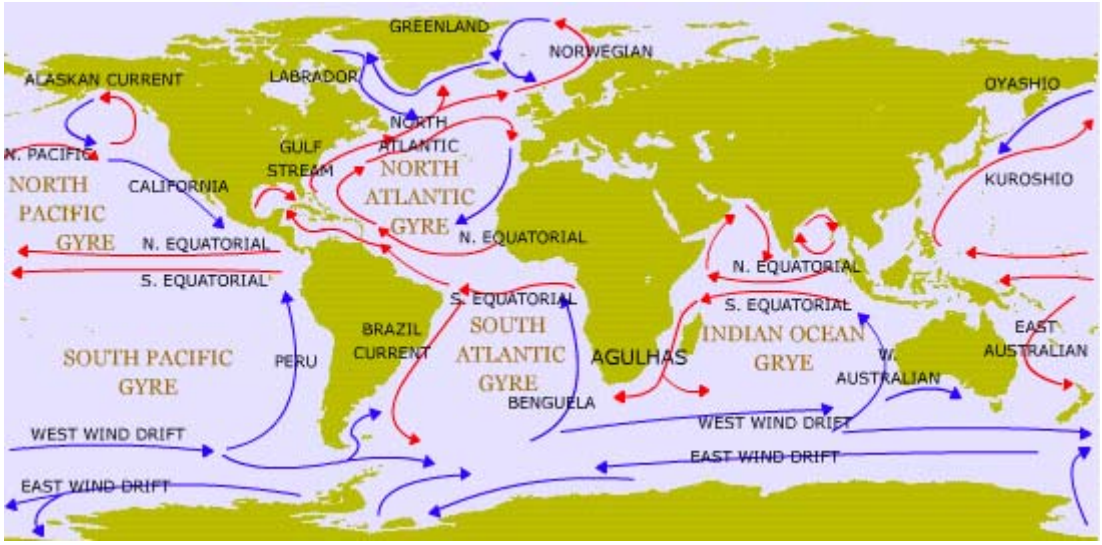

Figure 5 - Global ocean currents.

(2) Cold ocean currents are corridors of cold water moving from higher latitudes toward the equator; warm ocean currents are corridors of warm water moving from the tropics poleward. In relation to the U.S., there are two currents that effect the east and west coast, the Gulf Stream and the California Current, respectively. The Gulf Stream is a warm current and it affects the east coast of the U.S. It is caused by the circulation around the Bermuda High; which is located in the northern Atlantic. The moderating affects of the Gulf Stream on the east coast of the U.S. are most notable during the winter months where, on average, temperatures are a few degrees warmer than surrounding inland areas. In contrast, the California Current, which is a cold current, affects the west coast of the U.S. It is caused by the circulation around the Pacific High, which is located in the northern Pacific. The effects of the California Current on the west coast of the U.S. are most pronounced in the summer where, on average, temperatures remain a few degrees cooler than surrounding inland areas.

d. Elevation. On average, temperature decreases with height within the troposphere. Stations located in higher elevations, such as mountains or plateaus (Tibetan Plateau), will generally have cooler temperatures than stations at sea level.

(1) Temperature is not all that decreases with height. Atmospheric pressure and density also decrease with height. Because of the reduced density, the overlying atmosphere absorbs and reflects a smaller portion of incoming solar radiation.

(2) The result is the amount of incoming radiation is more intense at higher levels leading to rapid and intense daytime heating.

(3) Rapid nighttime cooling is also the rule of thumb in mountain stations. Therefore, mountain stations generally have a greater daily temperature range than stations at lower elevations.

TRANSITION. The temperature controls just discussed have an affect on climate and everyday weather; however, the temperature will also change on a daily basis at most every location.

4. Diurnal Changes. According to Webster's Dictionary "*diurnal*" means relating to or occurring in a 24-hour period, daily. Diurnal temperature changes are caused by the Earth's rotation, which causes a location to move into daylight for part of the day and then into darkness for the remainder of the day.

(1) As morning approaches, the Sun's angle increases. As the Sun's angle increases, the intensity of incoming radiation increases; which reaches a maximum intensity at noon local and gradually decreases through the afternoon.

(2) Although the intensity of incoming radiation reaches a maximum at noon (solar noon), the maximum temperature occurs a few hours later. This is called the *lag of the maximum* (see Figure 6).

(a) The intensity of incoming radiation gradually begins to decrease after noon local, but it still exceeds the outgoing radiation from the Earth's surface. This produces an energy surplus for up to several hours in the afternoon. Simply stated, if the amount of incoming radiation exceeds the rate of the Earth's re-radiation of energy, the temperature continues to rise.

(b) When the amount of incoming radiation no longer exceeds the amount of out-going radiation, the temperature begins to decrease.

(c) Due to lag of the maximum, the actual maximum temperature is delayed by a few hours (usually two to three) until the mid to late afternoon. During the evening and into the night, the Earth's surface begins to cool as energy from the Sun is lost. The minimum temperature, therefore, usually occurs about the time of sunrise, when the entire process begins again.

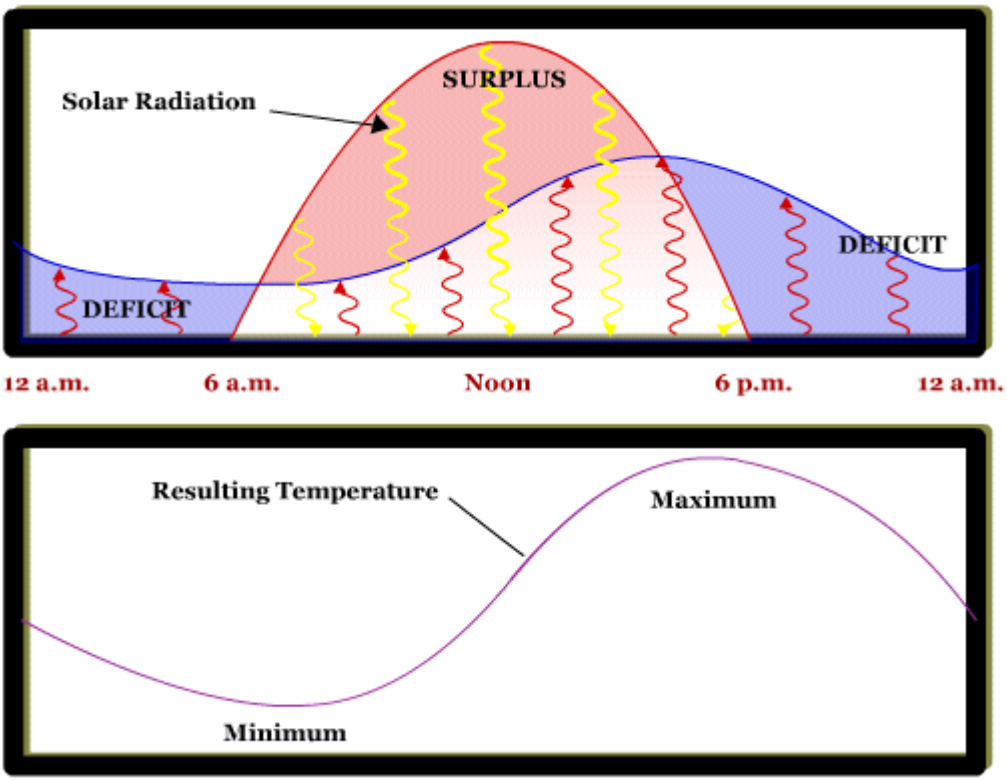

Figure 6 - Diurnal Temperature Lag.

OPPORTUNITY FOR QUESTIONS:

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

2. Questions to the Class.

a. QUESTION. What is an inversion?

b. ANSWER. When temperature remains isothermal or increases with height.

c. QUESTION. What are the three types of inversions?

d. ANSWER. (1) Radiation, (2) Subsidence, and (3) Frontal.

e. QUESTION. What are the four different temperature controls?

f. ANSWER. (1) Latitude, (2) Land/Water distribution, (3) Ocean currents, and (4) Elevation.

g. QUESTION. What does lag of the maximum mean?

h. ANSWER. It is the lag in the time from when the intensity of incoming radiation is at its greatest (noon local) to when the actual maximum temperature actually occurs (usually a few hours later).

SUMMARY: Standard Atmosphere is what the atmosphere would be like under ideal conditions, it very rarely occurs and is more so used as a baseline to judge how actual conditions vary from the standard. Inversions are important in determining what type of weather may occur at a station. Temperature controls are necessary to regulate the temperature, otherwise the temperature would be the same no matter where you are on Earth. Diurnal temperature changes show how the Earth budgets energy. During the day it absorbs radiation from the Sun and the temperature increases. During the night it re-radiates some of the absorbed energy and it cools off.

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