UNITED STATES MARINE CORPS

LESSON PLAN

MOISTURE MEASUREMENTS

INTRODUCTION:

1. Gain Attention. Imagine each of these scenarios: August in Beaufort, SC and the temperature outside is a balmy 95°F with 95% humidity; January in Quantico, VA and the temperature outside is a frigid 25°F with 95% humidity. Why would it feel more humid in Beaufort than in Quantico, both stations have the same 95% humidity?

2. Overview. This period of instruction discusses the various methods of determining moisture content. Refer to QMMPH1-016 Atmospheric Moisture for an introduction to moisture parameters.

3. Introduce Learning Objectives.

a. Terminal Learning Objective. With the aid of and in accordance with the reference, determine the moisture content of the air using a specified device and a specific measurement type.

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

(1) Calculate current surface relative, specific and absolute humidities.

(2) For a given level, determine the mixing and saturation mixing ratio.

(3) Define and discuss the various methods that can be employed to determine moisture content.

4. Method/Media. This period of instruction will be taught using the lecture method with the aid of Macromedia Flash presentation "Introduction to the Earth's Dynamics".

5. Evaluation. You will be evaluated by physically demonstrating the enabling and terminal learning objectives.

TRANSITION. One should already be familiar with the basic moisture parameters and how their values provide essential information about the state of the atmosphere. The next topic introduces the fundamental calculations or equations to compute various moisture measurements.

BODY:

1. Moisture Equations and Calculations. There are several different types of moisture measurements used in meteorology. Each has their own specific application to weather phenomena.

a. Absolute Humidity. This is the mass of water vapor in a column of air, expressed in grams per cubic meter (g/m^3).

(1) Absolute humidity can be calculated by determining the mass of the water vapor (in grams) and dividing that by the volume of air (cubic meters).

$$\text{Absolute Humidity} = \frac{\text{Mass of water vapor (grams)}}{\text{Volume of air (cubic meters)}}$$

(2) As air advects from one location to another, changes in pressure and temperature causes a change in the air's volume. When these volume changes occur, even though there may be no changes in water vapor, the absolute humidity changes.

(3) It can be difficult to monitor the water vapor content of a moving air mass, if one is using the absolute humidity values. Therefore, forecasters usually prefer to utilize the mixing ratio to express the water vapor content of the air.

b. Relative Humidity. This is the ratio, expressed as a percentage, of the amount of water vapor or moisture in the air to the maximum amount of moisture that the air would hold at the same dry-bulb temperature and atmospheric pressure (RH can vary from 0 to 100 %). RH is inversely proportional to the temperature, when the actual amount of water vapor is held constant. In this case, an increase in temperature would lead to a decrease in RH, and a decrease in temperature would lead to an increase in RH. Higher temperatures are also capable of holding greater amounts of moisture than lower temperatures. The formula for RH is:

$$RH = \frac{\text{Water vapor content}}{\text{Water vapor capacity}} \times 100$$

c. Specific Humidity. This is the ratio of the mass of water vapor to the total mass of air. Specific humidity is a reliable measure of the actual moisture content in the air. It is measured in grams per kilogram (g/kg). The formula for specific humidity is:

$$\text{Specific Humidity} = \frac{\text{Mass of water vapor}}{\text{Total mass of air}}$$

(1) Example: In a given parcel, the mass of water vapor is 1 gram. The total mass of the parcel is 1 kilogram. The specific humidity would be 1 g/kg.

(2) Specific humidity is also inversely proportional to latitude. An increase in latitude would lead to a decrease in specific humidity. From this statement we can make the assumption that specific humidity is highest at the Equator and lowest at the Poles (see figure 1). This is because the greater heat at the Equator evaporates more water, the more water vapor in the air, the higher the specific humidity. The colder air at the poles is not capable of holding a lot of

water vapor; the lower the amount of water vapor, the lower the specific humidity.

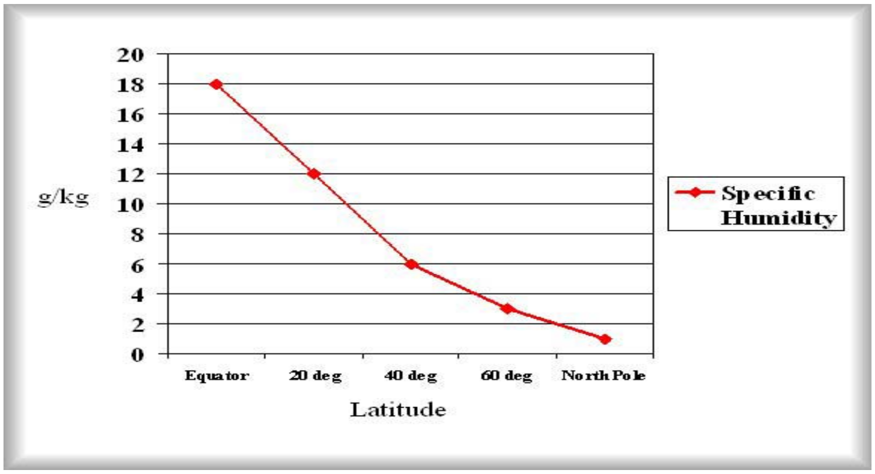

Figure 1 – Specific Humidity Versus Latitude.

d. <u>MIXING RATIO.</u>

a. Mixing ratio **(*w*)** is the ratio of the mass of the water vapor to the mass of the dry air.

$$w = \frac{MassOfWaterVapor}{MassOfDryAir}$$

b. Mixing ratio is a dimensionless quantity. However, since mass of water vapor is much less than the mass of dry air in typical atmospheric condition, mixing ratio is more commonly expressed in g/kg.

$$w = \epsilon \frac{e}{p - e}$$

where $\epsilon \approx 0.622$ is the ratio of the molecular weight of water vapor to dry air, "e" is the vapor pressure, and "p" represents atmospheric pressure.

e. <u>Saturation Mixing Ratio</u>. Students sometimes confuse the saturation mixing ratio with the mixing ratio. The saturation mixing ratio is in relation to the temperature (the maximum amount of water vapor that can be in the air at a certain temperature). The mixing ratio line that passes through the temperature is the saturation mixing ratio on the Skew-T. For that matter, the temperature is also used on the Skew-T to find the saturation vapor pressure.

(1) When liquid water and water vapor reaches *thermodynamic equilibrium*, that is evaporation is the same as condensation, which is referred to as saturation.

(2) Saturation can be interpreted as the maximum amount of water vapor that can exist in a stable condition. Under normal circumstances, excessive water vapor will condense into liquid water. Supersaturation in typical atmospheric condition is possible but rare.

(3) The variables describing the saturation are (1) saturation vapor pressure (e_s), (2) saturation mixing ratio (w_s), (3) specific humidity (q_s), absolute humidity ρ_s, and (4) temperature (T).

e. Saturation Vapor Pressure. Saturation of water vapor (e_s) is a function of temperature only. However, saturation mixing ratio (w_s) will depend on total atmospheric pressure (p) since a change of atmospheric pressure means a change in the mass of dry air, and the mixing ratio depends on the mass of the dry air.

$$w_s = w_s(T,p) = \epsilon \frac{e_s}{p - e_s}$$

TRANSITION. The calculations just discussed provide a few examples of how moisture can be derived for a given location. Forecasters also have several aids they may use in determining the amount of atmospheric moisture present in the atmosphere.

2. Utilizing Atmospheric Charts for Moisture Measurement.

a. Upper-Air Analysis. Single stations throughout the world send up Rawinsonde balloons to detect the atmosphere’s current state. The data that is received from these Rawinsondes is compiled and plotted on a Skew-T (Log P) Diagram. The Skew-T serves as a way to analyze most of the parameters that were previously discussed, such as mixing ratio, saturation mixing ratio, dew point depression, vapor pressure, etc…

b. Constant Pressure and Surface Charts. Forecasters may also use atmospheric charts that are produced from the data that is compiled from the rawinsondes. They may look for current moisture values by analyzing the dew point depressions for a given location or evaluate conditions for moisture advection into a given region.

3. Equipment Used for Moisture Measurements.

a. Sling Psychrometer. It consists of two glass thermometers containing a liquid, usually mercury. One thermometer measures the air temperature while the other one measures the wet-bulb temperatures. After the wick is dipped in distilled water, a weather observer whirls the sling psychrometer around, using the handle.

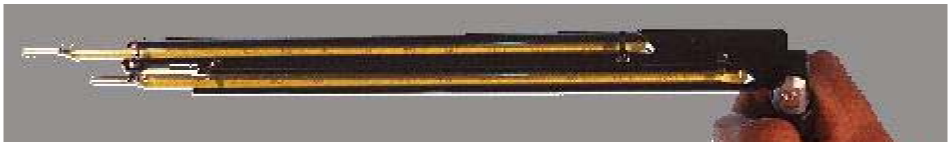

Figure 1 – Image of Sling Psychrometer.

As the instrument is whirled, water evaporates from the wick on the wet-bulb thermometer and cools the thermometer. The wet-bulb thermometer cools to the lowest value possible in a few minutes. This value is known as the wet-bulb temperature. The drier the air the more the thermometer cools and hence, the lower the wet-bulb temperature. The observer uses a table - these are found in basic meteorology texts - or using a computer program.

b. Hygrometers - Any of several instruments used for measuring atmospheric humidity. Some types of hygrometers are:

(1) Psychrometer - measures the temperature difference between a wet-bulb and a dry-bulb thermometer. A sling psychrometer (shown above) is mounted in a frame, then whirled in the air for ventilation.

(2) Hair hygrometer - measures the expansion and contraction of a human hair that is mounted under tension. Human (or animal) hair turns out to be a pretty good way to measure the humidity, as anyone who's ever complained about a "bad hair day," can tell you. The graphic below shows how this works.

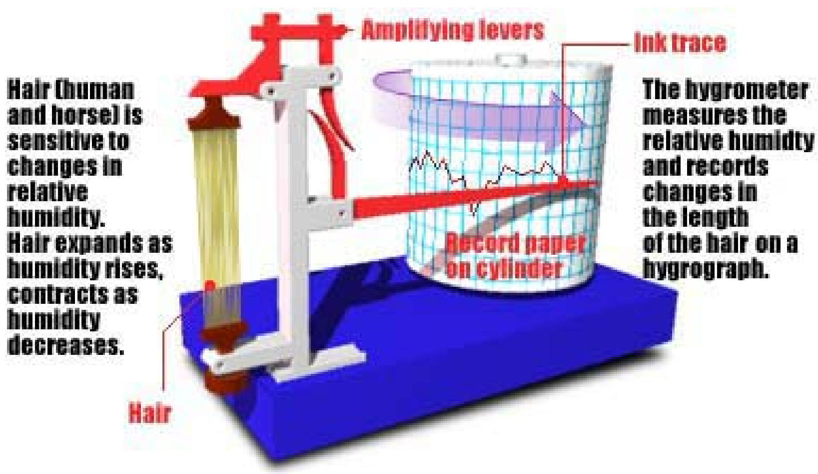

Figure 2 – Image of how a hair hygrometer works.
(Image provided by USA Today)

(3) Dew point hygrometer - measures the temperature for the formation and evaporation of dew that is observed using a photoelectric cell.

(4) Diffusion hygrometer - measures the diffusion of water vapor through a porous membrane.

(5) Lithium chloride hygrometer - measures the temperature and electrical conductivity of a hygroscopic salt that becomes conductive when it absorbs water.

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 unit of measurement is absolute humidity reported in?

   b. ANSWER. Grams per cubic meter, (g/m^3)

   c. QUESTION. How is relative humidity related to temperature?

   d. ANSWER. It is inversely proportional.

   e. QUESTION. How is specific humidity related to latitude?

   f. ANSWER. It is inversely proportional.

SUMMARY: Throughout this period of instruction we have discussed absolute humidity, relative humidity, and specific humidity, as well as, how relative humidity is related to temperature and how specific humidity is related to latitude.

REFERENCE:

Meteorology and Oceanographer Analyst/Forecaster (MOAF), Physics I Chapter 5, pgs. 5-11 – 5-12. N61RCB1-ST-102. Rev. October 2002.

Specific Humidity. Lyndon State College Meteorology. Dr. Nolan Atkins. "http://apollo.lsc.vsc.edu/classes/met130/notes/chapter5/specific_hum.html".

University of Aberdeen, Department of Physics. "http://www.abdn.ac.uk/physics/meteo/met5sum.pdf".

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