UNITED STATES MARINE CORPS

LESSON PLAN

VORTICITY

INTRODUCTION:

1. Gain Attention. The planet Earth, a top, a parcel of air, and the props on an aircraft… What do all of these things have in common? They all have vorticity.

2. Overview. During this period of instruction, the student(s) shall be introduced to the various different types of vorticity.

3. Introduce Learning Objectives.

a. Terminal Learning Objective. Without the aid of references, but in accordance with the period of instruction, the students shall successfully define and explain all aspects of vorticity.

b. Enabling Learning Objective(s). Without aid of references, the student(s) shall complete the following:

(1) Define vorticity.

(2) Name and define the five (5) different types of vorticity.

(3) Define and discuss the different types of vorticity advection.

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 be evaluated by successfully demonstrating gained knowledge by correctly answering questions at the end of this period of instruction.

TRANSITION. Vorticity is an important factor in forecasting the weather at a local station or over a regional area of interest. The first section presents the definition of Vorticity.

BODY:

1. Defining Vorticity. Vorticity can be defined as the measure of the rate of rotation of the air. Though the rotation can be about an axis that is horizontal or vertical, normally it is the vertical component of vorticity that is being referred to. Everything that spins or rotates has vorticity. This includes tornadoes, hurricanes, and the earth. Air also rotates around highs and lows, so that also has vorticity. Vorticity contains several characteristics defined below:

a. If a parcel spins cyclonically, counterclockwise, in the Northern hemisphere, it has positive vorticity.

b. If a parcel spins anticyclonically, clockwise, in the Northern hemisphere, it has negative vorticity.

TRANSITION. Objects may rotate in one direction or the other, and be classified as having positive or negative vorticity. There are several different types of vorticity that affect air parcel within the atmosphere.

2. Types of Vorticity.

a. Curvature Vorticity. Curvature vorticity is a result from the movement of a parcel through a curved flow. An example of this would be a chip of wood floating down a stream. The chip spins as it rounds the curves in the stream. As a parcel moves through the flow pattern of troughs and ridges it also spins.

(1) Troughs. As a parcel of air encounters a trough, it begins to spins cyclonically giving the parcel positive vorticity. The positive rotation of the parcel will continue until it reaches the inflection point where rotation ceases.

(2) Ridges. As a parcel of air encounters a ridge, it begins to spin anticyclonically giving the parcel negative vorticity. The negative rotation of the parcel continues until it reaches the inflection point and ceases to spin.

(3) Inflection Point. This is the point where the parcel stops spinning and begins to spin in the opposite direction it was previously spinning in. For example, if the parcel of air was moving down a ridge and approaching a trough, at the inflection point, the parcel would stop its negative spin and begin its positive spin.

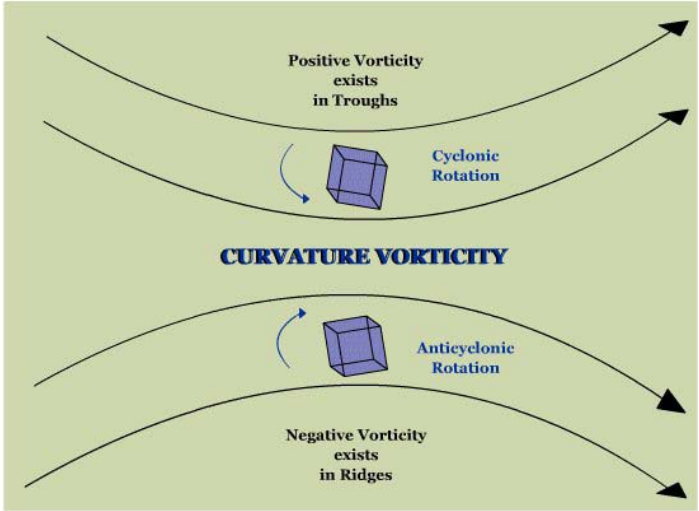

Figure 1 - Curvature Vorticity.

b. Shear Vorticity. Shear vorticity exists when there is a variation in wind speed and/or direction (*wind shear*). It is the actual shear that causes the parcel of air to rotate in a certain direction. There are two (2) types of shear vorticity, positive (cyclonic) and negative (anticyclonic).

(1) Positive Shear Vorticity. A parcel of air will have a positive rotation when the stronger wind velocities are on the -n side of the flow (below or to the right of the parcel). The faster winds will cause the parcel to spin cyclonically.

(2) Negative Shear Vorticity. A parcel of air will have a negative rotation when the stronger wind velocities are on the +n side of the flow (above or to the left of the parcel). The faster winds will cause the parcel to spin anticyclonically.

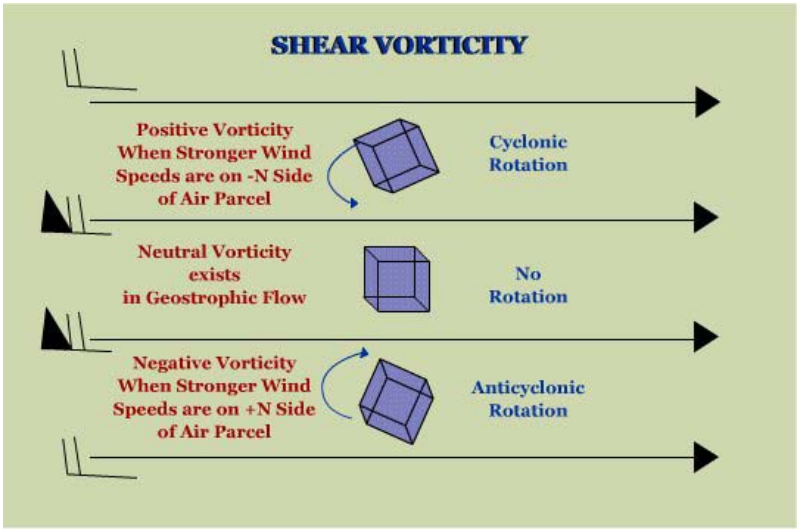

Figure 2 – Shear Vorticity.

c. Relative Vorticity. Relative vorticity (ζ) is the sum of curvature and shear vorticity. Once the parcel's curvature vorticity is determined, then the shear vorticity is determined. The sum of these vorticies will either produce a positive or negative rotation for the parcel of air.

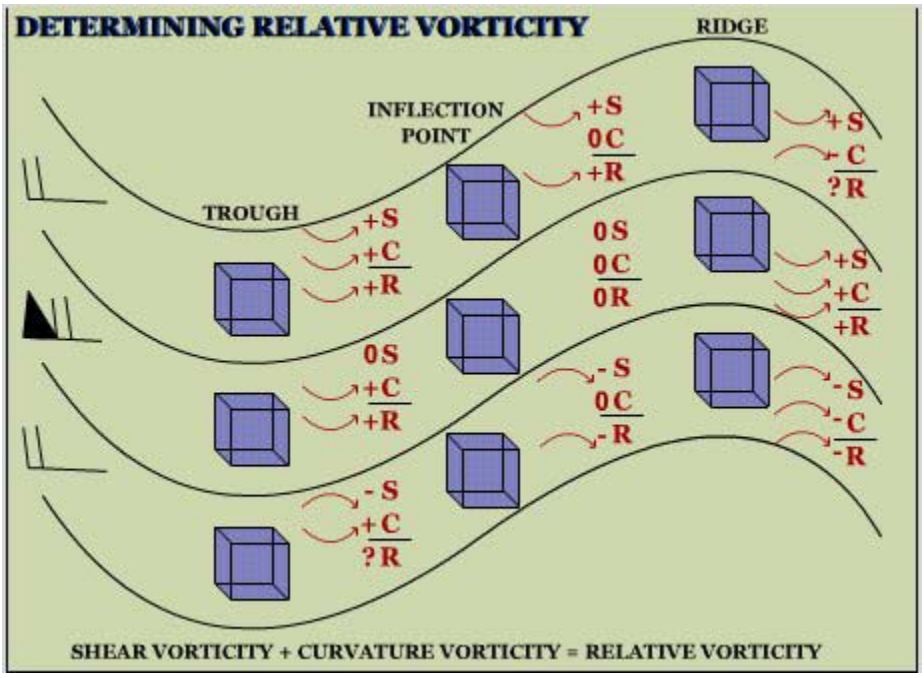

Figure 3 – Illustration demonstrating the relationship between curvature and shear Vorticity that determines the relative Vorticity of a parcel of air.

d. Planetary Vorticity. The spin of a parcel that is caused by the spinning Earth about a local vertical. It is always positive in the Northern Hemisphere and is formulated by the Coriolis parameter.

(1) Since the Earth rotates about an axis, which goes through the poles. If you were to stand on the North Pole, all of the earth's rotation would be conveyed on you. However, you probably will never go stand on the North Pole. That doesn't mean that planetary vorticity isn't important elsewhere; we have to look at local verticals.

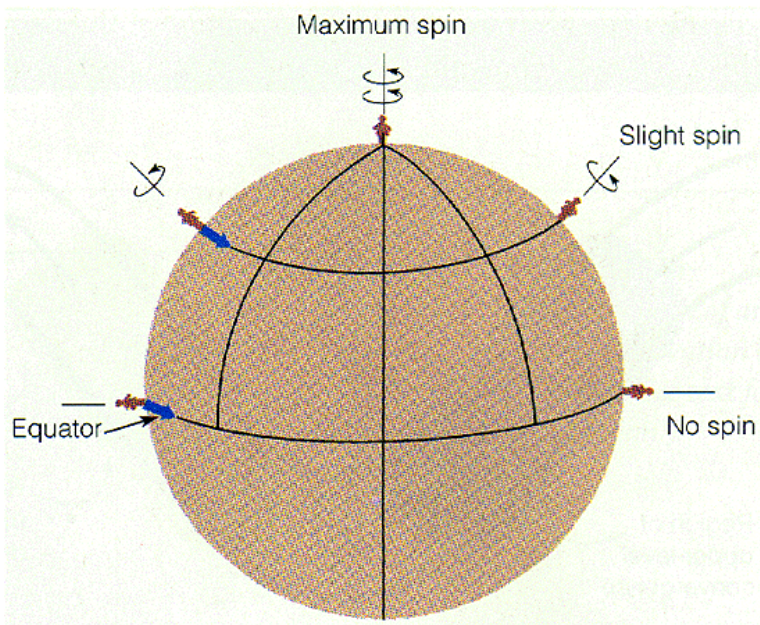

Figure 4 - Illustration provided by *from Meteorology Today by C. Donald Ahrens©1994 West Publishing Company*. Demonstrates how the Earth's rotation affects planetary Vorticity.

(2) A local vertical, seen in the figure, is a line that is perpendicular to the surface of the planet. When the local vertical is the same as the earth's axis, like when you are at the pole, all of the earth's vorticity is conveyed to objects there. When the local vertical is perpendicular to the axis, there is no rotation by the earth in that direction. Therefore, planetary vorticity decreases as you travel from the poles to the equator. But remember, planetary vorticity is always positive in the Northern Hemisphere

e. Absolute Vorticity. Absolute voriticity measures the *total* spin of an air parcel. It is the sum of both relative vorticity and planetary

vorticity.

(1) Absolute vorticity can be stated mathematically as $\eta = \zeta + f$, where "η" is absolute vorticity, "ζ" is relative vorticity and "f" is the coriolis parameter.

(2) Recall from previous discussions that the strength of the Coriolis parameter varies with latitude. However, it is usually large enough to result in a positive absolute vorticity for all synoptic scale motions in the Northern hemisphere.

TRANSITION. Are there any questions to anything that has been cover thus far? It is important that the class understands all of the material gone over before going over the last type of vorticity to be covered in this class absolute vorticity.

3. Vorticity Advection. Absolute vorticity is measured and analyzed using a 500mb Vorticity Chart. The chart depicts areas of minimum and maximum absolute vorticity. There are three (3) types of vorticity advection: positive vorticity advection (PVA), negative vorticity advection (NVA) and neutral vorticity advection.

a. Positive Vorticity Advection (PVA). The increasing of absolute vorticity with time at a given location due to the horizontal advection of higher vorticity values.

b. Negative Vorticity Advection (NVA). The decreasing of absolute vorticity with time at a given location due to the horizontal advection of lower vorticity values.

c. Neutral Vorticity Advection. No change in absolute vorticity with time at a given location due to no horizontal vorticity advection.

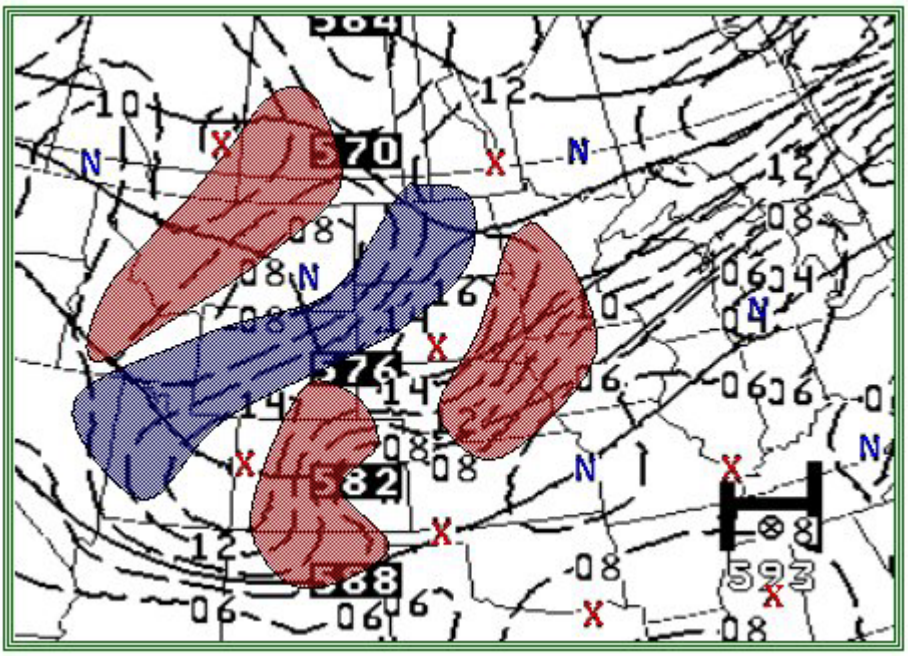

Figure 5 - 500mb Vorticity chart. PVA is shaded in red and NVA is shaded in blue.

TRANSITION. Vorticity advection is used in determining if upper-level convergence or divergence is occurring in a region. The next period of instruction provides a detailed discussion on vorticity advection and divergence/convergence.

OPPORTUNITY FOR QUESTIONS:

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

2. Questions to the Class.

a. QUESTION. Why does everything on Earth have vorticity?

b. ANSWER. Because Earth spins, so everything on Earth spins (Planetary vorticity).

c. QUESTION. Name the five (5) types of vorticity advection.

d. ANSWER. Curvature, Shear, Relative, Planetary, Absolute.

e. QUESTION. Which vorticity advection type occurs when higher absolute vorticity values advect into a region?

f. ANSWER. Positive Vorticity advection (PVA).

SUMMARY: During this period of instruction, the student was introduced to the basic concepts of vorticity. The five (5) types, curvature, shear, relative, planetary, and absolute vorticity were introduced and discussed, as well as, the three (3) vorticity advection types.

REFERENCE.

Meteorological and Oceanographer Analyst/Forecaster (MOAF) Dynamics I – Vorticity. N61RCB1-ST-201, last revised October 2002.

Ahrens, Donald C. Meteorology Today. 4th Edition. West Publishing Company, 1991.

Vorticity Basics. Jeff Haby. Last accessed 8/8/2004. http://theweatherprediction.com