UNITED STATES MARINE CORPS

LESSON PLAN

CONVERGENCE AND DIVERGENCE

INTRODUCTION:

1. Gain Attention. Giant clouds that form thunderstorms are called cumulonimbus that often have their tops flatten out. These are called anvils. What do you think causes an anvil to form, or spread out laterally?

2. Overview. In previous topics (QMMPH1-031 Atmospheric Forces), the forces that put the air into motion were defined. However, in those definitions, spacing between the isobars is kept constant, even for curved airflow. In reality, pressure fields will usually change rapidly, resulting in an irregular pressure gradient distribution. A situation like this often causes airflow to *converge* or *diverge* rather than flow evenly.

3. Introduce Learning Objectives.

a. Terminal Learning Objective. Without the aid of, but in accordance with the reference(s), the student(s) shall determine areas of divergence and convergence utilizing a given surface and upper-level constant pressure chart in a time period of fifteen minutes. One instructor assist is allowed.

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

(1) The difference between two and three-dimensional convergent and divergent motions.

(2) Explain the terms “confluence” and “diffluence” and provide an examples as to when they might occur.

(3) State an example of speed convergence and divergence.

(4) Explain the relationship that is needed between upper-level divergence and low-level converge in order to sustain the life of a surface low pressure system.

(5) Define the Chimney and Damper Effect.

4. Method/Media. This period of instruction will be taught using the lecture method with the aid of a Macromedia Flash presentation “QMMCBT-001 Introduction to the Dynamics of the Atmosphere”.

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

TRANSITION. The first topic of discussion introduces the fundamental terms that are related to air motions in the horizontal, or two-dimensionally.

BODY:

1. 2-Dimensional Convergence and Divergence.

a. Defining "Convergence" and "Divergence". Imagine a volume with invisible but defined boundaries. Convergence occurs when the wind movement provides a horizontal net inflow of air into a particular region. Divergence occurs when the wind movement provides a horizontal net outflow of air from a particular region. Both convergence and divergence can be broken down into directional and speed components that can act together or opposite one another.

(1) Directional Convergence/Divergence. Directional convergence, *confluence,* exists when air from different directions comes together, or flow inward, into a particular region. A physical example of this is interstate roadways where several major highways all merge onto the interstate. There are vehicles coming from each highway, all trying to merge, or "converge", onto the interstate at once. The end result is usually a mass pile up of cars where all the roadways meet. Directional divergence, *diffluence*, exists when air from a particular region flow outward away from the source. The same interstate example can be used. Imagine a major interstate where there are several off-ramps at a given location, and most of the cars exit the interstate going onto different highways. The cars are spreading out, "diverging", from the original source point (the interstate).

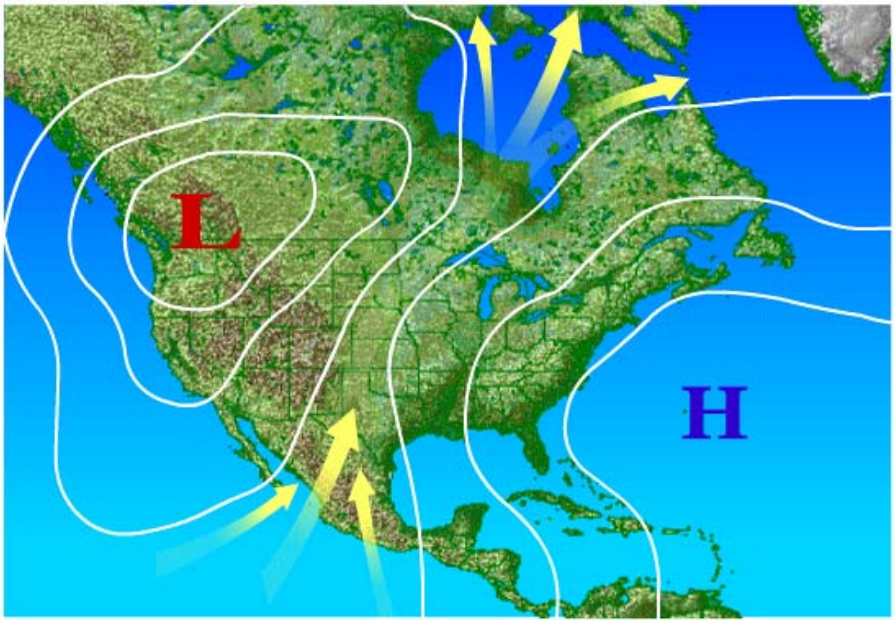

Figure 1 – An example of directional convergence and divergence between two (2) synoptic scale systems.

(2) Speed Convergence/Divergence. Speed convergence occurs when faster moving air parcels travel into an area currently occupied by slower moving parcels (high wind velocities to low velocities) causing a net addition, or pile up, of air parcels. This is much like when you are driving your car at 60 mph and the vehicle in front of you is traveling at 40 mph, if you don't change your speed or move around the car, your faster moving car will "converge" into the slow moving car. Speed divergence occurs when air parcels enter regions of successively greater wind speeds, or higher velocities. Speed divergence occurs as traffic speeds up and spreads out after passing an accident.

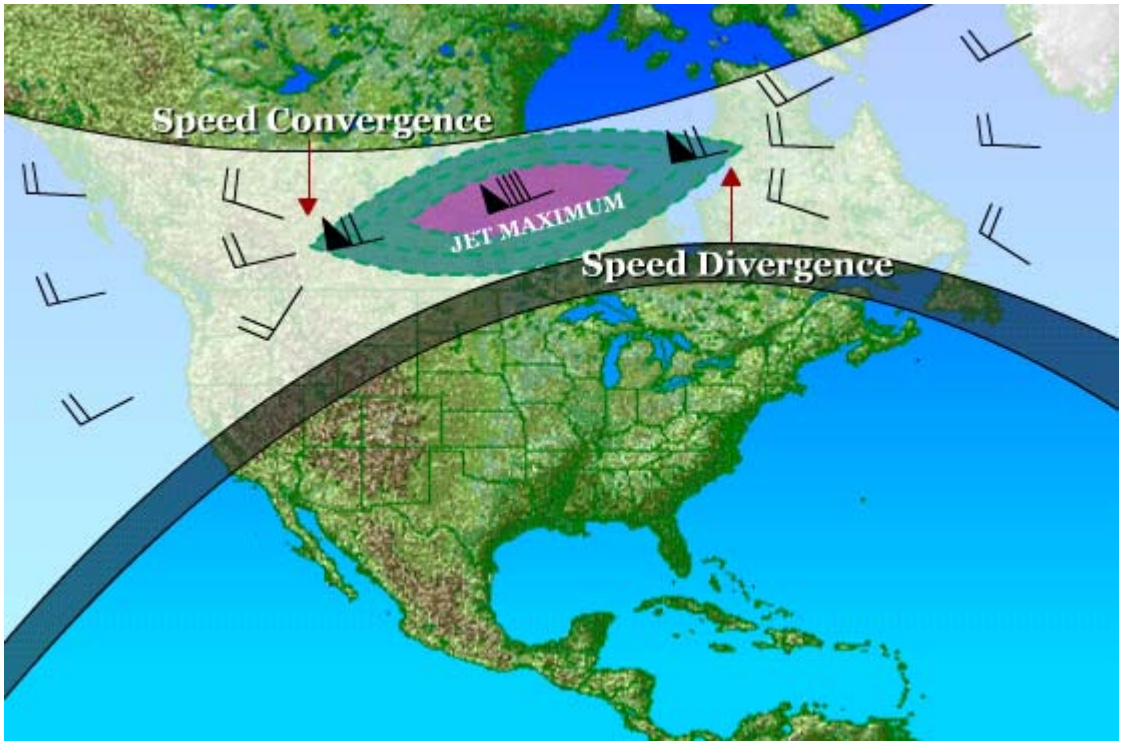

Figure 2 - A jet maximum provides a good example of speed convergence and divergence, as well as, confluence and diffluence.

b. Confluence and diffluence do not guarantee convergence and divergence respectively. The combination of air speed and direction must be weighed. The spacing of the isobars and the strength and location of the jet stream determine what type of air flow results. To determine if convergence or divergence will occur at a level, use the isoheights or isotachs to determine if convergence and divergence are occurring. Both factors of wind and speed need to be considered simultaneously as for they can reinforce or cancel each other out.

TRANSITION. By discussing 2-dimensional airflow and how it correlates to convergence and divergence of horizontal winds, an important question arises. How does horizontal wind flow relate to vertical (3-dimensional) wind flow? In the next section, the relationship between horizontal and vertical airflow will be discussed.

2. 3-Dimensional Convergence and Divergence.

a. Vertical Airflow Associated with Pressure Systems.

(1) Low Pressure Systems.

(a) Air flows inward, toward the center of Low pressure systems (cyclones). As the air begins to converge, and essentially pile up, the air must go somewhere. The only place for the air to go is upwards. When this happens, the net inward transport of air causes a shrinking of the area occupied by the air mass. Whenever horizontal convergence occurs, the column of air must increase in height to compensate for the decrease in area. This process generates a taller and heavier column of air. And unless there is an aid to keep the heavier air up, the air will sink and fill the low pressure center.

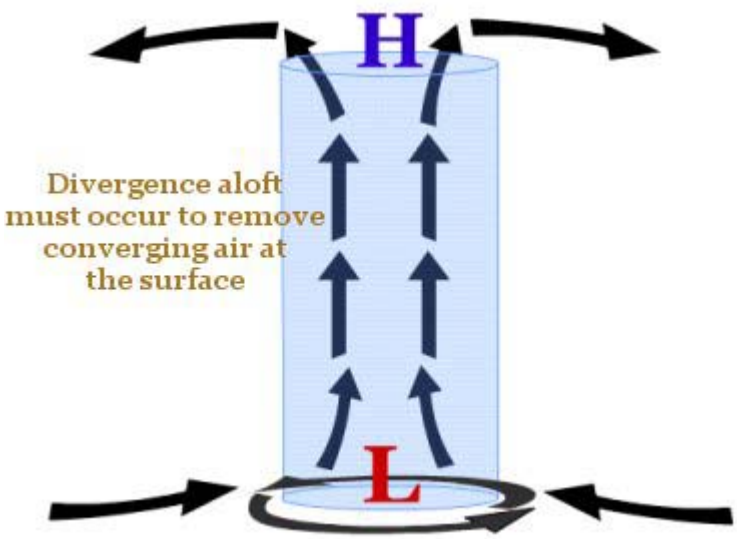

Figure 3 - Illustration demonstrating a balance between low-level convergence and upper-level divergence.

(b) In order for the surface low pressure system to exist for very long, compensation must occur aloft. Surface convergence could be maintained if divergence aloft occurred at a rate equal to the inflow of the surface air.

(c) Divergence aloft may even exceed surface convergence, meaning there is more air leaving the column than there is coming into the column. When this happens, it results in air rushing out of the top of the column more quickly, increasing surface convergence by creating a "suction" effect and acting to further enhance the acceleration of the upward vertical motion. This process is known as "The Chimney Effect". The

correct assembly of divergent patterns aloft, directional divergence aloft or speed divergence, supports this process. If the rising air is moist, the process can produce severe weather and aid in cyclogenesis.

(d) As often as not, it is actually divergence aloft that creates a surface Low. The spreading out of air aloft initiates a reverse vacuum effect and allows for air to flow upwards directly below the divergence. If the divergence, and vacuum effect, is strong enough, it eventually works its ways down to the surface.

(2) High Pressure Systems. Air flows outward, away from the center of High pressure systems (anticyclones). As the air diverges, they spread out laterally.

(a) To replace the air that is laterally spreading out at the surface (divergence), convergence aloft and general subsidence (downward vertical motion) of the air column must occur. Anticyclones, like cyclones, are supported from aloft. As long as upper-level converging air balances surface diverging air, the central pressure in the center of the High will not change.

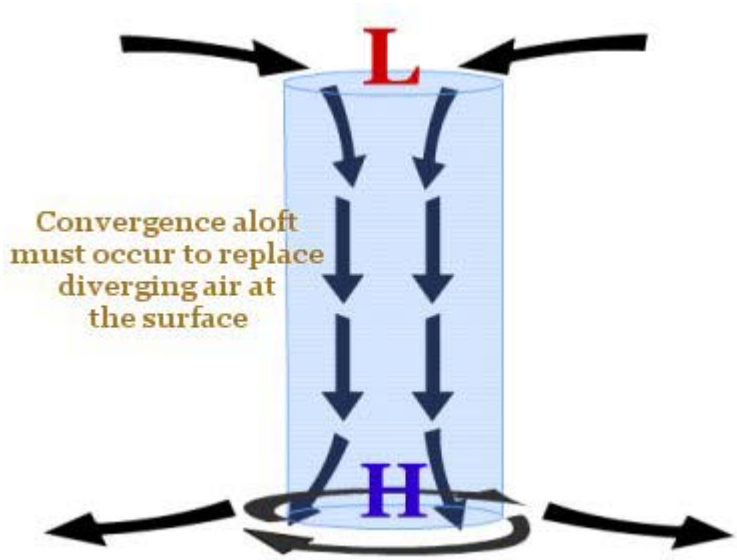

Figure 4 - Divergence at the surface is counterbalanced by convergence aloft.

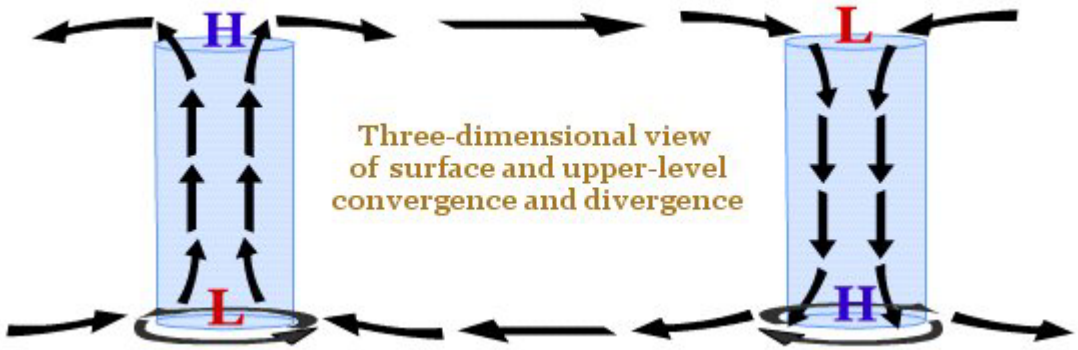

Figure 5 - Illustration of how surface and upper-level pressure systems and associated vertical motions look three-dimensionally.

(b) The "*damper effect*" is the opposite of the chimney effect. When converging winds aloft add mass into a column of air, it creates net convergence and thereby increases the mass within the column. As the mass increases, the surface pressure rises and, in turn, generates low-level divergence.

(c) When winds converge aloft, they can only go downward due to the highly stable tropopause. The cold, dense air at the upper levels tends to sink and the convergent upper-level winds help push the air further down the column. This also forms the damper effect.

(d) Because descending air is compressed and warmed, extensive cloud formation and precipitation are unlikely in an anticyclone.

b. The Level of Non-Divergence. In the atmosphere there is an inflection point at which convergence changes to divergence. This is called the *level of non-divergence*. It normally exists between the 600mb and 500mb height levels.

OPPORTUNITY FOR QUESTIONS:

1. Questions from the Class. At this time, are there any questions concerning the content you just learned?

2. Questions to the Class.

a. QUESTION. What causes speed convergence?

b. ANSWER. Winds of higher velocities moving into a region of lower velocities.

c. QUESTION. How is the airflow within a surface Low pressure system maintained?

d. ANSWER. Divergence aloft must balance surface convergence.

SUMMARY: During this period of instruction, 2 and 3-dimensional wind flow patterns were discussed. The concepts of speed and directional convergence/divergence were explained and their relation to vertical motion. The 3-dimensional wind flow process in association with pressure systems was introduced and explained.

REFERENCE.

Glossary of Meteorology American Meteorological Society, 2000. Glickman, Todd S.

The Atmosphere, An Introduction to Meteorology. Frederick K. Lutgens and Edward J. Tarbuck. 1998.

Handbook of Dynamic Meteorology. Commanding Officer, Naval Ice Center for Commander, NMOC. 1994.

Meteorology Today, An Introduction to Weather, Climate, and the Environment, Fourth Edition. C. Donald Ahrens. 1982.