UNITED STATES MARINE CORPS

LESSON PLAN

THREE-CELL THEORY

INTRODUCTION:

1. Gain Attention. Much like the air conditioning in one's car or the central heating in one's house, the earth's atmosphere is constantly circulating air from pole to pole. This large scale mixing process can be simplified into three cells existing in each hemisphere.

2. Overview. During this period of instruction, the student shall learn about the three-cell theory of atmospheric circulation consisting of the Hadley, Ferrell, and Polar cells.

3. Introduce Learning Objectives.

a. Terminal Learning Objective. Without the aid of references, but in accordance with instruction, explain the cause for global circulation of the atmosphere, to include the dynamics of each cell, as well as, the wind components that have been produced from the interaction between the three cells.

b. Enabling Learning Objective(s). Without the aid of references, define and discuss:

(1) State the three circulation cells that affect global circulation.

(2) Describe the cause of each cell and how they interact to produce the surface wind components.

(3) Describe each of the surface wind components.

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. The student shall verbally demonstrate knowledge of subject matter upon completion of the period of instruction.

TRANSITION. The single cell theory would be appropriate if there were no landmasses on Earth, however, there are. The three-cell theory is composed of three circulation cells vice one.

BODY:

1. Hadley Cell.

a. Near the equator, where solar radiation is greatest, air is warmed at the surface and rises. This creates a band of low air pressure centered on the equator known as the intertropical convergence zone (ITCZ).

b. As this air rises into the upper atmosphere due to convergence and convection it reaches the troposphere and then begins flowing horizontally to the North and South Poles. This rising air comprises one segment of a circulation pattern called the Hadley Cell.

c. The Hadley cell eventually returns air to the surface of the earth near 30 degrees North and South. The descending portion of the Hadley Cell produces a band of high air pressure at these latitudes creating the subtropical high semi-permanent pressure systems.

d. From this zone the surface air travels in two directions. The winds generated between the subtropical high and the equatorial band of low pressure are deflected from east to west due to coriolis force and are called the Trade Winds or the Tropical Easterlies. The other portion of the surface air moves towards the poles from the subtropical high zone is also deflected and is known as the Westerlies.

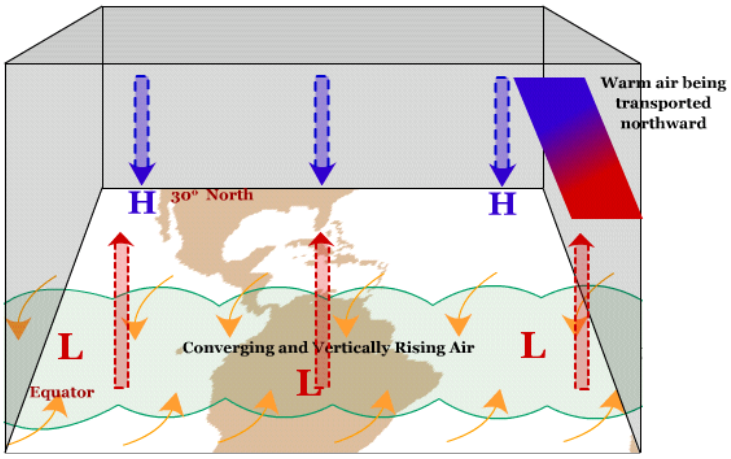

Figure 1 - Diagram of the Hadley cell depicting vertical and horizontal air motions.

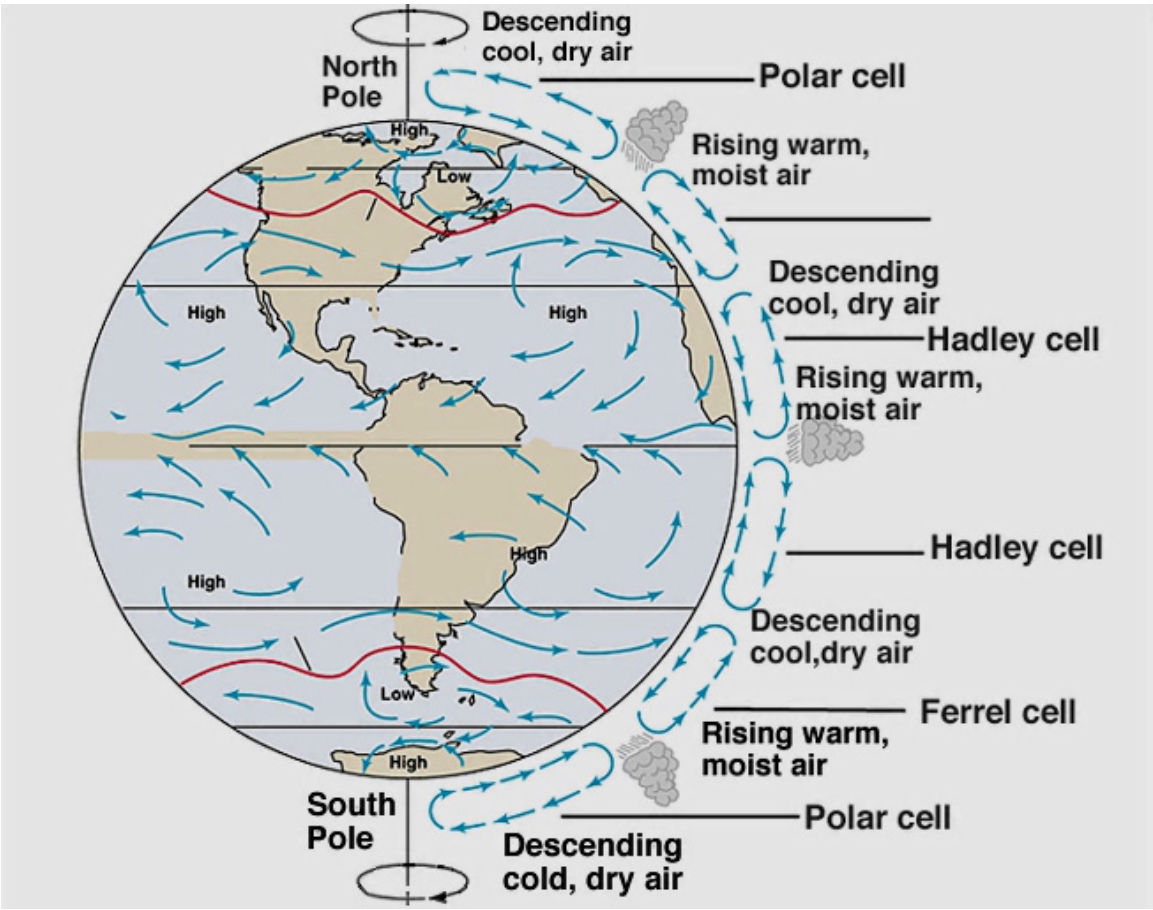

Figure 2 - Diagram of the three-cell circulation pattern.

2. Ferrell Cell.

a. As the air originating from the subtropical high regions continues towards the poles it encounters cold air moving away from the poles.

b. These two air masses meet at a zone of low pressure near the surface and subsequently converge and rise into the atmosphere. This boundary is known as the polar front and is located near 60 degrees N and S latitudes.

c. As the air rises, it diverges at the troposphere and travels either equator ward or poleward. The upper-level air traveling towards the equator eventually converges aloft near the subtropical high where it is returned back to the surface completing the circular motions of the Ferrell cell.

3. Polar Cell.

a. The Polar cell originates at 90 degrees North and South where cold heavy air sinks toward the equator and is also affected by the deflecting coriolis force creating the Polar Easterlies.

b. Once this air reaches the polar front, it converges with the

poleward flowing air of the Ferrell cell forcing it aloft. Once aloft, the air returns to the poles and sinks back down completing the Polar cell circulation.

2. Surface Wind Components.

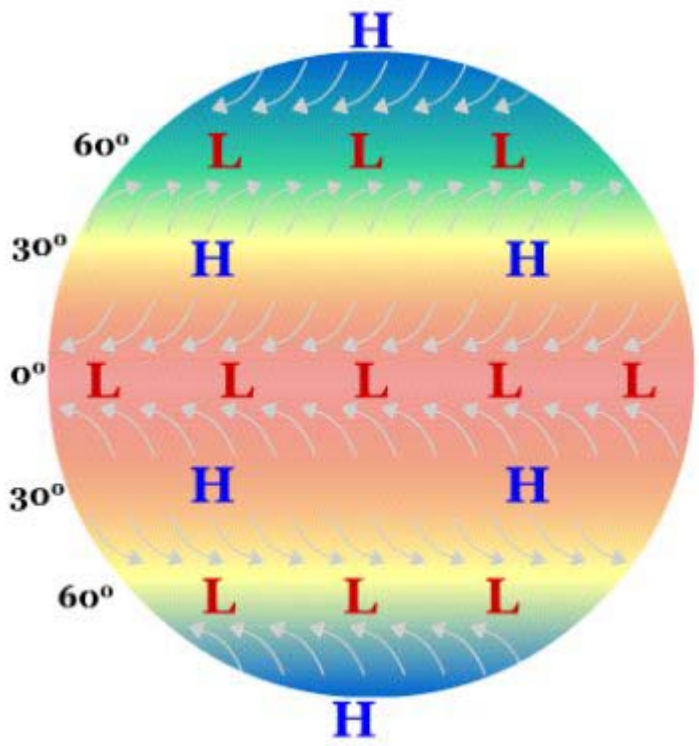

Figure 3 - Global wind and pressure systems derived from the 3-cell theory.

a. Subtropical High Pressure Systems. Subtropical highs are semi-permanent warm core, high-pressure systems located equatorward of the Polar Front Jet.

(1) On atmospheric charts they are represented by both ridging at the surface as well as aloft. They are centered over subtropical latitudes (approximately 30 N and 30 S) of the North and South Atlantic, North and South Pacific, and the Indian Ocean.

(2) These areas of higher pressure are caused by the presence of descending air currents from the interaction of the Hadley and Ferrell cell.

(3) These high-pressure systems are very diffuse and move north and south as well as over water and over land with the season. They intensify over the ocean during the summer and weaken during the winter. During this season, the air over the ocean bodies remains relatively cool because of the slower heating of water relative to land surfaces, known as thermal lag.

(4) Over land, intensification takes place in the winter months. At this time, land cools off quickly, relative to ocean, forming large cold continental air masses.

(5) The eastern side of each subtropical high is associated with subsiding stable air, which produces low relative humidities and sunny skies, while the atmosphere at the far western side of each subtropical high is less stable and can be associated with cloudy, and humid weather.

(6) These highs feature a weak horizontal pressure gradient over a broad area at around the system's center, therefore, surface winds are very light or even calm over subtropical oceans.

b. Inter-tropical Convergence Zone. The Inter-tropical Convergence Zone (ITCZ) is a discontinuous belt of thunderstorms and rain showers located parallel to the equator.

(1) The formation of this band of low pressure and bad weather is the result of solar heating that force the air in the region to rise by convection and results in abundant precipitation.

(2) The other main reason is the convergence boundary of the trade winds. This convergence boundary separates the northeast trade winds of the Northern Hemisphere and the southeast trade winds of the Southern Hemisphere.

(3) This zone is near the equator, from about 5°N and 5°S. This zone of abundant precipitation, the ITCZ, moves seasonally, always being drawn toward the area of most intense solar heating, or warmest surface temperatures.

(4) This boundary can have a variation of more than 40° of latitude due to the variation of land temperatures and the distribution of ocean and land. The ITCZ moves toward the Southern Hemisphere from September through February and reverses direction towards the Northern Hemisphere for summer.

c. Westerlies. The mid-latitude Westerlies are the highly variable planetary-scale winds that blow from southwest in the Northern Hemisphere and from northwest in the Southern Hemisphere between 30° and 60° latitude. In middle- and upper-troposphere, mid-latitude Westerlies blow west to east in a wavelike pattern of ridges and troughs. These winds are responsible for the development and displacement of the weather systems (highs, lows, and air masses) and for the poleward heat transfer.

d. Polar High Pressure Systems. Polar highs are located over the cold Polar Regions, associated with subsiding, cold, anticyclonic circulation. Polar highs extend from the poles close to latitude 60 north and south.

e. Polar Easterlies. Polar easterlies are caused by the out-flowing wind of the Polar High. Polar Easterlies are global winds

that move in the opposite direction of a pole, and turns to the east due to the Coriolis force. They are the rather shallow and diffuse body of easterly winds located poleward of the sub polar low-pressure belt. In the mean in the Northern Hemisphere, these easterlies exist to an appreciable extent only north of the Aleutian low and Icelandic low. Polar Easterlies occur at both the South and North pole, it is a global wind system that occupies most of the area between the Polar highs and about 60° of latitude In many aspects they are the same as other global winds, such as the Trade Winds. The Polar Easterlies are usually weak in the summer, and very strong in the winter. During the winter the polar wind can reach far into the middle latitudes.

f. Sub polar Low Pressure Systems. Are caused by the distribution of land and water and coupled with the sub-tropical high will cause semi-permanent pressure systems known as sub-polar lows. These are found near 40-60 degrees north and south. This location goes along with the placement of the polar front jet, with the jet in this area it increases storm passage in this region, which deepens and keeps the semi-permanent area of low pressure around. They are stronger in the northern hemisphere in the winter and stronger in the southern hemisphere in the summer. There are two main sub-polar low-pressure systems that you may hear of and they are the Aleutian low in the North Pacific and the Icelandic low in the North Atlantic.

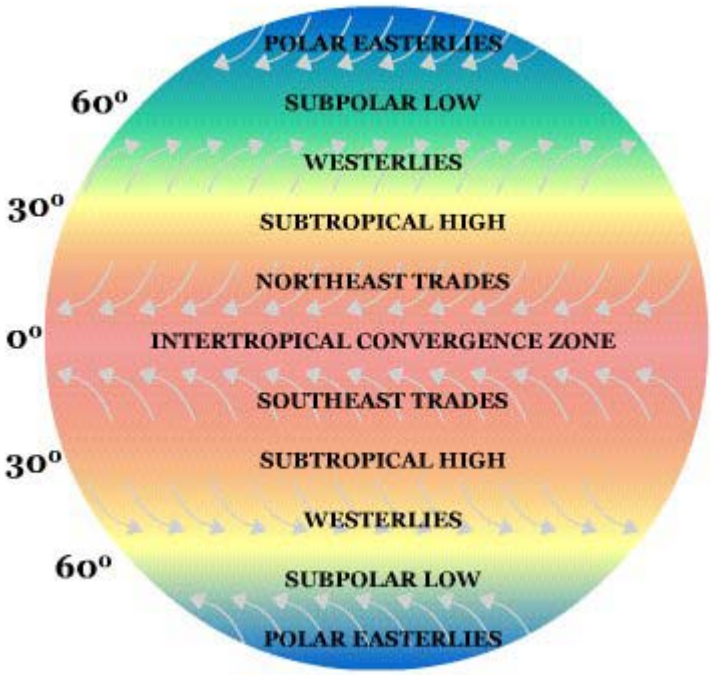

Figure 4 – Names of surface global winds.

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. There are no questions for the class at this time.

SUMMARY: This period of instruction covered the dynamics of the three-cell theory, explicitly stating how the cells act to create various surface wind flow patterns and pressure systems.

REFERENCE:

University of Southern California, Department of Earth Sciences. http://earth.usc.edu/geol150/weather/circulation.html

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