UNITED STATES MARINE CORPS

LESSON PLAN

JET STREAMS

INTRODUCTION:

1. Gain Attention. Why does it take less time to travel from Japan to California than from California to Japan?

2. Overview. During this period of instruction, the student(s) shall learn the definition of a jet stream and jet maxima, the different types of jet streams, causes of jet streams, and a general synopsis of seasonal locations.

3. Introduce Learning Objectives.

a. Terminal Learning Objectives. With the aid of references, but in accordance with the instruction, define and discuss why the various types of jet stream exist, seasonal migration patterns, and the typical characteristics of a jet stream.

b. Enabling Learning Objectives. Without the aid of references, but in accordance with the instruction, define and discuss the following:

(1) The various characteristics of jet streams, to include jet core, jet axis, jet maxima, and dimensions.

(2) State the approximate seasonal location of the polar front jet during the winter and summer months in the northern hemisphere.

(3) Define the origin of each jet stream.

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 Earth's Atmosphere".

5. Evaluation. You will not be evaluated at the end of this period of instruction; however, there will be a question and answer period at the end of this period of instruction.

TRANSITION. Recall in previous lectures the topic of global circulation. We know that the interaction from the Ferrel and Polar cells produce a westerly flow in the middle latitudes of the Northern hemisphere, called the "Westerlies". The next section takes us down, from the global scale to the synoptic scale and introduces a major feature within the atmosphere, the jet streams.

BODY:

1. Jet Stream Characteristics and Terminology. In the Northern hemisphere, the upper-level airflow is from west to east. Embedded within this wind flow, is a relatively narrow band of stronger winds.

These stronger winds are similar to jets of fast moving water, and have been named "jet streams".

a. Jet Core. The "*jet core*" can be defined as a relatively strong band of winds concentrated in the upper levels of the atmosphere.

(1) The characteristics of the jet core (stream) are three-dimensional. They are typically several thousands of kilometers in length, several hundred kilometers in width, and tens of kilometers in depth (see figure 1). Because the jet streams are wider than they are deep, wind shear (a change in wind direction or velocity) is greater in the vertical than in the horizontal.

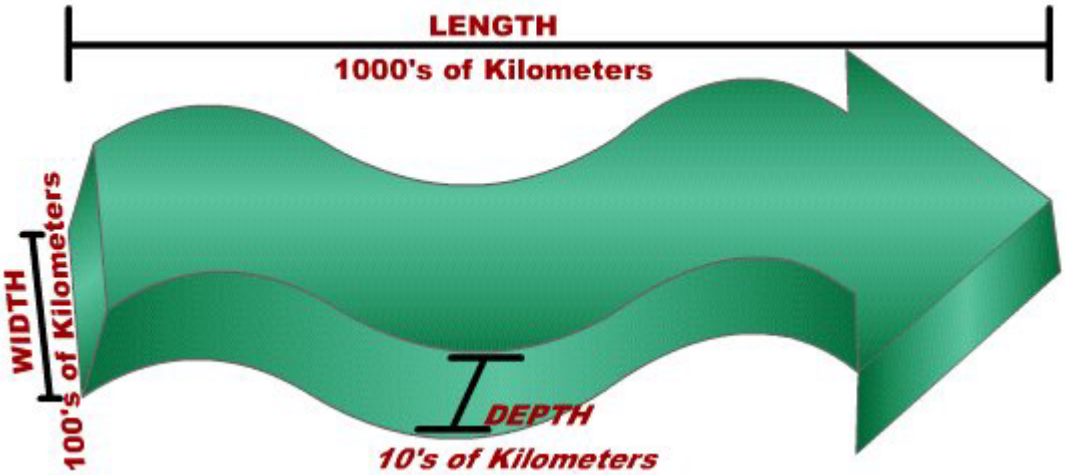

Figure 1 - Three dimensional view of jet core depicting length, width, and depth.

(2) Starting at 300 millibars (approximately 24,000 feet), 50 knots denotes the criteria for identification of jet stream winds. Within this relatively strong band of winds, there may be an even stronger area where the wind speeds reach a maximum.

b. Jet Axis. The "*jet axis*" typically runs through the center of the jet stream where it annotates the strongest winds within the core.

c. Jet Maximum. The "jet maximum" (maxima for plural) is a region where the wind speeds reach a maximum, hence the name. Jet maxima are typically shaped like a football and have a direct affect on upper-level divergence and convergence in two (2) different aspects.

(1) The jet maximum can be broken into two halves; a convergent half and a divergent half.

(a) Where the winds converge, both in direction and speed, on the –S side of the jet maximum, is the convergent half. Because the polar front jet stream is located between polar and mid-latitude leafs, the air parcels converge (subgradient winds exist) and are forced downward. This upper-level convergence produces subsidence, or downward vertical motion.

Figure 2 – The jet maximum can be divided into two quadrants. A convergent quadrant, where confluence and speed convergence occur, and a divergent quadrant where diffluence and speed divergence occur.

(b) Where the winds diverge, both in direction and speed (supergradient winds), on the +S side of the jet maximum, is the divergent half. Because there is a net removal of mass in this area, air parcels are drawn upward in vertical motion, and it is therefore associated with upper-level diverge. It is this region that favors convective development on the surface through cyclogenesis or frontogenesis (the development or intensification of a cyclone or frontal system respectively).

(2) The jet maximum can also be broken into four (4) quadrants that are also directly related to convergence and divergence and Vorticity advection in Geostrophic or straight-line flow. The didy of "Cops (convergent) Don't (divergent) Do (divergent) Cops (convergent)" is frequently used when deciphering the different quadrants.

(a) The left rear quadrant is associated with convergence and negative Vorticity advection.

(b) The right rear quadrant is associated with divergence and positive Vorticity advection.

(c) The left front quadrant is associated with divergence and positive Vorticity advection.

(d) The right front quadrant is associated with convergence and negative Vorticity advection.

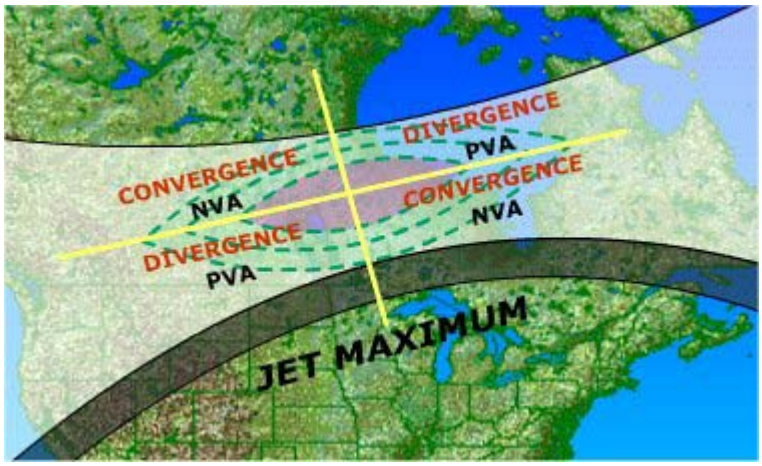

Figure 3 - The jet maximum can be divided into four quadrants and associated with upper-level divergence and positive Vorticity advection then convergence and negative vorticity advection.

(3) When a jet maximum lies within a trough of low pressure, only the left rear and front quadrants can be assessed. The right rear and front quadrants become difficult to assess.

(4) When a jet maximum lies within a ridge of higher pressure, only the right rear and front quadrants can be assessed. The left rear and front quadrants become difficult to assess.

INSTRUCTOR NOTE: The association between convergence and divergence and Vorticity advection will be discussed in the next period of instruction QMMPH1-040 Vertical Motions.

TRANSITION. With a basic understanding of the different characteristics of jet streams, the next topic discusses how jet streams are actually formed in the upper-level of the atmosphere.

4. Origination of the Jet Streams. There are actually three (3) different types of jet streams that meteorologists refer to, the Artic jet, the Polar Front jet, and the Subtropical jet streams. For the purpose of this period of instruction, the Polar Front and Subtropical jet streams will only be discussed.

a. Polar Front Jet Stream (PFJ). The Polar Front jet stream is located where the Ferrel and Polar cells meet, between the polar and mid-latitude tropospheric leafs, around 60° north and south latitude. It is in this region where there is an extensive height contour gradient and therefore a strong pressure gradient. The primary cause of the PFJ is a horizontal temperature contrast found in this gradient. The height of the Polar Front jet stream varies with seasonal changes, but can generally be found between 18,000 feet and 30,000 feet.

b. Subtropical Jet Stream (STJ). The Subtropical jet stream is located where the Hadley and Ferrel cells meet, between the mid-

latitude and tropical tropospheric leafs, around 15° to 35° north and south latitude. The primary cause of the Subtropical jet stream is the upper-level convergence between the Hadley and Ferrel cells. Recall that surface air at the Equator converges from the two Hadley cells and rises due to convection. The air will reach a maximum altitude at about 14 kilometers (top of the troposphere), and then begin to flow poleward horizontally. The Coriolis force causes the deflection of this moving air in the upper atmosphere, and by about 30° of latitude, the air begins to flow in a *zonal* pattern, or from west to east. This zonal flow is known as the subtropical jet stream. The zonal flow also causes the accumulation of air in the upper atmosphere, for it is no longer flowing in a north-south direction (meridional). To adjust for the converging air aloft, the air then sinks back to the surface and its result is the subtropical high pressure zone or belt.

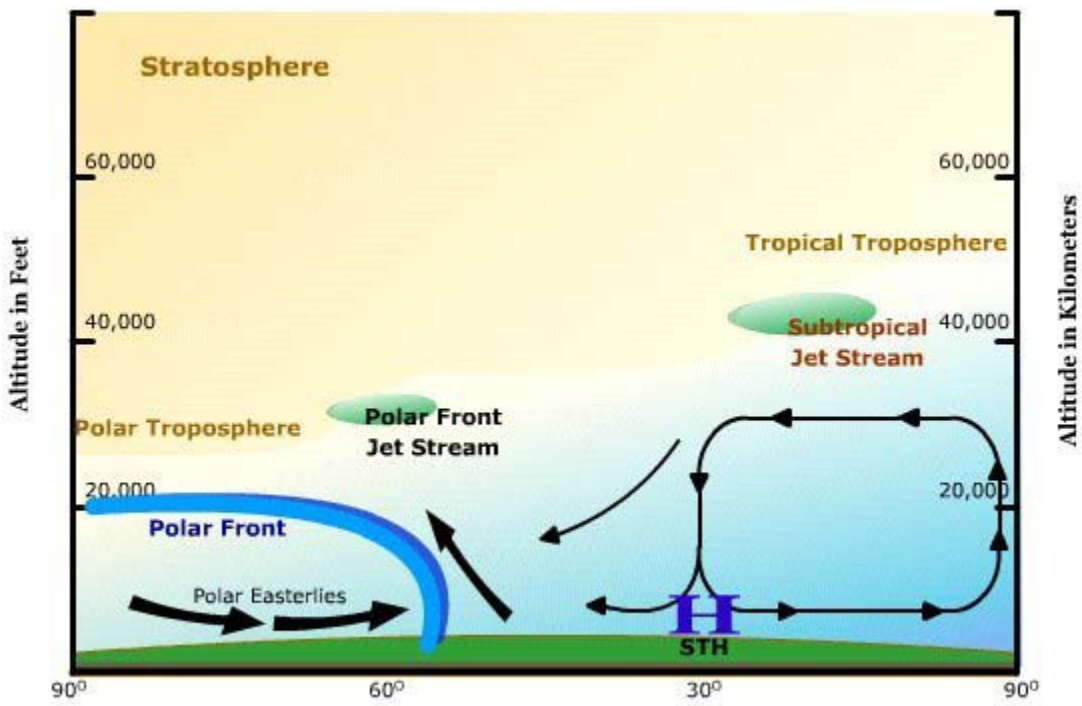

Figure 4 – Cross sectional view of the tropospheric leafs (folds) and respective locations of the Polar Front and Subtropical jet streams.

TRANSITION. We already know that weather conditions change with seasons. The next section focuses on how seasonal changes affect the location and strength of the Polar Front and Subtropical jet streams.

5. Seasonal Locations and Changes.

a. Polar Front Jet Stream.

(1) The PFJ migrates with the seasonal temperature changes. As autumn turns into winter, the vertical rays of the Sun are now located south of the Equator. In the Northern hemisphere, temperatures are cooling accordingly while the Polar Front jet

stream migrates towards the Equator, following the Sun. The horizontal temperature gradients have shifted equatorward and strengthened due to increasing temperature gradients. The polar front jet is stronger and farther Equatorward in the winter than in the summer.

(2) During the summer months, the polar front jet is located farther north or closer to the north pole because the vertical rays of the Sun are now move towards the northern side of the Equator until they reach the northern most point of 23.5°N at the summer solstice.

b. Subtropical Jet Stream. The STJ is also stronger in the winter than in the summertime for the same reasoning. During the warmer summer months, there is less of a temperature gradient in the upper-levels of the atmosphere in the tropical and subtropical regions. If the STJ is reflected on upper-air charts, then it is relatively weak in nature.

(1) The winds within the subtropical jet stream are often greatest in regions of confluence. Where this occurs, the subtropical jet is located at its most poleward extent. The radius of the Earth at this point is smaller and wind velocities will increase in order to conserve angular momentum.

(2) The STJ is very important in transporting warm moist air poleward to interact with cool dry polar air. This produces strong temperature, contour, and isotach gradients associated with severe weather.

TRANSITION. The polar front and subtropical jet streams are both associated with their own dynamics and significance. However, there are times at which these two jet streams merge and overlap each other.

4. Interaction between Jet Streams. The Polar front jet and subtropical jet streams both exist individually, but occasionally the polar front and subtropical jet streams will merge or overlap each other spatially and temporally. When the two (2) jet streams do interact, favorable conditions for the following weather may occur:

a. Severe to extreme turbulence may develop where the two jet streams converge. The turbulence will be most severe between the two jet cores.

b. When the subtropical jet works its way up into the middle latitudes, it also aids in frontogenesis and atmospheric dynamics in the region where strong gradients exist along the polar front.

c. This interaction can also favor the development of severe thunderstorms. Satellite imagery often confirms severe weather activity as a characteristic wedged-shaped cloud pattern in the region where the two jet streams diverge.

TRANSITION. Location of jet streams are of important significance to meteorologists. There are several rules of thumb used to aid in determining jet stream type and location.

5. Identification of Jet Streams. There are several different ways to identify the jet streams. The following guidelines provide a generalized jet location. Seasonal and situational adjustments to actual jet placements should be made.

a. Polar Front Jet.

(1) Typically found on the 300 or 250 millibar charts, in the tightest contour gradient, depending on the season.

(2) Typically located above the tightest contour gradient on the 500 mb level.

(3) Typically located in the center of the tightest thickness packing on the Surface-500mb Thickness Chart.

(4) Elongated black, dry, areas on a water vapor satellite shot.

(5) Found on the poleward side of polar surface front.

b. Subtropical Jet.

(1) Typically found on the 250 or 200 millibar charts, in the tightest contour gradient, depending on the season. The subtropical jet stream is stronger and more visible during the Northern hemisphere colder months than in the warmer months.

(2) Generally located between 10° and 35° latitude.

(3) Typically located in the center of the tightest thickness packing on the Surface-500mb Thickness Chart.

(4) Elongated black, dry, areas on a water vapor satellite shot.

(5) Associated with areas of transverse banding on satellite imagery.

OPPORTUNITY FOR QUESTIONS:

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

2. Questions to the Class.

a. QUESTION. What are the physical dimensions of a jet stream?

b. ANSWER. Can be thousands of kilometers in length, hundreds of kilometers in width and several to tens of kilometers in depths.

c. QUESTION. What is primary cause of the Polar Front Jet Stream?

d. ANSWER. Horizontal temperature contrast between the polar and mid-latitude tropospheric leafs.

SUMMARY: During this period of instruction the student(s) has been instructed on the different types of jet stream, their characteristics, and respective origins. Seasonal migration patterns for the polar front jet stream were introduced and discussed, as well as, the significance of the interaction between the polar front jet stream and the subtropical jet stream.

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.

The Atmosphere: An Introduction to Meteorology. Frederick K. Lutgens and Edward J. Tarbuck. 9th ed. New Jersey: Pearson Education Inc., 2004.