

Project Atmosphere Canada



MODULE

9

Westerlies and The Jet Stream

Teacher's guide



Canadian Meteorological
and Oceanographic
Society

La Société Canadienne
de Météorologie et
d'Océanographie



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Project Atmosphere Canada (PAC) is a collaborative initiative of Environment Canada and the Canadian Meteorological and Oceanographic Society (CMOS) directed towards teachers in the primary and secondary schools across Canada. It is designed to promote an interest in meteorology amongst young people, and to encourage and foster the teaching of the atmospheric sciences and related topics in Canada in grades K-12.

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On behalf of
Environment Canada and the Canadian Meteorological and
Oceanographic Society

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INTRODUCTION

The Upper-Air Westerlies

The Upper-Air Westerlies

Many properties of the atmosphere vary dramatically as we move upward from the surface. Because most of the sun's rays readily pass through the clear atmosphere to warm the planet's surface, the atmosphere is strongly heated from below. Thus, the highest temperatures are typically found at the Earth's surface and decrease as altitude increases. This bottom atmospheric layer of decreasing temperatures, ranging from 6 to 16 km in depth, is called the *troposphere* or "weather layer".

Above the troposphere, we find a layer of air whose temperature increases with altitude. The cause of this heating is the absorption of solar ultraviolet radiation by oxygen species and chemical reactions which form and dissociate ozone (the three-atom species of oxygen). Here ozone is naturally formed and destroyed, and several of the components of the process release heat which is then transferred to the surrounding air. The effect of this warming produces a layer of constant temperature topped by a layer of increasing temperatures with altitude. This layer is called the *stratosphere* or "stable layer". The boundary zone between the troposphere and the stratosphere, where the temperature stops decreasing and becomes constant with height, is termed the *tropopause*.

Both air pressure and air density decrease with increasing altitude. Air pressure is the weight per unit surface area of an air column extending from the given height to the top of the atmosphere. Therefore, atmospheric pressure is greatest at sea level.

Air is highly compressible, as is readily seen by inflating a tire. Therefore, it is most dense at the bottom of the atmosphere where the weight of the air above compresses it to high densities. At higher altitudes, the air is less dense because of the lesser weight of overlying air at upper levels. The result is that both air pressure and air density initially decrease very rapidly with altitude and then decrease more slowly. Half of all air molecules are found within only 5.5 km of sea level. The next one-quarter of the atmospheric mass is located between 5.5 to nearly 11 km.

Not only do atmospheric properties such as temperature, pressure and density vary with altitude, but so does the nature of the air's motion. On the *planetary* (or global) scale the winds blowing at middle latitudes in the middle and upper troposphere blow predominantly from the west. These upper-air, *prevailing westerlies* encircle the globe in a wave-like pattern, undulating north and south as they flow along the latitude belt.

The upper-air winds play an important role in the daily march of weather across the planet. They push air masses from their regions of origin and steer storm systems from one place to another.

Understanding the basic characteristics of these upper-air (tropospheric) westerlies is a prime key to understanding the variability of mid-latitude weather.

ACTIVITY

The Upper-Air Westerlies

After completing this activity, you should be able to:

- Describe the wave patterns exhibited by the meandering upper-air westerlies.
- Explain the general relationships between the upper-air westerlies and the paths surface air masses and storms take.

Investigations

1. The upper-air westerlies flow generally from west-to-east around the planet in a wave-like pattern of ridges and troughs undulating northward and southward as shown in Figure 1. Ridges are topographic crests, usually pointing northward, and troughs are elongated depressions, usually pointing southward, on constant-pressure surfaces in the Northern Hemisphere. In Figure 1, the "H" locates ridges and "L" locates troughs on this constant-pressure map.

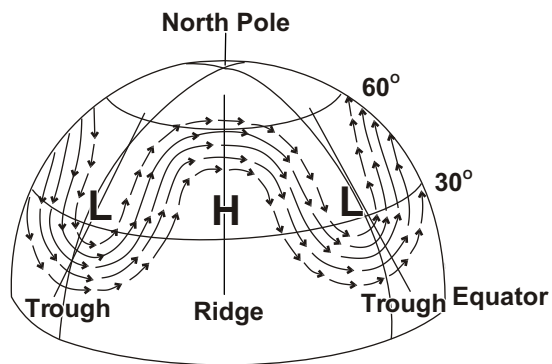


Figure 1 - Northern Hemisphere depicting upper-air westerlies with troughs and ridges

2. The upper-air westerlies exhibit clockwise (anticyclonic) curvature in ridges. As shown in Figure 1, a line can be drawn that divides a ridge into two, often symmetrical, sectors.

Such a line is known as the *ridge line*. Note that west of the ridge line, winds are from the southwest (a warm weather direction) and east of the ridge line, winds are from the northwest (a cold weather direction). We conclude that winds to the west of a ridge line favour (**cold, warm**) advection, and winds to the east of a ridge line favour (**cold, warm**) air advection.

3. The upper-air westerlies curve counterclockwise (cyclonic) in troughs. As shown in Figure 1, a line can be drawn that divides a trough into two roughly symmetrical sectors. The line is known as a *trough line*. Note that west of the trough line, winds are from the northwest (a cold weather direction) and east of the trough line, winds are from the southwest (a warm weather direction). We conclude that winds to the west of a trough line favour (**cold, warm**) air advection, and winds to the east of a trough line favour (**cold, warm**) air advection.
4. Ridges and troughs usually progress from west to east so that as a ridge line shifts eastward, a location that had been experiencing cold air advection then experiences warm air advection. Similarly, as a trough line moves eastward, a location that had been experiencing warm air advection then experiences cold air advection.
5. Upper-air winds steer low pressure systems as well as air masses in the direction of their flow. A surface low that is centred to the east of a trough line and west of a ridge line can be expected to move toward the (**northeast, southwest**).
6. The wavy pattern of the upper-air westerlies consists of ridges alternating with troughs.

The distance between successive ridge lines or, equivalently, between successive trough lines is termed the *wavelength*. At any one time, the number of waves encircling the Earth in the middle latitudes is usually 3, 4, or 5. The *amplitude* of the wave pattern is the distance between the extreme northern position of the ridge line and the extreme southern position of the trough line. At one extreme, shown in Figure 2a, upper-air westerlies blow almost directly from west to east with little sign of ridges and troughs. This westerly flow pattern is described as *zonal*, because the flow is along the latitude zones, and the amplitude is small. At the other extreme, shown in Figure 2b, upper-air westerlies blow in huge north/south loops with high amplitude ridges and troughs. This westerly flow pattern is described as *meridional* because the flow tends to align itself more with the meridians. The circulation patterns displayed in Figures 2a and 2b are the opposite extremes of many possible patterns exhibited by middle latitude upper-air westerly waves.

7. With time the wave pattern of the upper-air westerlies moves and changes. These changes may involve a change in the number of waves, the wavelength, or the amplitude of the wave.
8. When the upper-air westerly flow pattern across Canada is zonal, the source region for much of the air over Canada is from the

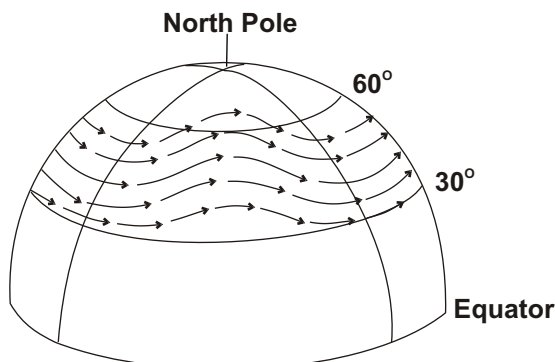


Figure 2a

Pacific Ocean. On the other hand, when the upper-air flow pattern is meridional, the air over Canada generally originates from cold air masses from the High Arctic (in areas where winds are from the northwest) or warm air masses from the southern United States and/or the Gulf of Mexico (where winds are from the southwest).

9. Go to the Environment Canada Web Site to view the latest 500 hPa upper-air analysis chart:

<http://weatheroffice.ec.gc.ca>

Navigate to the **Weather Maps** page, select **Analysis Charts** and click on the **500 hPa Analysis Chart**

10. Using the 500 hPa analysis provided in Figure 3, examine the analysis and the patterns, troughs and ridges drawn on the map from the perspective of:
 - a) Describing the wave patterns exhibited by the meandering upper-air westerlies.
 - b) Explaining the general relationships between the upper-air westerlies and the paths air masses and storms take.
11. As a supplementary activity, examine the latest 500 hPa analysis found on the Environment Canada Web Site to view the upper-air westerlies within the context of "today's" weather patterns.

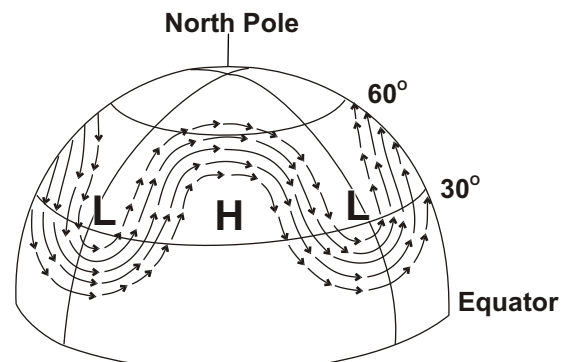


Figure 2b

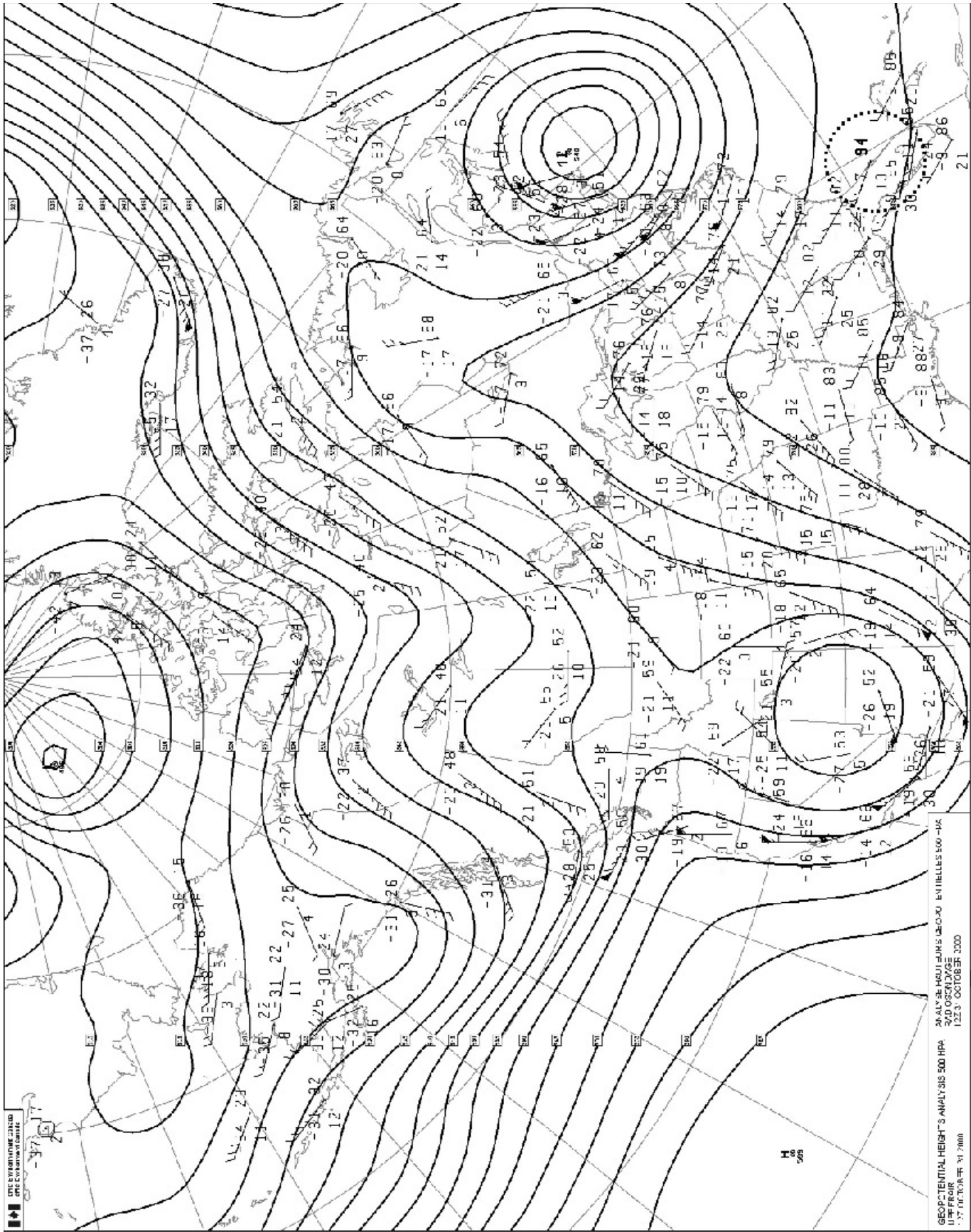


Figure 3 - Environment Canada 500 hPa Analysis for 12Z Oct 31, 2000. The solid lines on the chart are called 'contours' or iso-lines where the height above sea level of the 500 hPa level are the same.

