ACTIVITY The Jet Stream

Jet Stream Investigation

The location of the polar-front jet stream is often closely related to the daily weather pattern across North America. The following two activities investigate the causes of jet streams and the relationships of the polar-front jet stream with surface weather.

Each activity can be stand-alone. One activity does not need to be done before the other. However, Activity 1 requires the construction of two sets of five pressure blocks. There are two sets of instructions for making the pressure blocks. The first suggestion is for the construction of a permanent set of pressure blocks while the second option uses more readily available but less durable material for classroom exercises. Finally, Activity 1 requires more time to complete than Activity 2.

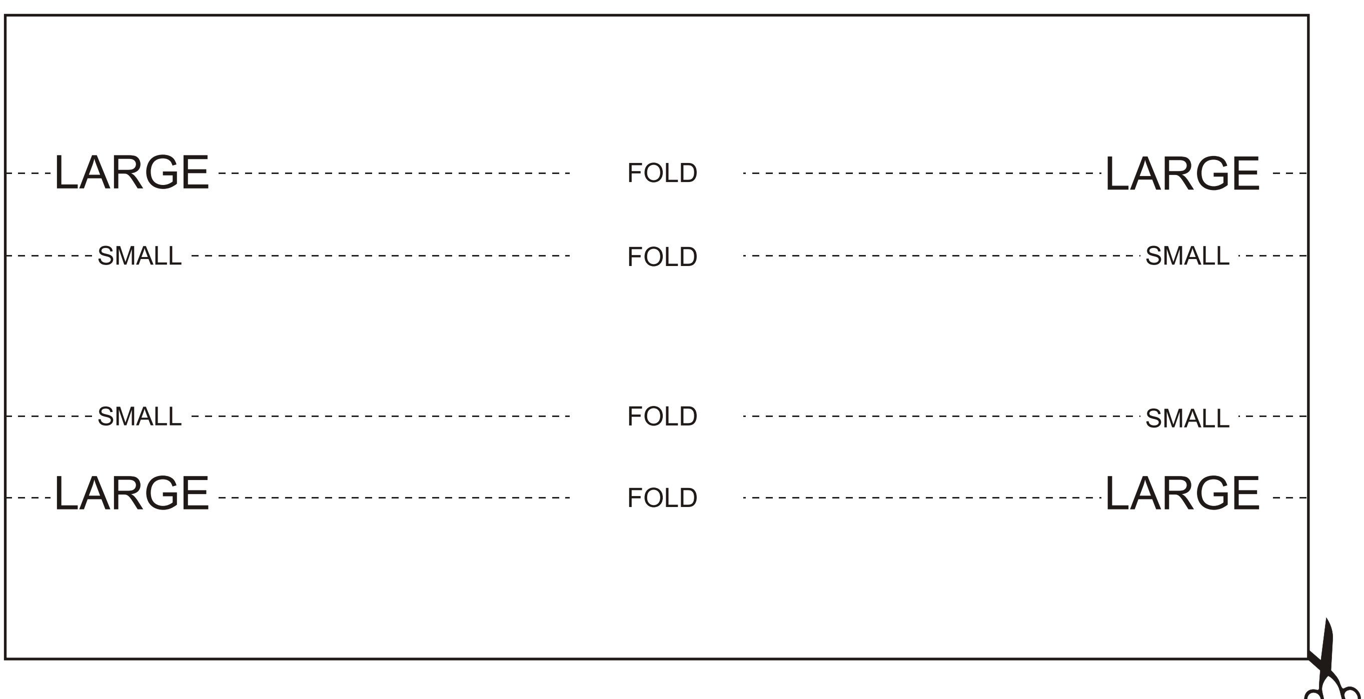
Pressure Blocks Construction

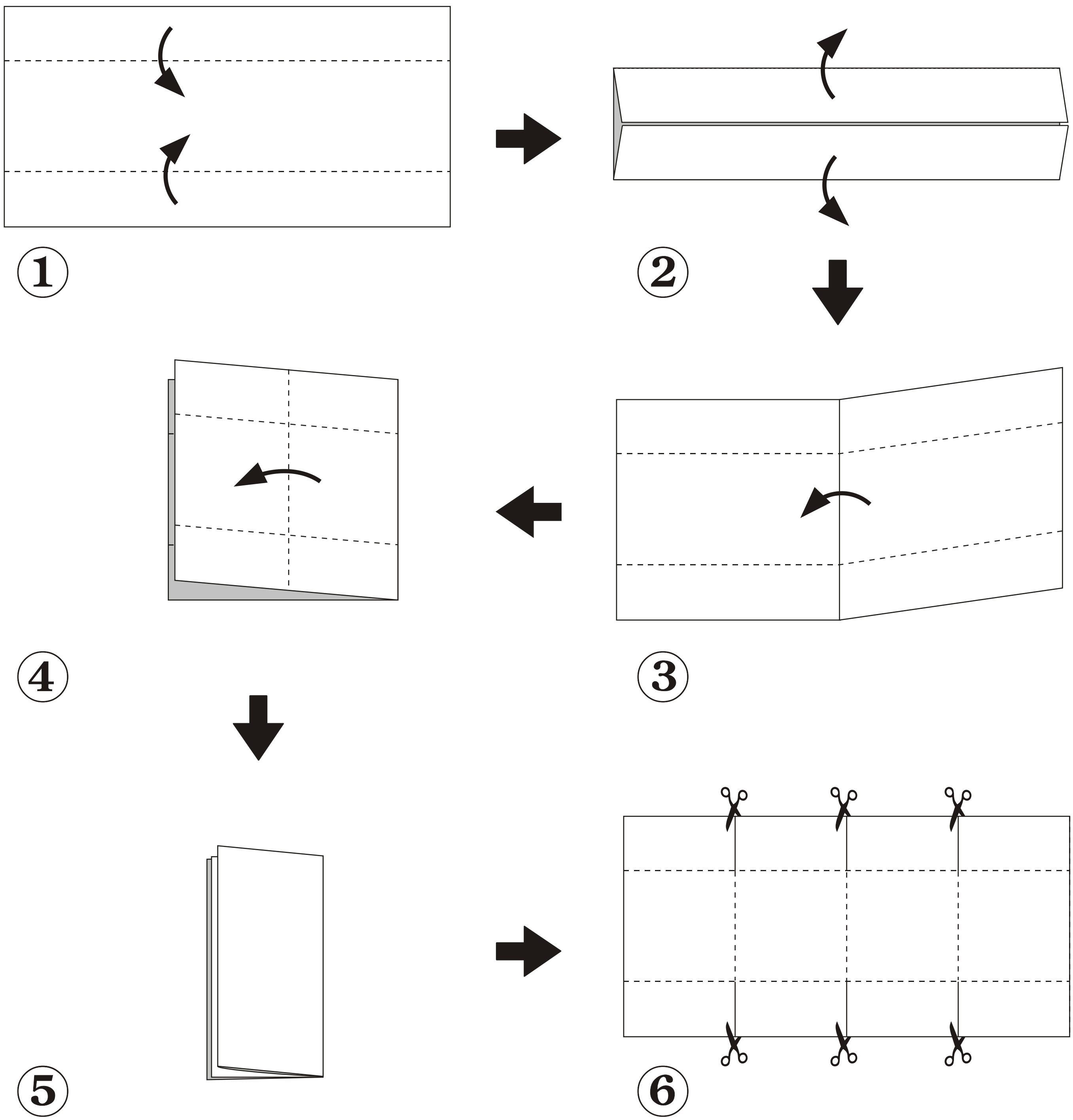
Materials

- 1 red file folder, 1 blue file folder, tape, scissors, ruler, pencil

Procedure

1. You will be making two sets of pressure blocks, 5 large red blocks and 5 small blue blocks. Both sizes of blocks will be constructed from the same size card shown below.
2. The pattern below has guidelines for the large and small blocks. Copy and cut out the pattern. On the red file folder, trace the pattern edges for a set of 5 cards. Make tick marks indicating the position of the LARGE guidelines. Draw the LARGE guidelines across each card. On the blue folder, repeat the process except make tick marks for and draw in the SMALL guidelines across each card. Cut out all 10 cards.
3. To form a block, fold a card along the top and bottom guidelines you have drawn. Make a sharp crease. Unfold the card.
4. Fold the card in half, bringing the short sides together. Make a sharp crease. Fold the card in half again in the same direction. Make a sharp crease. Unfold the card.
5. With scissors, clip the long edge of the card on the fold creases up to the line you drew.
6. Fold the card into a box (short sides together). Tape edge. Fold and tape down flaps at either end. Repeat for all cards (blocks).
7. Since the same size card was used in every block, you now have 10 blocks each of equal weight. The bases of the blocks also have the same size.





Construction of a Permanent Set of Pressure Blocks

Cut blocks from solid materials such as wood or insulation material. The blocks should all have the same size square bases. The tall blocks should be twice the height of the short blocks. All blocks should weigh the same. Adjust the weight by drilling holes in the short blocks and inserting metal weights. Paint short blocks blue and tall blocks red.

ACTIVITY 1 Pressure, Air Pressure and Jet Streams

Upon completing this activity, you should be able to:

- Explain what pressure is and how it can vary vertically and horizontally.
- Describe how density contrasts between warm and cold air produce pressure differences at different levels in the atmosphere.
- Explain how pressure differences in the atmosphere can lead to high-speed winds called jet streams.

Introduction

One of the most important properties of the atmosphere is air pressure. It is important because differences in air pressure from place to place put air into motion just as in the case of air rushing out of the open valve of an inflated tire. Pressure differences at altitudes of nine or more kilometres lead to the development of high-speed winds, called Jet Streams.

This activity uses sets of blocks to investigate basic understandings about pressure and pressure differences produced by density variations. These understandings are then applied to the atmosphere to introduce the basic causes of jet streams.

Materials

- Two 5-block sets of Pressure Blocks (See **Pressure Blocks Construction**)
- Two 8 cm X 13 cm cards (or index cards), pencil, straight edge

Investigations

To study pressure, we must first define it. Pressure is a force acting on a unit area of surface Air pressure is the weight (weight is a force) of a column of air acting on a unit area of horizontal surface, e.g. kilopascal (kPa) is a pressure unit. To represent the concept of pressure concretely, two sets of blocks with the following characteristics will be used.

a) all blocks have the same weight,

b) all blocks have the same size square bases,

c) all blocks exert the same downward pressure on the surface beneath them (because the same weight is acting on the same size base).

1. Take one block from each set and place it on its square base on a table surface. Because both blocks weigh the same and their bases have the same area, the blocks exert ***(equal)***, ***(unequal)*** pressure on the table.
2. The shorter blocks have half the volume of the taller blocks while containing the same mass (we know this since they weigh the same). Because density is mass per unit volume, the smaller blocks are (***twice***) (***half***) as dense as the larger blocks.
3. Place another identical block on top of each block already on the table. Each stack is now exerting ***(the same***) (***twice the***) amount of pressure on the table as it did initially. The pressure exerted on the table by the tall stack is (***equal***) (***not equal***) to the pressure exerted on the table by the short stack.

4. Position the two stacks side-by-side and add another identical block to each stack (for a total of 3 in each stack). Insert an index card horizontally through the two stacks so that two shorter blocks and one taller block are positioned beneath the card. Compare the pressures exerted on the card by the overlying blocks. The taller-block stack exerts (***greater***) (***equal***) (***less***) pressure on the card than does the shorter-block stack.

5. Add <u>a short block</u> to its respective stack. Lift the top tall block and overlay the stacks with another index card. Add the rest of the blocks to their respective stacks. The pressure exerted on the table by the tall stack remains (***equal***) (***un-equal***) to the pressure exerted on the table by the short stack.

6. Each block exerts one unit of pressure (1 UP) on the surface beneath it. In the table below, indicate the pressure in UP units each stack exerts on each surface. For each surface, compute and record the pressure difference between the two stacks.

7. Starting at the <u>table top</u> and moving upward, the <u>difference</u> in downward pressure exerted by the overlying portions of the stacks (***increases***) (***decreases***). In the (***taller less dense***), (***shorter more dense***) stack, the pressure decreases more rapidly with height.

8. Look at Figure 5: Pressure Blocks, Side View. Following the examples shown, draw lines on the chart to record the positions of the tops/bottoms of all the blocks so the chart represents a side view of the two stacks. Place a large dot at the mid-point of each top/bottom line you drew. Following the examples given, use a straight edge to draw lines from the dots in one stack to the dots in the other stack representing the same pressures. These lines connecting equal pressure dots become (***more***) (***less***) inclined with an increase in height.

9. Figure 6: Vertical Cross Section of Pressure shows a cross-section of the atmosphere based on upper-air soundings obtained simultaneously at Norman, Oklahoma (OUN) and at The Pas, Manitoba (YQD) approximately 2,175 kilometres to the north of Norman. Air pressure values in hectopascals (hPa) are plotted as dots at the elevations where they were observed, starting with nearly identical values at the surface. At Norman (OUN), the air pressure at approximately 12,300 meters above sea level was (***300***) (***250***) (***200***) hPa.

	Tall-Block Pressure (UP)	Short-Block Pressure (UP)	Pressure Difference (UP)
On Top Card			
On Lower Card			
On Table Top			

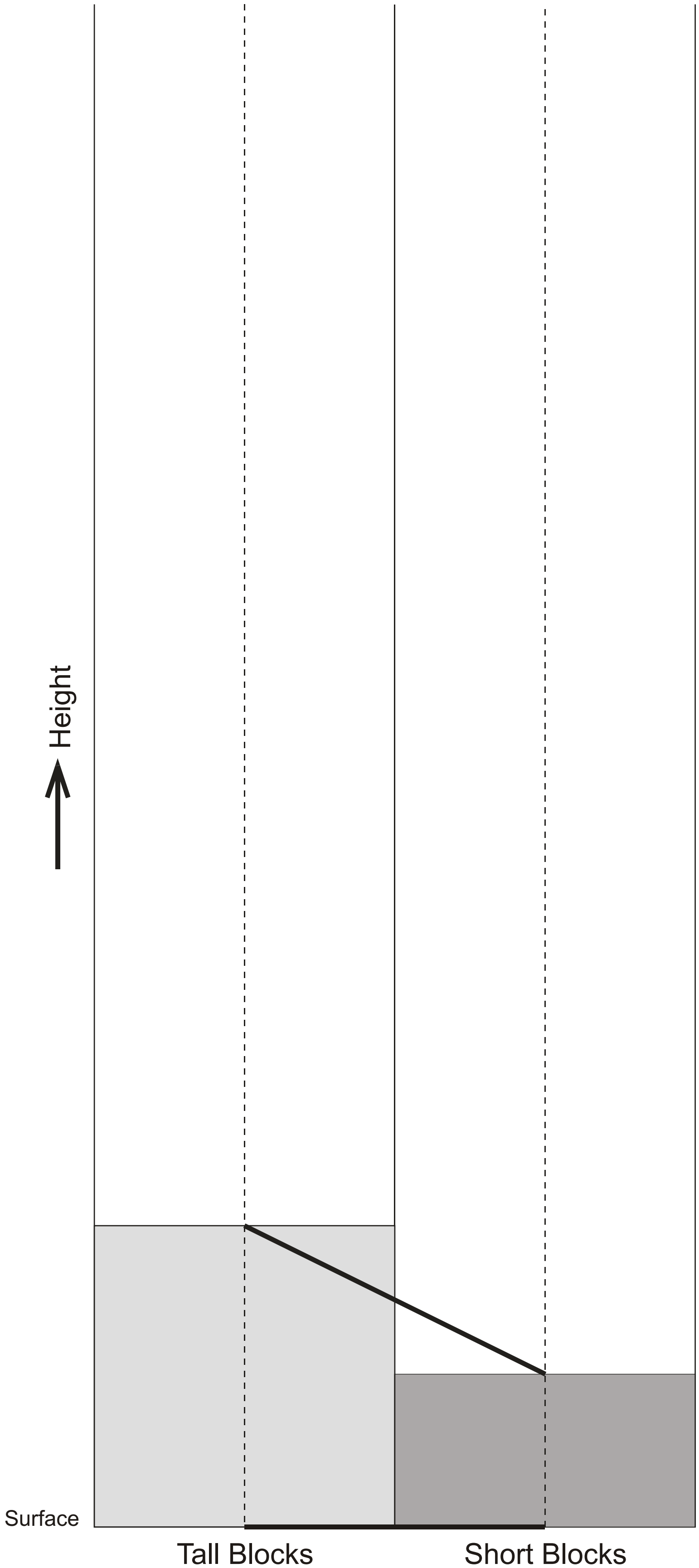


Figure 5 - Pressure Blocks, Side View

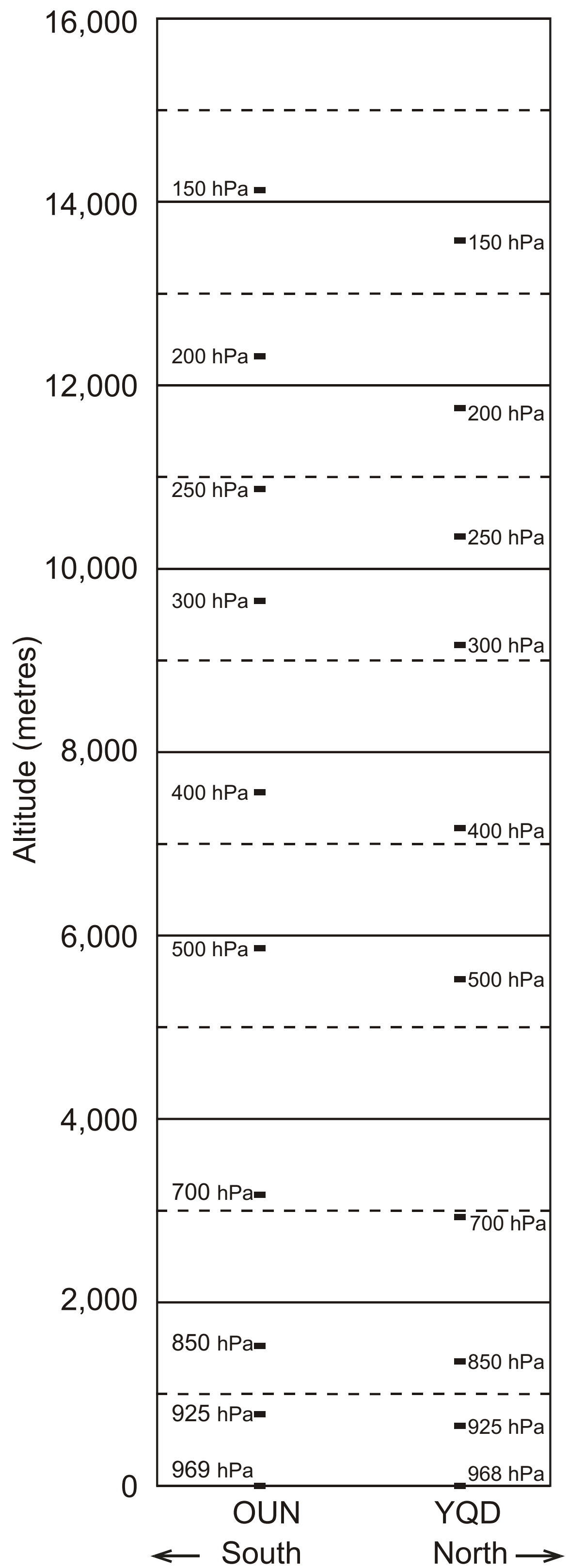


Figure 6 - Vertical Cross Section of Air Pressure (00Z Sept 12, 1993)

10. Air above The Pas, station YQD, was colder and therefore more dense than the air above the more southern station, OUN. Following the examples shown at the surface and at 925 hPa, draw straight lines connecting equal air-pressure dots on the graph. Above the Earth's surface these lines representing equal air pressures are (***horizontal***) (***inclined***).

11. Compare the lines of equal pressure you drew on the two figures. They appear quite different because one deals with rigid blocks while the other deals with air, and secondly, their scales are much different. However, both reveal the effect of density on pressure. The lines of equal pressure slope (***downward***) (***upward***) from the lower-density tall blocks or warm air column above OUN to the higher-density short blocks or cold air column above YQD, respectively.

12. Because of the sloping of the equal-pressure lines in Figure 6, it can be seen that at 12,300 meters above sea level the air pressure in the warmer air at OUN is (***higher than***) (***the same as***) (***lower than***) the air pressure in the colder air at YQD.

13. Because air is gaseous, air pressure at any point acts in all directions. Differences in air pressure arising from differences in air density produce horizontal forces directed from higher to lower pressure. Thus, air is put into motion horizontally from where the pressure is higher towards where the pressure is lower. Draw a horizontal arrow at the altitude of 12,300 meters to show the direction the horizontal force is acting at that elevation. This arrow points <u>towards</u> the (***north***) (***south***).

14. Air put into motion by these horizontal forces does not flow directly towards lower pressure. It is deflected by the Earth's rotation. This change in direction is called the Coriolis effect. In the Northern Hemisphere, air is deflected to the right of the direction towards which it is moving until it is travelling along a path perpendicular to the pressure-generated force. Which statement best describes the motion of the air under the influence of a pressure generated force (represented by your arrow) and the Coriolis effect?

    a) Air flowing southward turns right until it is moving towards the west.

    b) Air flowing northward turns right until it is moving towards the east.

15. At the time the upper-level observations were made, the highest wind speeds were recorded where the air pressure was near 200 hPa. Accordingly, the maximum wind speed was probably occurring near the altitude of (***10,000***), (***12,000***), (***14,000***) meters above sea level.

16. These upper-level high-speed winds, produced in large part by the density differences between warm and cold air, tend to concentrate in "rivers" of air. They are called <u>jet streams</u>. In Figure 7, the Upper-Level Exercise Map, the dark line represents the approximate location of the jet stream at the time the OUN and YQD observations were made. Draw an arrowhead on one end of the jet stream to show the direction the air is flowing.

Figure 7 - Upper-Level Exercise Map

ACTIVITY 2 The Polar - Front Jet Stream

Upon completing this activity, you should be able to:

- Determine the location of the polar-front jet stream based upon upper-atmosphere wind data.
- Describe influences of the polar-front jet stream on weather and aviation.

Introduction

The polar-front jet stream is like a high-speed river of air in the upper atmosphere. It separates warm and cold regions at the Earth's surface. It may be several hundred kilometres across from north to south, 1,500 to 3,000 meters thick and at an altitude of 9,000 to 13,000 meters. The polar-front jet stream generally flows from west to east, and is strongest in the winter when core wind speeds are sometimes as high as 400 kilometres per hour. Changes in the jet stream indicate changes in the circulation of the atmosphere and associated local weather.

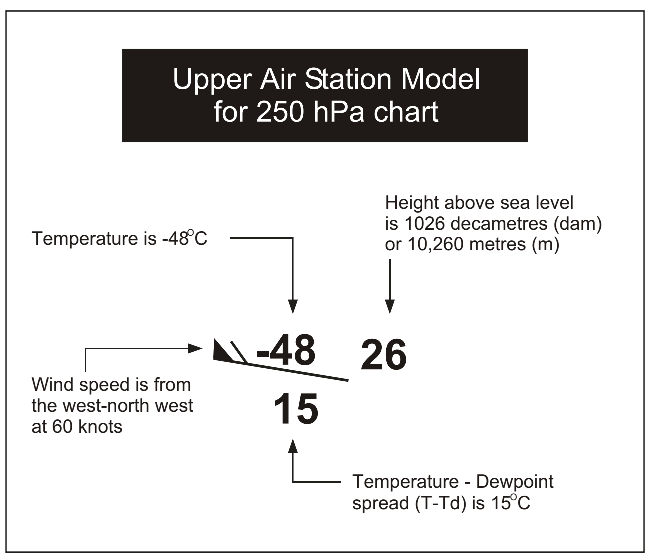
Materials

- pencil

Investigations

The highest upper-level wind speeds are frequently observed at altitudes of approximately 9 to 13 kilometres above sea level. In Figure 8, the upper air data chart displays plotted data depicting wind speed and direction observed at 12Z (7 a.m. EST) at altitudes where the air pressure was 250 hectopascals (hPa). At map time, the actual altitudes at which the air pressure was 250 hPa varied from 9,030 metres to 10,970 metres above sea level. Upper level data are routinely displayed on constant-pressure charts because of the usefulness of such charts to meteorologists. The data were acquired by tracking balloon-borne weather instruments, called radiosondes, which measure and transmit weather data as they rise through the atmosphere.

Wind information is depicted by "arrows" or “wind barbs” at locations on the map where radiosondes were launched. On the wind bard, the straight line represents the wind direction while the feathers represent the wind speed. Winds are named for the direction from which they are blowing. Wind speed is reported in knots (1knot equals 1.9 kilometres per hour); each full-length feather represents 10 knots, each half feather stands for 5 knots, and each flag means 50 knots. For example, in Figure 8, the plotted 250 hPa upper air data for The Pas, MB at 12Z on September 13, 2000 depicts a wind from the west-north west with a speed of 60 knots (or 114 km/h).



The wind information at the 250 hPa level received from each radiosonde can be plotted on a chart and used to analyze the upper air wind patterns and to locate the jet stream. In Figure 9, you will find the upper air 250 hPa data for 12Z Ocotber 13, 2000 plotted and also a number of shaded area. Within the shaded areas, the wind speeds at 250 hPa are 60 knots or greater. The darker the shading the higher the wind speed, i.e. 60 kts, 90 kts and 120 kts, which will help you identify the jet stream and the jet streak or jet max (or maximum). In this case, the jet maximums exceed 100 knots. The dotted lines encircling these shaded areas connects the points where the winds speed is 60 knots and are referred to as *isotachs*.

1. Using Figure 8, with a pencil, draw a line or lines to enclose the region(s) where the 250 hPa wind speeds are 60 knots or greater. Lightly shade the enclosed area. Draw a dark, heavy, smooth, curved arrow through the core of highest wind speeds. Add an arrowhead to show wind direction. Note: In Figure 8, you will see 4 stations with a dotted circle around them, which have been flagged by the computer that some aspects of the data set may have an error. So do not use those circled stations in your analysis.

2. The large arrow you drew on your map approximates the location of the existing polar-front jet stream across North America. Now imagine that you are in a gondola attached to a helium-filled balloon that is located over Prince George, BC. Assuming your balloon stays at the 250-hPa level, describe your path as you travel across the country. Over what cities, provinces or US states are you likely to pass over as you cross North America? At what point would you leave the east coast?

3. What is your approximate speed measured with respect to the surface of the Earth?

4. Even though the wind speed is 60 knots or greater, as measured relative to the ground, an anemometer attached to the gondola shows the wind to be calm. Explain why.

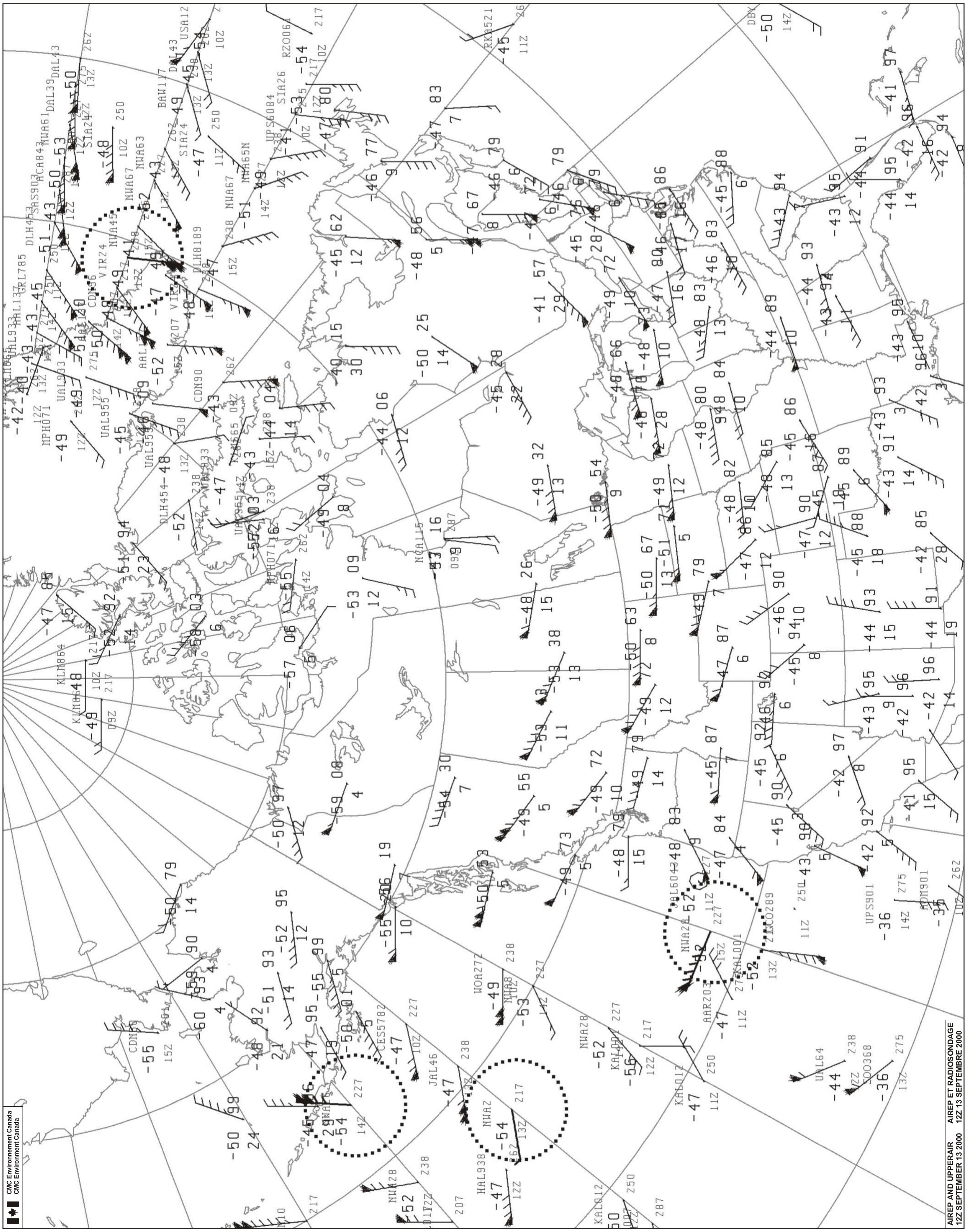


Figure 8 - CMC Environment Canada 250 hPa upper air chart depicting plotted data for 12Z September 13, 2000. Wind speeds are plotted in knots (1knot equals 1.9 km/h)

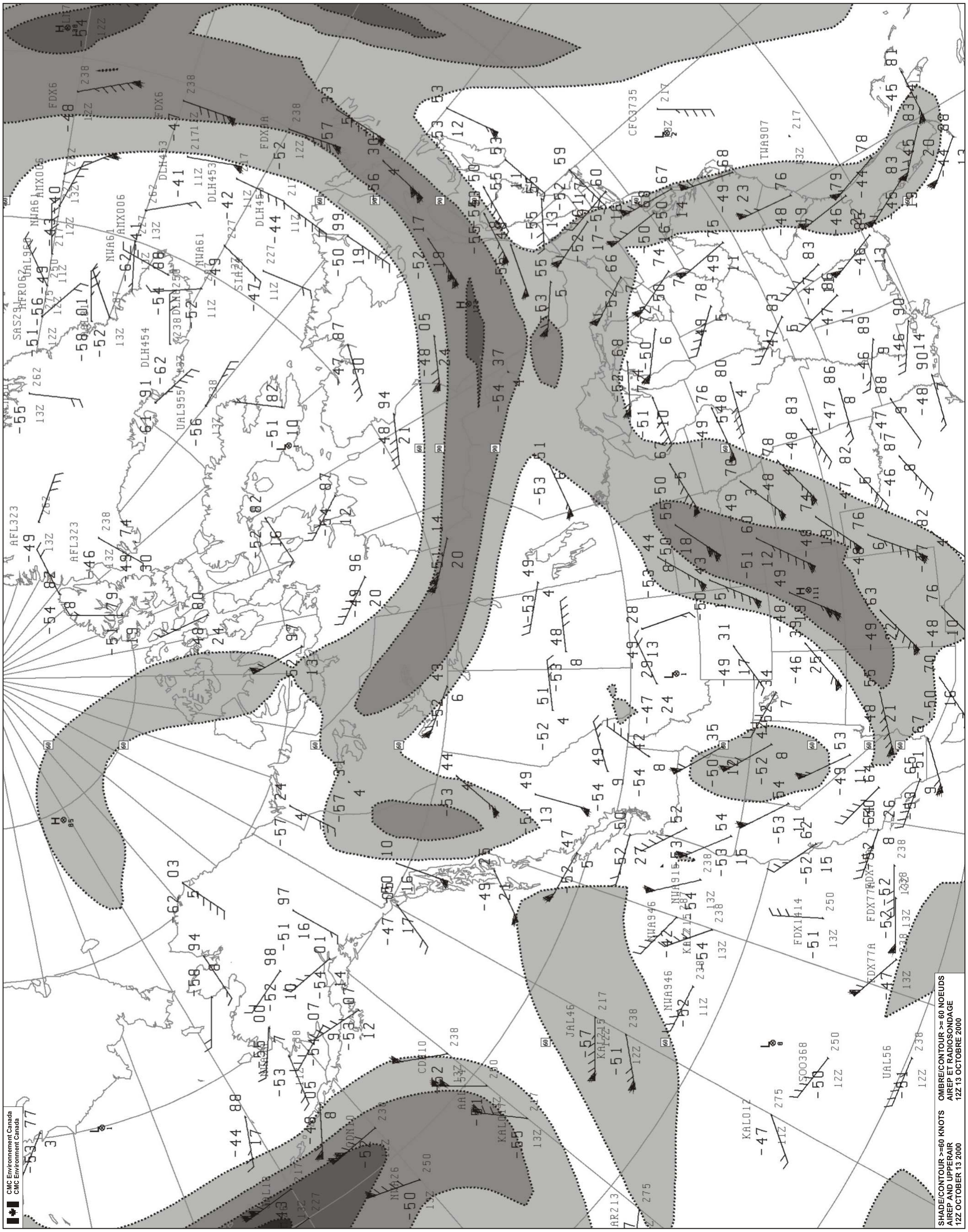


Figure 9 - CMC Environment Canada 250 hPa upper air chart depicting plotted data and Jet Stream analysis for 12Z October 13, 2000. Wind speeds are plotted in knots (1knot equals 1.9 km/h)

5. Look at winds on either side of the jet. The winds on either side of the jet are ***(slower)*** ***(faster)*** than the jet stream winds and have ***(the same)***, ***(a different)*** direction.

6. The polar-front jet stream is like a "river" of high-speed air embedded in the planetary-scale circulation of the atmosphere. The drawings below in figures 10a and 10b illustrate the wavy and westerly (or eastward) flow of air at upper levels in the middle latitudes of the Northern Hemisphere (planetary-scale circulation). The wave pattern can vary considerably in amplitude (latitude range).

   a) Indicate which drawing **(*10a*)** or **(*10b*)** best matches the upper-air flow of Figure 4 found on page 10.

   b) Which drawing **(*10a*) or (*10b*)** best matches today's the upper air flow as depicted by the 250 hPa analysis found on the Environment Canada web site?

7. Across North America, storms tend to follow the path of the polar-front jet stream. In Figure 9, a storm in the Denver area at map time is likely to be moving towards ***(the Great Lakes)***, ***(Florida)***.

8. Knowledge of the location of the jet stream is very important to commercial aviation. Explain why at map time on figure 8, an airline flight from Montreal to Vancouver would take considerably more time than a flight from Vancouver to Montreal.

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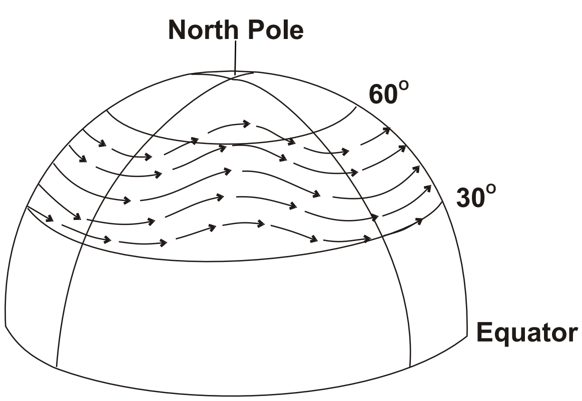

Figure 10a

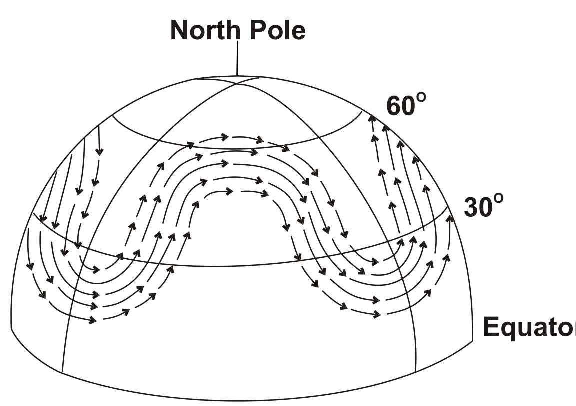

Figure 10b