

# INTRODUCTION

## The Jet Stream

As World War II was approaching its conclusion, the United States introduced the first high-altitude bomber, an airplane called the B-29. It could fly at altitudes well above 6 kilometres. When the B-29s were being put into service from a Pacific island base, two air force meteorologists were assigned to prepare wind forecasts for aircraft operations at such altitudes.

To make their prediction, the meteorologists primarily used surface observations and what is known in meteorology as the “*thermal wind*” relationship. In plain language, this relationship states that if you stand with your back to the wind, and the air is colder to your left and warmer to your right, the wind speed on your back will get stronger as you ascend in the atmosphere. Using this relationship, the meteorologists predicted a 168-knot wind blowing from the west. Their commanding officer could not believe the forecast, believing the forecast speed much too high. However, on the next day, the B-29 pilots reported wind speeds of 170 knots from the west as predicted! The *jet stream*, as it would come to be known, was discovered.

Actually atmospheric scientists had theorized the existence of jet streams at least as early as 1937. The bomber pilots just confirmed it. Today, almost every radio and television weathercast mentions the positions of jet streams and their impact on daily and coming weather events.

### The Jet Stream

The jet stream is a narrow current of relatively strong winds concentrated as in the upper atmosphere. There are two main jet streams found in the global circulation: the *subtropical jet stream* and the *polar-front jet stream* (also known as the *polar jet stream* and often just the *jet stream*).

The *subtropical jet stream* is found between the tropical and middle latitude atmospheric circulations. Although not as clearly related to surface weather features as its polar counterpart, the subtropical jet sometimes reaches as

far north as the southern United States. It is an important transporter of atmospheric moisture into storm systems.

The *polar-front jet stream* occurs over the polar front, where relatively cold air at higher latitudes comes in contact with warm air from the lower latitudes, and near the tropopause. It has an important influence on the weather of the middle latitudes. This is of special interest to meteorologists because of its influence on the development and maintenance of middle-latitude storm systems which evolve where warm and cold air masses come in contact.

The *polar-front jet stream* encircles the globe at altitudes between 9 and 13 kilometres above sea level in segments thousands of kilometres long, hundreds of kilometres wide, and several kilometres thick. It generally flows from west to east in great curving arcs as it undulates north and south. It is strongest in winter when core wind speeds are sometimes as high as 400 kilometres per hour.

The polar-front jet stream's location is one of the most influential factors on the daily weather pattern across North America. Meteorologists focus on the nature and position of the polar-front jet stream as they prepare weather forecasts. Changes in the jet stream indicate changes in the movement of weather systems and thus changes in weather.

The jet stream is also of great importance to aviation, as the B-29 pilots quickly found out. Westbound, high-altitude flight routes are planned to avoid the jet-stream head winds, which would slow the aircraft and consume precious fuel. Eastbound flights welcome time-saving tail winds from the jet stream to increase their speed and thus save fuel. However, the jet stream produces strong *wind shears*, large changes in wind speed over short vertical and horizontal distances, in some locations. The resulting air turbulence experienced in shear zones can be very hazardous to aircraft and passengers.

**BASIC UNDERSTANDINGS****The Jet Stream****Characteristics of the Polar-Front Jet Stream**

1. *Jet streams* are relatively high speed west-to-east winds concentrated as narrow currents at altitudes of 9 to 14 kilometres above sea level. These meandering “rivers” of air can be traced around the globe in segments thousands of kilometres long, hundreds of kilometres wide and several kilometres thick.
2. Two high-altitude jet streams affect the weather of middle latitudes; they are the subtropical jet stream and the polar-front jet stream.
3. The subtropical jet stream is located between tropical and middle latitude atmospheric circulations. Although not clearly related to surface weather features, it sometimes reaches as far north as the southern United States. It is an important transporter of atmospheric moisture into storm systems.
4. The polar-front jet stream is associated with the boundary between higher latitude cold and lower latitude warm air, known as the polar front. Because of its link to surface weather systems and features, the polar-front jet stream is of special interest to weather forecasters.
5. The polar-front jet stream is embedded in the general upper-air circulation in the middle latitudes where winds generally flow from west to east with broad north and south swings. As seen from above,

these winds display a gigantic wavy pattern around the globe.

6. The maximum wind speeds in the polar-front jet stream can reach speeds as high as 400 kilometres per hour.
7. The average position of the polar-front jet stream changes seasonally. Its winter position tends to be at a lower altitude and at a lower latitude than during summer months.
8. Because north-south temperature contrasts are greater in winter than in summer, the polar-front jet stream winds are faster in winter than in summer.
9. Small segments of the polar-front jet stream where winds attain their highest speeds are commonly known as a jet streak or jet max (maximum). One or two jet streaks are usually present in the polar-front jet stream crossing North America.

**What Causes the Polar-Front Jet Stream?**

10. Fundamental to the formation of the polar-front jet stream is the physical property that warm air is less dense than cold air when both are at the same pressure.
11. The polar front represents the boundary between higher latitude cold air and lower latitude warm air. This temperature contrast extends from the Earth's surface up to the altitude where the polar-front jet stream is found.

12. In the vicinity of the polar front, air pressure drops more rapidly with an increase in altitude in the more dense cold air than in the less dense warm air.
13. The effect of temperature on air density results in air pressure at any given altitude being higher on the warm (equatorward) side of the polar front than on the cold (poleward) side.
14. When cold and warm air reside side by side, the higher the altitude, the greater the pressure difference between the cold and warm air at the same altitude.
15. Across the polar front, at upper levels (including the jet stream altitude), horizontal pressure differences cause air to flow from the warm-air side of the front towards the cold-air side of the front.
16. Once this air is in motion, it is deflected by the Earth's rotation (called the Coriolis effect) from flowing directly from high to low pressure. Upper-level air flowing poleward from higher pressure towards lower pressure is deflected to the right in the Northern Hemisphere (or to the left in the Southern Hemisphere). The resulting flow produces a jet stream moving generally towards the east, parallel to and above the polar front.
17. The polar-front jet stream exists along the region where cold polar air and warm air masses are in contact. Hence, weather is relatively cold when the polar-front jet stream is south of a particular location and relatively warm when the jet stream is north of the location.
18. The polar-front jet stream can promote the development of storms. Storms are most likely to develop under a jet streak.
19. As a component of the planetary-scale prevailing westerly circulation, the polar-front jet stream steers storms across North America, generally from west to east.
20. Go to the Environment Canada Web Site to view the latest 250-hPa upper-air analysis chart:  
**<http://weatheroffice.ec.gc.ca>**  
Navigate to the **Weather Maps** page, select **Analysis charts** and click on the **250 hPa Analysis Chart**  
Using either the Environment Canada 250 hPa analysis from the web or the sample CMC Environment Canada 250 hPa Analysis Chart found in Figure 4, examine 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 Jet Stream.

## Relationships between the Polar-Front Jet Stream and Our Weather

17. The polar-front jet stream exists along the region where cold polar air and warm air masses are in contact. Hence, weather is relatively cold when the polar-front jet

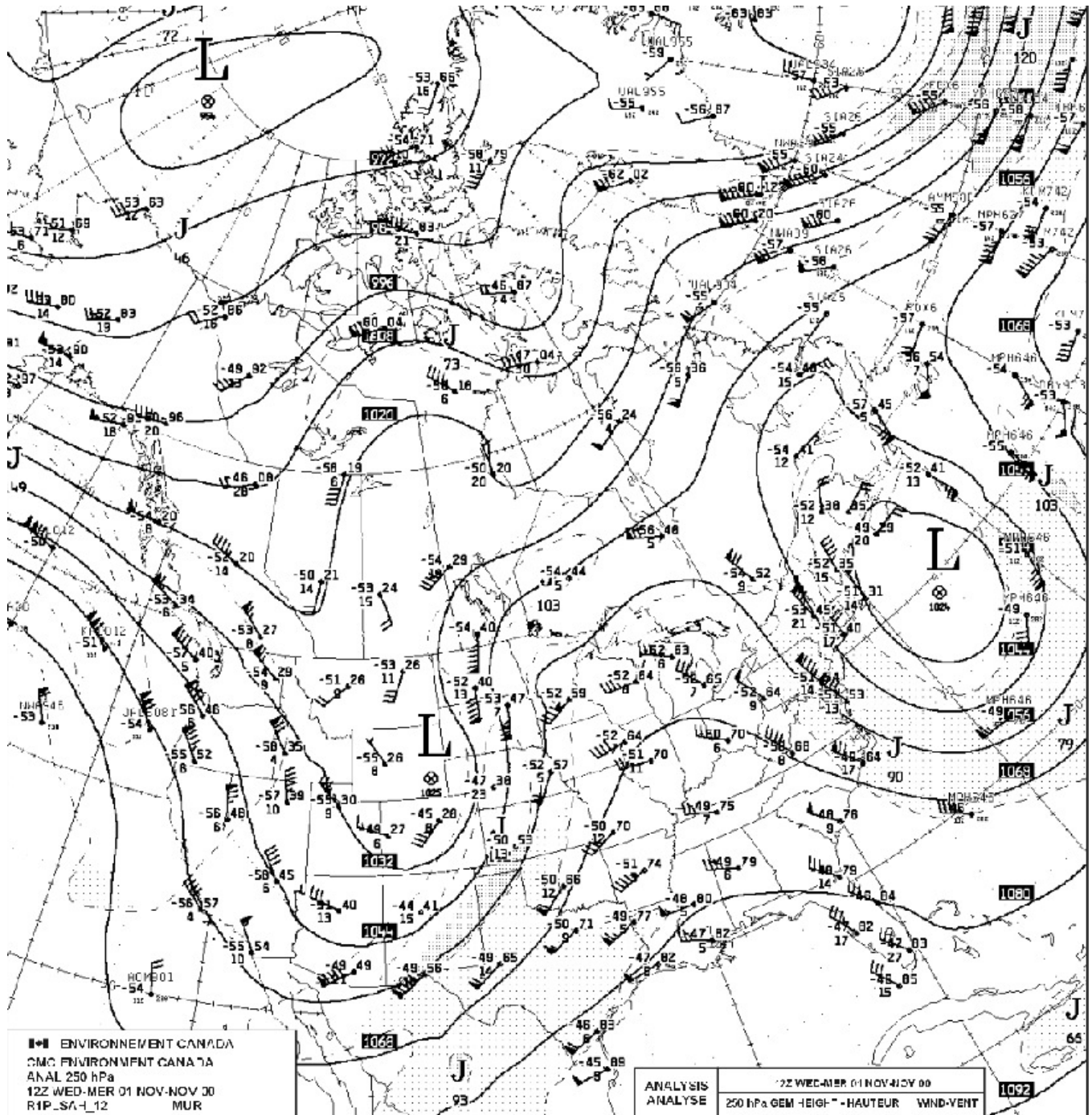


Figure 4 - CMC Environment Canada 250 hPa Analysis Chart for 12Z Nov 1, 2000