Project Atmosphere Canada

MODULE 8

Pressure — Highs and Lows

Teacher's guide

Canadian Meteorological and Oceanographic Society
La Société Canadienne de Météorologie et d'Océanographie

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Project Atmosphere Canada

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
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INTRODUCTION

Atmospheric Pressure

The Earth's atmosphere and ocean are in continual motion. This motion results from an unequal distribution of energy within the earth-atmosphere system. Forces arise from this non-uniform distribution and work to move heat and energy from where it is warmer to where it is colder (e.g., from the tropics to mid and high latitudes). Motion is initiated by differences in pressure (pressure is the amount of force acting on a unit surface area). *Atmospheric pressure* is the force exerted on an object or person by the weight of the air above. Atmospheric scientists and oceanographers monitor pressure as part of their investigation of Earth's dynamic atmosphere and ocean.

The force of gravity pulls molecules and particles in the atmosphere toward the centre of the Earth. The resulting weight of the air pushing down on itself and on the surface of the planet creates atmospheric pressure. Air is treated as a fluid when studying the dynamics of the atmosphere. Although it's common to refer to the atmosphere pressing "down", we know that pressure acts in all directions in a fluid. All sides of an object, then, are subjected to practically the same pressure. For example, atmospheric pressure pushing down on the surface of a bucket of water is transmitted equally through the liquid to the walls of the bucket and is balanced by the same atmospheric pressure acting on the outside walls of the bucket.

In Canada, the unit of atmospheric pressure most often heard on weather broadcasts is the *kilopascal (kPa)*. The average pressure exerted by the atmosphere at sea level is one kilogram per square centimetre or 101.325 kPa. A pascal (Pa) is defined by the *Encyclopaedia Britannica* as "a pressure of one newton (the basic unit of force) per square metre" and is named after the 17th century mathematician and physicist Blaise Pascal who proved that air pressure decreased with altitude. Because a pascal is such a small pressure unit, the kilopascal, which is equal to 1000 newtons per square metre, is more commonly used.

When studying the concepts of pressure in the upper atmosphere, the common unit becomes the hectopascal (hPa) which is simply the kilopascal times 10 or 10,000 Pa. Scientists involved in the measurement and analysis of atmospheric pressure may also use the term *millibar* as the unit of atmospheric pressure. One millibar is equal to one hectopascal.

Atmospheric pressure can also be expressed in other units such as "pounds per square inch" and "inches of mercury" which refers back to the historical use of the mercury barometer in measuring air pressure. For conversion purposes, one pound per square inch equals 6.895 kPa and one of inch of mercury equals 3.386389 kPa.

The analysis of the distribution of pressure on a surface weather map consists of drawing a series of lines called *isobars* which connect points of equal pressure. After the isobaric analysis is completed, the familiar weather map with its *Highs* and *Lows* takes form.

Highs and Lows

"What's the weather?" and "What's the weather going to be?" are questions people frequently ask because weather and its changes strongly influence our activities and lives. When we are aware of current and anticipated weather, we can make informed choices that range from selecting appropriate clothing for the day to those that might be related to work and recreation. Less frequently, but by no means less importantly, the decisions and actions we take can reduce the amount of property damage and the number of injuries and fatalities due to hazardous weather.

Adequate answers to our questions about the weather can often be found on the daily weather map. Prominently featured on the maps appearing on television and in newspapers are the words *High* and *Low* or the letters **H** and **L**. These are the symbols for centres of broad-scale pressure systems. They and their locations are key to describing and understanding probable weather conditions throughout the map area.

The Highs and Lows or the **H**s and **L**s on maps represent centres of broad regions of relatively high or low surface air pressure. They also provide information that enables meteorologists to predict possible atmospheric conditions up to a day or more in advance. Highs and Lows govern atmospheric conditions throughout their expanses. Highs are generally fair weather systems. Widespread cloud and stormy weather conditions are generally associated with Lows.

Mid-latitude Highs and Lows tend to move from west to east, changing the weather at locations along their paths. In the Northern Hemisphere, the mid- or middle latitude is the zone between the Tropic of Cancer, at latitude 23.5 degrees North, and the Arctic Circle latitude, 66.5 degrees North. Highs follow Lows and Lows follow Highs in an endless procession. No two Highs or two Lows are exactly alike, but they share enough common characteristics that descriptive models of each can be employed to make sense of the weather.

The purpose of this module is to introduce you to atmospheric pressure and the descriptive models of Highs and Lows. As a result of successfully completing this module, you will be able to:

1. Summarize in general terms:
   (a) descriptive models of Highs and Lows and
   (b) the weather associated with each.
2. Apply these models to interpret weather maps and to describe probable current and future weather at different locations on a weather map.

BASIC UNDERSTANDINGS

Weather Systems

1. The weather of middle latitudes is dominated by broad-scale weather systems called Highs and Lows.
2. Highs and Lows are regions of relatively high and low surface air pressure, respectively. Surface air pressure is the force exerted per unit area on an object at the Earth's surface by the air above, approximately 100,000 newtons per square metre or 100 kilopascals.
3. Highs are generally fair-weather systems hundreds or even thousands of kilometres across. Lows, typically less expansive, exhibit cloudy and often stormy weather conditions.
4. Highs and Lows are atmospheric features that last for several days or sometimes a week or longer. Mid-latitude Highs tend to persist for longer periods of time than do Lows.
5. Highs and Lows have characteristic circulation and structural patterns organized around their pressure centres. The weather at a specific place depends to a large extent on its location relative to the centres of nearby Highs or Lows.
6. In mid-latitudes, Highs and Lows tend to migrate, one following the other, from west to east across the continent with their paths usually showing northward or southward swings.
7. Weather at particular locations will often change in predictable sequences depending on the paths of the migrating High and Low pressure centres.
8. Highs and Lows are modified by the nature of the surfaces over which they travel. They become more humid when travelling over bodies of water and warmer or cooler depending on the temperatures of the underlying surface.

Weather Characteristics of a High

9. Highs depicted on surface weather maps typically mark the high-pressure centres of an air mass. Air masses are broad domes of air in which temperatures and humidity are relatively uniform in the horizontal. When the area of highest pressure is elongated, it is called a *high pressure ridge*, or simply a *ridge*.
10. Air masses form when air resides for weeks over a fairly uniform land or water surface. The overlying air gradually takes on the temperature and moisture characteristics of the underlying surface.
11. Warm surfaces produce warm air masses and cold surfaces produce cold air masses. Dry air masses form over land areas and humid air masses over bodies of water. Dry, cold air masses generally form over Central Canada. The Gulf of Mexico is the prime source of warm, humid air masses. Air masses forming over the North Pacific Ocean or North Atlantic Ocean are humid and cool.
12. Sooner or later, air masses move away from their source regions. They carry their temperature and humidity characteristics with them and display internal circulations around their high-pressure centres.

13. Air near the centre of a surface High flows outward towards lower pressure. The Earth's rotation plus the frictional effects of the surface cause the air to spiral outward from the region of maximum pressure. In the Northern Hemisphere, the spiral is clockwise as seen from above. In the Southern Hemisphere, it is counter-clockwise.

14. Highs are commonly called *anticyclones* because they are opposite in nature to *cyclones*, another name for Lows. The wind circulation pattern in Highs has a sense of rotation opposite to that of cyclones and the Earth's rotation; it is called *anticyclonic*.

15. Air sinks within Highs to replace the outwardly spiralling air at the surface.

16. Sinking air in Highs is warmed by compression. As a result, liquid water vaporizes, and clear skies tend to prevail in Highs.

17. Air pressure varies little over a broad region about the centre of a High so that winds are light and sometimes calm, particularly under the High centre.

18. The circulation within Highs generally transports colder air from higher to lower latitudes in regions to the east of the pressure centre. Along their western flanks, warmer air flows from lower to higher latitudes.

19. During North American winters, cold Highs tend to track from the northwest towards the southeast. In summer, warm Highs tend to drift slowly from west to east and can stall for several days or even weeks.

20. The generally clear and relatively calm conditions under Highs favour strong night-time cooling and the formation of dew, frost or fog.

Weather Characteristics of a Low

21. Lows appearing on surface weather maps mark a weather system organized around a centre of relatively low pressure. The low-pressure centre is typically located along a boundary (front) between air masses that have contrasting temperatures and/or humidities. When a low pressure centre becomes elongated, it is often referred to as a *low pressure trough*, or simply a *trough*.

22. Lows are weather systems characterized by warm and cold sectors, air-mass boundaries called fronts (labelled warm, cold, or stationary depending on their movement), and a variety of weather including cloudy and stormy conditions which can change rapidly over short distances across the fronts.

23. Air flowing towards the centre of a surface Low is deflected by the Earth's rotation and the frictional effects of the surface to produce an inward spiral. In the Northern Hemisphere, this spiral is counter-clockwise as seen from above. In the Southern Hemisphere, it is clockwise.

24. Lows are commonly called *cyclones.* The circulation in Lows has a sense of rotation that is counter-clockwise in the Northern Hemisphere, the same as that of the Earth's rotation, and it is called *cyclonic*.

25. Air spiralling into a Low forces upward motion around the centre. Rising air expands and cools, so that clouds form and precipitation can develop.

26. Within Lows, along the horizontal plane, changes in air pressure with distance are typically greater than those found in Highs. Thus, Lows tend to have significantly higher wind speeds associated with them.

27. In winter, over North America, the formation of Lows, known as *cyclogenesis*, tends to occur over the Pacific Ocean and the Gulf of Mexico, on the Great Plains just east of the Rocky Mountains, and off the mid-Atlantic coast.

28. Winter Lows tend to track towards the east and northeast and exit North America through New England and Atlantic Canada.

29. Winter Lows are generally more intense than summer Lows primarily because of greater temperature contrasts between neighbouring air masses. Central pressures are generally lower and winds are stronger in winter Lows than summer Lows.

30. In spring and early summer, Lows forming over the Great Plains of the United States are often accompanied by lines of thunderstorms, some of which may be severe.

31. In summer, over North America, the principal storm track is across southern and central Canada. In winter, the principal storm tracks shift southward, often deep into the United States.