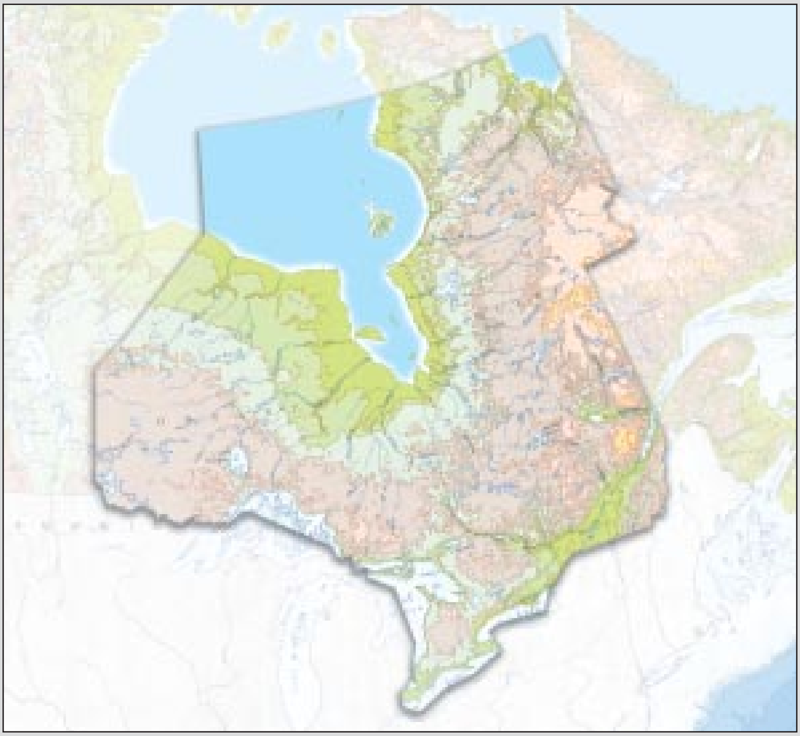
The Weather of Ontario and Quebec



Graphic Area Forecast 33

NAV CANADA

The Weather of Ontario and Quebec

Graphic Area Forecast 33

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The Weather of Ontario-Quebec
Graphic Area Forecast 33 Ontario-Quebec

Preface

For NAV CANADA's Flight Service Specialists (FSS), providing weather briefings to help pilots navigate through the day to day fluctuations in the weather is a critical role. While available weather products are becoming increasingly more sophisticated and at the same time more easily understood, an understanding of local and regional climatological patterns is essential to the effective performance of this role.

This Ontario-Quebec Local Area Knowledge Aviation Weather manual is one of a series of six publications prepared by Meteorological Services of Canada for NAV CANADA. Each of the six manuals corresponds to a specific graphic forecast area (GFA) Domain, with the exception of the Nunavut – Arctic manual which covers two GFA Domains. This document forms an important part of the training program on local aviation weather knowledge for FSS working in the area and a useful tool in the day-to-day service delivery by FSS.

Within the GFA domains, the weather shows strong climatological patterns controlled either by season or topography. This manual describes the Domain of the GFACN33 (Ontario-Quebec). This area offers beautiful skies and landscapes for flying but can also provide harsh flying conditions. As most pilots flying the region can attest, these variations in weather can take place quiet abruptly. From the cold shores of Hudson Bay to the lush hills of the Eastern Townships, local topography plays a key role in determining both the general climatology and local flying conditions in a particular region.

This manual provides some insight on specific weather effects and patterns in this area. While a manual cannot replace intricate details and knowledge of Ontario-Quebec that FSS and experienced pilots of the area have acquired over the years, this manual is a collection of that knowledge taken from interviews with local pilots, dispatchers, Flight Service Specialists, and MSC personnel.

By understanding the weather and hazards in this specific area, FSS will be more able to assist pilots to plan their flights in a safe and efficient manner. While this is the manual's fundamental purpose, NAV CANADA recognizes the value of the information collected for pilots themselves. More and better information on weather in the hands of pilots will always contribute to aviation safety. For that reason, the manuals are being made available to NAV CANADA customers.

Acknowledgements

This manual was made possible through funding by NAV CANADA, Flight Information Centre project office.

NAV CANADA would like to thank The Meteorological Service of Canada (MSC), both national and regional personnel, for working with us to compile the information for each Graphic Area Forecast (GFA) domain, and present it in a user-friendly, professional format. Special thanks also go to meteorologists Ross Klock, Mountain Weather Centre, Kelowna and Gilles Simard, Environmental Weather Services Office –East, Rimouski, Quebec and John Mullock, Mountain Weather Centre, Kelowna. Ross's and Gilles's regional expertise has been instrumental for the development of the Ontario-Quebec GFA document while John's experience and efforts have ensured high quality and consistent material from Atlantic to Pacific to Arctic.

This endeavour could not have been as successful without the contributions of many people within the aviation community. We would like to thank all the participants that provided information through interviews with MSC, including flight service specialists, pilots, dispatchers, meteorologists and other aviation groups. Their willingness to share their experiences and knowledge contributed greatly to the success of this document.

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January, 2002

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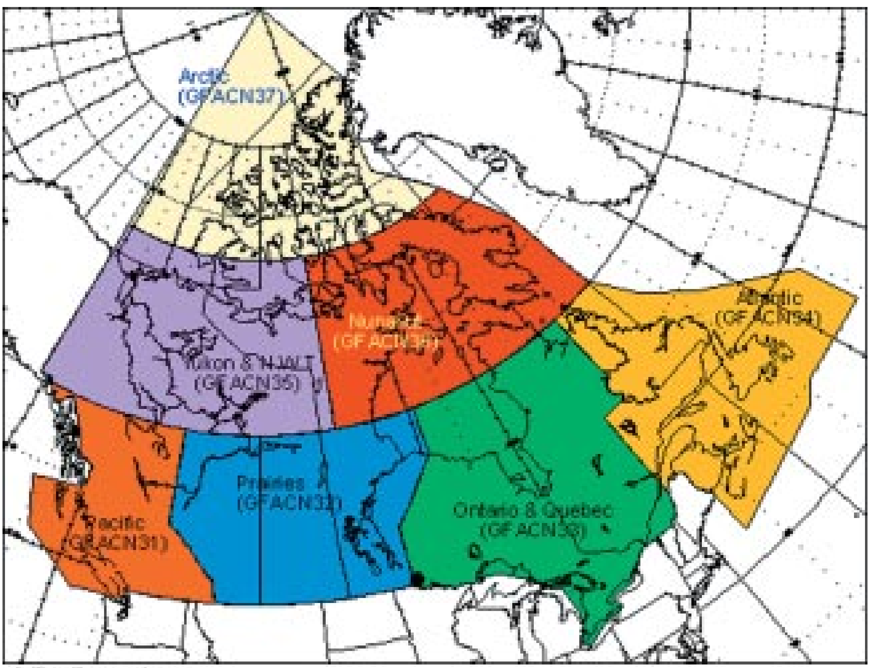
Introduction

Meteorology is the science of the atmosphere, a sea of air that is in a constant state of flux. Within it storms are born, grow in intensity as they sweep across sections of the globe, then dissipate. No one is immune to the day-to-day fluctuations in the weather, especially the aviator who must operate within the atmosphere.

Traditionally, weather information for the aviation community has largely been provided in textual format. One such product, the area forecast (FA), was designed to provide the forecast weather for the next twelve hours over a specific geographical area. This information consisted of a description of the expected motion of significant weather systems, the associated clouds, weather and visibility.

In April 2000, the Graphical Area Forecast (GFA) came into being, superceding the area forecast. A number of MSC Forecast Centres now work together, using graphical software packages, to produce a single national graphical depiction of the forecast weather systems and the associated weather. This single national map is then partitioned into a number of GFA Domains for use by Flight Service Specialists, flight dispatchers and pilots.



GFA Domains

This Ontario-Quebec Local Area Knowledge Aviation Weather Manual is one of a series of six similar publications. All are produced by NAV CANADA in partnership with the MSC. These manuals are designed to provide a resource for Flight Service Specialists and pilots to help with the understanding of local aviation weather. Each of the six manuals corresponds to a Graphical Area Forecast (GFA) Domain, with the exception of the Nunavut - Arctic manual which covers two GFA Domains. MSC aviation meteorologists provide most of the broader scale information on meteorology and weather systems affecting the various domains. Experienced pilots who work in or around it on a daily basis, however, best understand the local weather. Interviews with local pilots, dispatchers and Flight Service Specialists, form the basis for the information presented in Chapter 4.

Within the domains, the weather shows strong climatological patterns that are controlled either by season or topography. For example, in British Columbia there is a distinctive difference between the moist coastal areas and the dry interior because of the mountains. The weather in the Arctic varies strongly seasonally between the frozen landscape of winter and the open water of summer. These changes are important in understanding how the weather works and each book will be laid out so as to recognize these climatological differences.

This manual describes the weather of the GFACN33 (Ontario-Quebec). This area often has beautiful flying weather but can also have some of the harshest flying conditions in the world. As most pilots flying in the region can attest, these variations in flying weather can take place quite abruptly. From the Northern Ontario to the Eastern Townships of Quebec, local topography plays a key role in determining both the general climatology and local flying conditions in a particular region. Statistically, approximately 30% of aviation accidents are weather related and up to 75% of delays are due to weather.

This manual is “instant knowledge” about how the weather behaves in this area but it is not “experience”. The information presented in this manual is by no means exhaustive. The variability of local aviation weather in Ontario and Quebec could result in a publication many times the size of this one. However, by understanding some of the weather and hazards in these areas, pilots may be able to relate the hazards to topography and weather systems in areas not specifically mentioned.

Chapter 1

Basics of Meteorology

To properly understand weather, it is essential to understand some of the basic principles that drive the weather machine. There are numerous books on the market that describe these principles in great detail with varying degrees of success. This section is not intended to replace these books, but rather to serve as a review.

Heat Transfer and Water Vapour

The atmosphere is a "heat engine" that runs on one of the fundamental rules of physics: excess heat in one area (the tropics) must flow to colder areas (the poles). There are a number of different methods of heat transfer but a particularly efficient method is through the use of water.

Within our atmosphere, water can exist in three states depending on its energy level. Changes from one state to another are called phase changes and are readily accomplished at ordinary atmospheric pressures and temperatures. The heat taken in or released during a phase change is called latent heat.

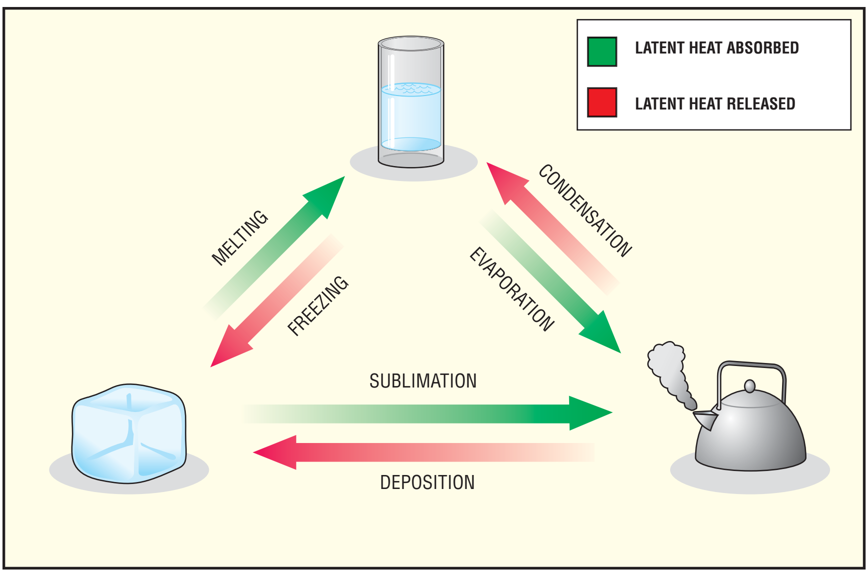


Fig. 1-1 - Heat transfer and water vapour

How much water the air contains in the form of water vapour is directly related to its temperature. The warmer the air, the more water vapour it can contain. Air that contains its maximum amount of vapour, at that given temperature, is said to be saturated. A quick measure of the moisture content of the atmosphere can be made by looking at the dew point temperature. The higher (warmer) the dew point temperature, the greater the amount of water vapour.

The planetary heat engine consists of water being evaporated by the sun into water vapour at the equator (storing heat) and transporting it towards the poles on the winds where it is condensed back into a solid or liquid state (releasing heat). Most of what we refer to as "weather," such as wind, cloud, fog and precipitation is related to this conversion activity. The severity of the weather is often a measure of how much latent heat is released during these activities.

Lifting Processes

The simplest and most common way water vapour is converted back to a liquid or solid state is by lifting. When air is lifted, it cools until it becomes saturated. Any additional lift will result in further cooling which reduces the amount of water vapour the air can hold. The excess water vapour is condensed out in the form of cloud droplets or ice crystals which then can go on to form precipitation. There are several methods of lifting an air mass. The most common are convection, orographic lift (upslope flow), frontal lift, and convergence into an area of low pressure.

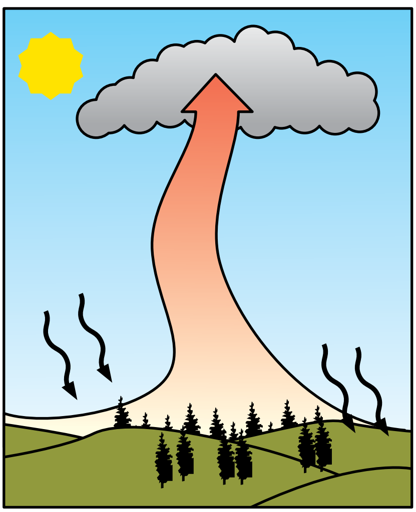


Fig. 1-2 - Convection as a result of daytime heating

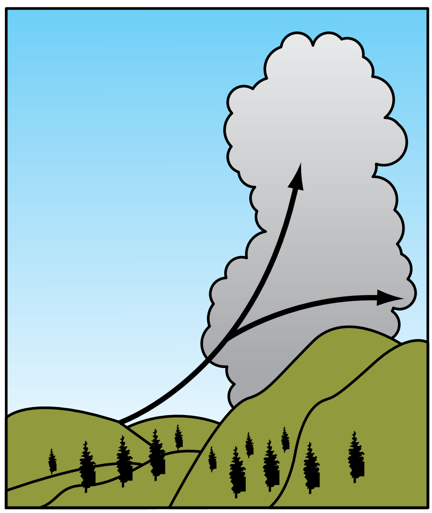


Fig.1-3 - Orographic (upslope) lift

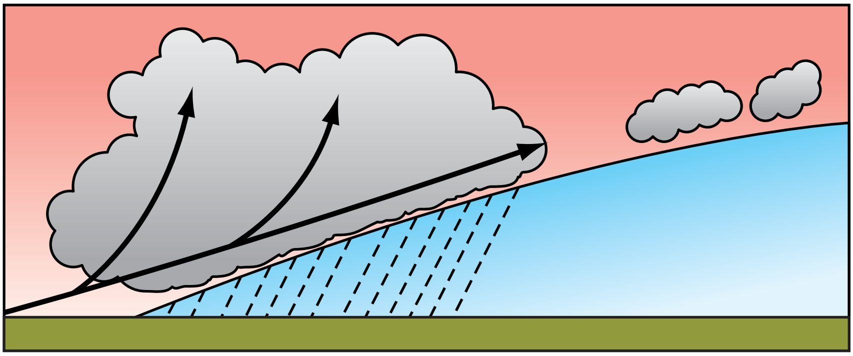


Fig.1-4 - Warm air overrunning cold air along a warm front

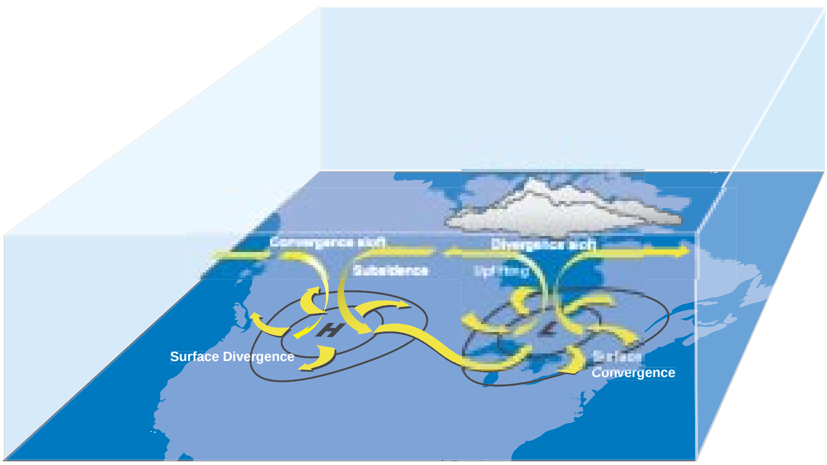


Fig. 1-5 - Divergence and convergence at the surface and aloft in a high low couplet

Subsidence

Subsidence, in meteorology, refers to the downward motion of air. This subsiding motion occurs within an area of high pressure, as well as on the downward side of a range of hills or mountains. As the air descends, it is subjected to increasing atmospheric pressure and, therefore, begins to compress. This compression causes the air's temperature to increase which will consequently lower its relative humidity. As a result, areas in which subsidence occurs will not only receive less precipitation than surrounding areas (referred to as a "rain shadow") but will often see the cloud layers thin and break up.

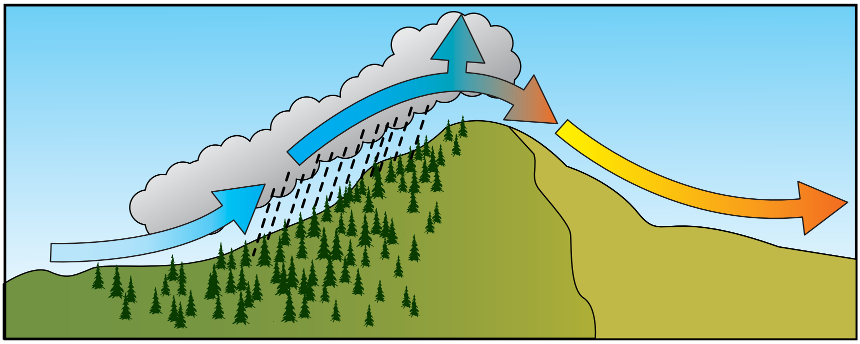


Fig.1-6 - Moist air moving over mountains where it loses its moisture and sinks into a dry subsidence area

Temperature Structure of the Atmosphere

The temperature lapse rate of the atmosphere refers to the change of temperature with a change in height. In the standard case, temperature decreases with height through the troposphere to the tropopause and then becomes relatively constant in the stratosphere.

Two other conditions are possible: an inversion, in which the temperature increases with height, or an isothermal layer, in which the temperature remains constant with height.

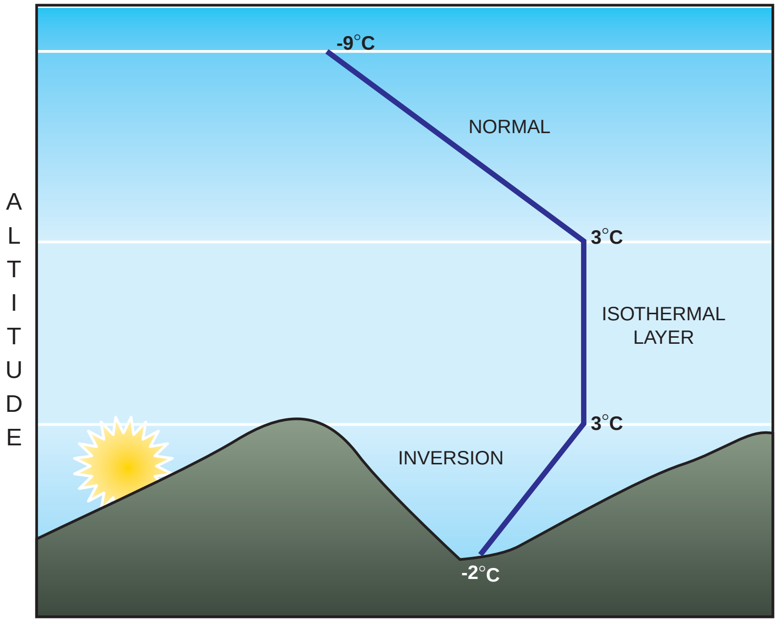


Fig. 1-7 - Different lapse rates of the atmosphere

The temperature lapse rate of the atmosphere is a direct measurement of the stability of the atmosphere.

Stability

It would be impossible to examine weather without taking into account the stability of the air. Stability refers to the ability of a parcel of air to resist vertical motion. If a parcel of air is displaced upwards and then released it is said to be unstable if it continues to ascend (since the parcel is warmer than the surrounding air), stable if it returns to the level from which it originated (since the parcel is cooler than the surrounding air), and neutral if the parcel remains at the level it was released (since the parcel's temperature is that of the surrounding air).

The type of cloud and precipitation produced varies with stability. Unstable air, when lifted, has a tendency to develop convective clouds and showery precipitation. Stable air is inclined to produce deep layer cloud and widespread steady precipitation. Neutral air will produce stable type weather which will change to unstable type weather if the lifting continues.

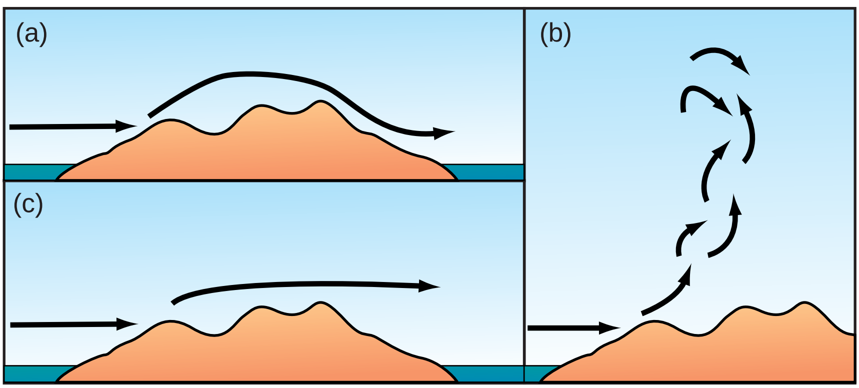


Fig. 1-8 - Stability in the atmosphere - (a) Stable (b) Unstable (c) Neutral

The stability of an air mass has the ability to be changed. One way to destabilize the air is to heat it from below, in much the same manner as you would heat water in a kettle. In the natural environment this can be accomplished when the sun heats the ground which, in turn, heats the air in contact with it, or when cold air moves over a warmer surface such as open water in the fall or winter. The reverse case, cooling the air from below, will stabilize the air. Both processes occur readily.

Consider a typical summer day where the air is destabilized by the sun, resulting in the development of large convective cloud and accompanying showers or thundershowers during the afternoon and evening. After sunset, the surface cools and the air mass stabilizes slowly, causing the convective activity to die off and the clouds to dissipate.

On any given day there may be several processes acting simultaneously that can either destabilize or stabilize the air mass. To further complicate the issue, these competing effects can occur over areas as large as an entire GFA domain to as small as a football field. To determine which one will dominate remains in the realm of a meteorologist and is beyond the scope of this manual.

Wind

Horizontal differences in temperature result in horizontal differences in pressure. It is these horizontal changes in pressure that cause the wind to blow as the atmosphere attempts to equalize pressure by moving air from an area of high pressure to an area of low pressure. The larger the pressure difference, the stronger the wind and, as a result, the day-to-day wind can range from the gentlest breeze around an inland airfield to storm force winds over the water.

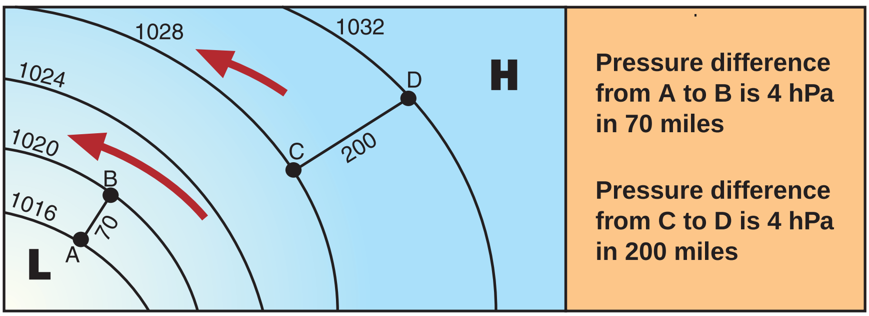


Fig. 1-9 - The greater pressure changes with horizontal difference, the stronger the wind

Wind has both speed and direction, so for aviation purposes several conventions have been adopted. Wind direction is always reported as the direction from which the wind is blowing while wind speed is the average steady state value over a certain length of time. Short-term variations in speed are reported as either gusts or squalls depending on how long they last.

Above the surface, the wind tends to be relatively smooth and changes direction and speed only in response to changes in pressure. At the surface, however, the wind is affected by friction and topography. Friction has a tendency to slow the wind over rough surfaces whereas topography, most commonly, induces localized changes in direction and speed.

Air Masses and Fronts

Air Masses

When a section of the troposphere, hundreds of miles across, remains stationary or moves slowly across an area having fairly uniform temperature and moisture, then the air takes on the characteristics of this surface and becomes known as an air mass. The area where air masses are created are called "source regions" and are either ice or snow covered polar regions, cold northern oceans, tropical oceans or large desert areas.

Although the moisture and temperature characteristics of an air mass are relatively uniform, the horizontal weather may vary due to different processes acting on it. It is quite possible for one area to be reporting clear skies while another area is reporting widespread thunderstorms.

Fronts

When air masses move out of their source regions they come into contact with other air masses. The transition zone between two different air masses is referred to as a frontal zone, or front. Across this transition zone temperature, moisture content, pressure, and wind can change rapidly over a short distance.

The principal types of fronts are:

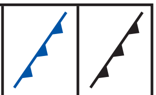
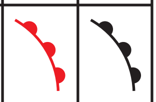
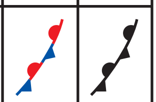
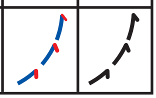
Cold Front - The cold air is advancing and undercutting the warm air. The leading edge of the cold air is the cold front.	
Warm front - The cold air is retreating and being replaced by warm air. The trailing edge of the cold air is the warm front.	
Stationary front - The cold air is neither advancing nor retreating. These fronts are frequently referred to as quasi-stationary fronts although there usually is some small-scale localized motion occurring.	
Trowal - Trough of warm air aloft.	

Table 1-1

Chapter 2

Aviation Weather Hazards

Introduction

Throughout its history, aviation has had an intimate relationship with the weather. Time has brought improvements - better aircraft, improved air navigation systems and a systemized program of pilot training. Despite this, weather continues to extact its toll.

In the aviation world, 'weather' tends to be used to mean not only "what's happening now?" but also "what's going to happen during my flight?". Based on the answer received, the pilot will opt to continue or cancel his flight. In this section we will examine some specific weather elements and how they affect flight.

Icing

One of simplest assumptions made about clouds is that cloud droplets are in a liquid form at temperatures warmer than 0°C and that they freeze into ice crystals within a few degrees below zero. In reality, however, 0°C marks the temperature below which water droplets become supercooled and are capable of freezing. While some of the droplets actually do freeze spontaneously just below 0°C, others persist in the liquid state at much lower temperatures.

Aircraft icing occurs when supercooled water droplets strike an aircraft whose temperature is colder than 0°C. The effects icing can have on an aircraft can be quite serious and include:

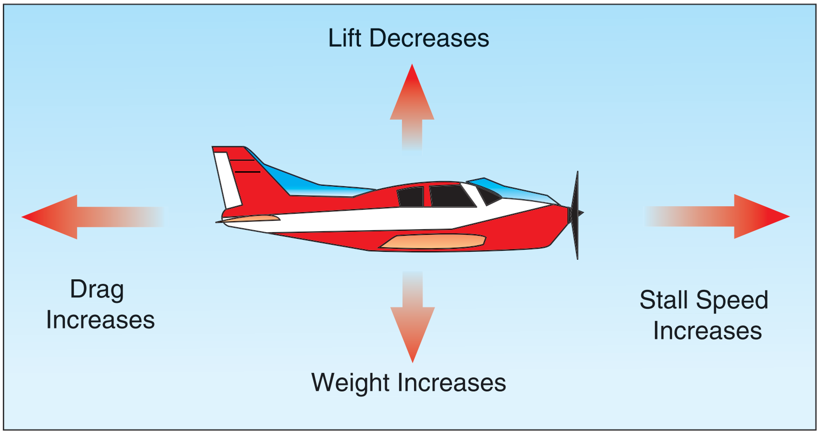


Fig. 2-1 - Effects of icing

- disruption of the smooth laminar flow over the wings causing a decrease in lift and an increase in the stall speed. This last effect is particularly dangerous. An "iced" aircraft is effectively an "experimental" aircraft with an unknown stall speed.
- increase in weight and drag thus increasing fuel consumption.
- partial or complete blockage of pitot heads and static ports giving erroneous instrument readings.
- restriction of visibility as windshield glazes over.

The Freezing Process

When a supercooled water droplet strikes an aircraft surface, it begins to freeze, releasing latent heat. This latent heat warms the remainder of the droplet to near 0°C, allowing the unfrozen part of the droplet to spread back across the surface until freezing is complete. The lower the air temperature and the colder the aircraft surface, the greater the fraction of the droplet that freezes immediately on impact. Similarly, the smaller the droplet, the greater the fraction of the droplet that freezes immediately on impact. Finally, the more frequent the droplets strike the aircraft surface, the greater the amount of water that will flow back over the aircraft surface. In general, the maximum potential for icing occurs with large droplets at temperatures just below 0°C .

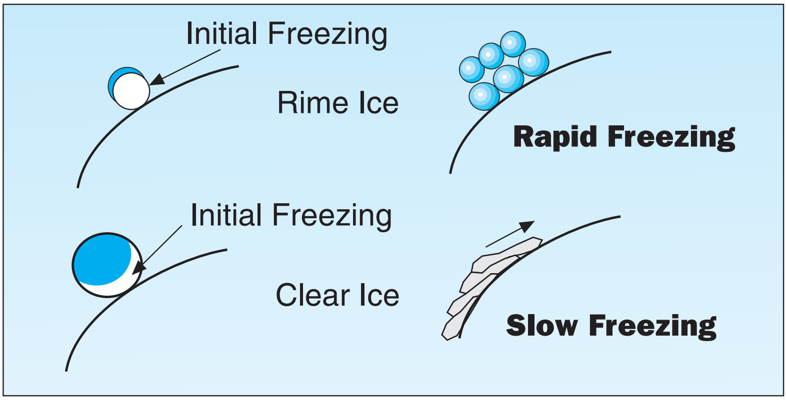


Fig. 2-2 - Freezing of supercooled droplets on impact

Types of Aircraft Ice

Rime Ice

Rime ice is a product of small droplets where each droplet has a chance to freeze completely before another droplet hits the same place. The ice that is formed is opaque and brittle because of the air trapped between the droplets. Rime ice tends to form on the leading edges of airfoils, builds forward into the air stream and has low adhesive properties.

Clear Ice

In the situation where each large droplet does not freeze completely before additional droplets become deposited on the first, supercooled water from each drop merges and spreads backwards across the aircraft surface before freezing completely to form an ice with high adhesive properties. Clear ice tends to range from transparent to a very tough opaque layer and will build back across the aircraft surface as well as forward into the air stream.

Mixed Ice

When the temperature and the range of droplet size vary widely, the ice that forms is a mixture of rime ice and clear ice. This type of ice usually has more adhesive properties than rime ice, is opaque in appearance, rough, and generally builds forward into the air stream faster than it spreads back over the aircraft surface.

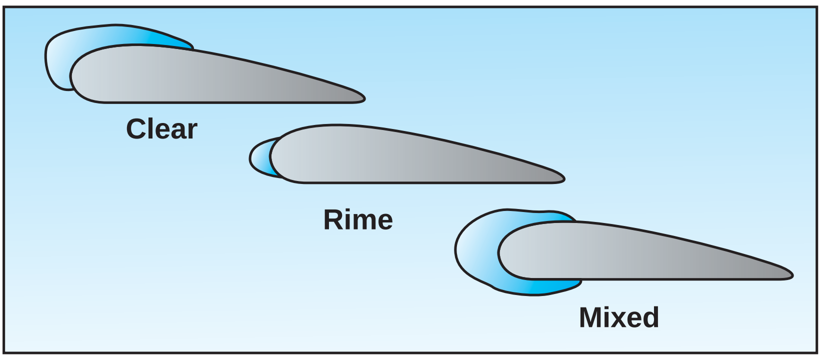


Fig. 2-3 - Accumulation patterns of different icing types

Meteorological Factors Affecting Icing

(a) Liquid Water Content of the Cloud

The liquid water content of a cloud is dependent on the size and number of droplets in a given volume of air. The greater the liquid water content, the more serious the icing potential. Clouds with strong vertical updrafts generally have a higher liquid water content as the updrafts prevent even the large drops from precipitating.

The strongest updrafts are to be found in convective clouds, clouds formed by abrupt orographic lift, and in lee wave clouds. Layer clouds tend to have weak updrafts and are generally composed of small droplets.

(b) Temperature Structure in the Cloud

Warm air can contain more water vapour than cold air. Thus, clouds that form in warm air masses will have a higher liquid water content than those that form in cold air.

The temperature structure in a cloud has a significant effect on the size and number of droplets. Larger supercooled droplets begin to freeze spontaneously around -10°C with the rate of freezing of all size of droplets increasing rapidly as temperatures fall below -15°C. By -40°C, virtually all the droplets will be frozen. The exceptions are clouds with very strong vertical updrafts, such as towering cumulus or cumulonimbus, where liquid water droplets can be carried to great heights before freezing.

These factors allow the icing intensities to change rapidly with time so that it is possible for aircraft only minutes apart to encounter entirely different icing conditions in the same area. Despite this, some generally accepted rules have been developed:

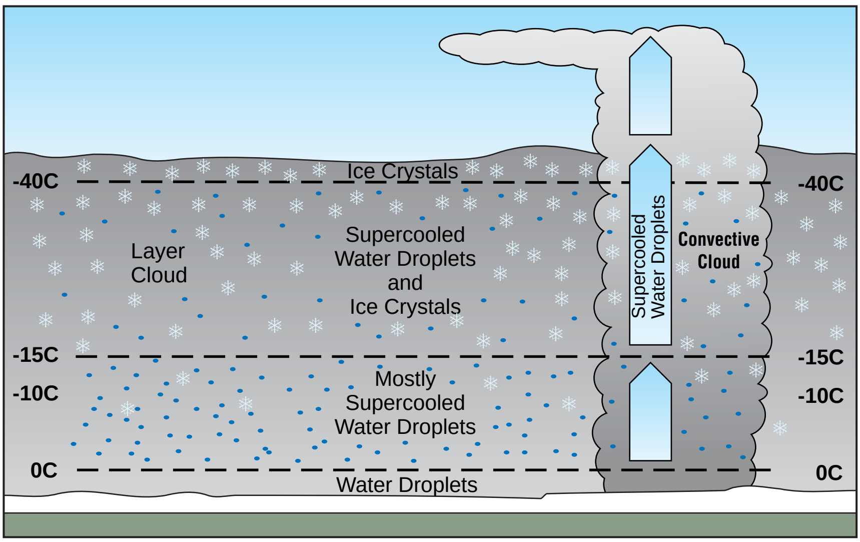


Fig. 2-4 - Distribution of water droplet-ice crystals in cloud

(1) Within large cumulus and cumulonimbus clouds:

- at temperatures between 0°C and -25°C, severe clear icing likely.
- at temperatures between -25°C and -40°C, light rime icing likely; small possibility of moderate to severe rime or mixed icing in newly developed clouds.
- at temperatures below -40°C, little chance of icing.

(2) Within layer cloud:

- the most significant icing layer is generally confined to the 0°C to -15°C temperature range.

- icing is usually less severe than in convective cloud due to the weaker updrafts and smaller droplets.
- icing layers tend to be shallow in depth but great in horizontal extent.

(3) Situations in which icing may be greater than expected:

- air moving across large unfrozen lakes in the fall and winter will increase its moisture content and destabilize rapidly due to heating from below. The cloud that forms, while resembling a layer cloud, will actually be a convective cloud capped by an inversion with relatively strong updrafts and a large concentration of supercooled drops.
- thick layer cloud formed by rapid mass ascent, such as in an intensifying low or along mountain slopes, will also have enhanced concentrations of supercooled drops. Furthermore, there is a strong possibility that such lift will destabilize the air mass resulting in embedded convective clouds with their enhanced icing potential.
- lenticular clouds can have very strong vertical currents associated with them. Icing can be severe and, because of the droplet size, tend toward clear icing.

Supercooled Large Drop Icing

Supercooled large drop (SLD) icing has, until fairly recently, only been associated with freezing rain. Several accidents and significant icing events have revealed the existence of a deadly form of SLD icing in non-typical situations and locations. It was found that large cloud drops, the size of freezing drizzle drops, could exist within some stratiform cloud layers, whose cloud top is usually at 10,000 feet or less. The air temperature within the cloud (and above) remains below 0°C but warmer than -18°C throughout the cloud layer. These large drops of liquid water form near the cloud top, in the presence of light to moderate mechanical turbulence, and remain throughout the cloud layer. SLD icing is usually severe and clear. Ice accretion onto flight surfaces of 2.5 cm or more in 15 minutes or less have been observed.

There are a few indicators that may help announce SLD icing beforehand. SLD icing-producing stratiform clouds often occur in a stable air mass, in the presence of a gentle upslope circulation, sometimes coming from a large body of water. The air above the cloud layer is always dry, with no significant cloud layers above. The presence of freezing drizzle underneath, or liquid drizzle when the surface air temperature is slightly above 0°C, is a sure indication of SLD icing within the cloud. Other areas where this type of icing is found is in the cloud to the southwest of a low pressure centre and behind cold fronts where low level stratocumulus are common (cloud tops often below 13,000 feet). Constant and careful attention must be paid when flying a holding pattern within a cloud layer in winter.

In Quebec, SLD icing-producing clouds are common to the east of James Bay and Hudson Bay in a westerly flow and to the south-east of James Bay in a northwesterly flow. They are also common in the northerly flow off the Hudson Strait and Ungava Bay. These low level clouds often produce drizzle or freezing drizzle.

In Ontario, SLD icing-producing clouds are common from Hudson Bay to, and including, the Timmins, Hearst, Kapuskasing escarpment in a northerly flow. They are also common in a southerly or southwesterly flow off Lake Superior, Lake Huron and Georgian Bay, from Terrace Bay to Elliot Lake to Sudbury to North Bay. These low-level clouds often produce drizzle or freezing drizzle.

The Glory: A Warning Sign for Aircraft Icing

Photo 2-1 - Glory surrounding aircraft shadow on cloud top. Credit: Alister Ling

The glory is one of the most common forms of halo visible in the sky. For the pilot it is a warning sign of potential icing because it is only visible when there are liquid water droplets in the cloud. If the air temperature at cloud level is below freezing, icing will occur in those clouds that produce a glory.

A glory can be seen by looking downwards and seeing it surround the shadow that your aircraft casts onto the cloud tops. They can also be seen by looking upwards towards the sun (or bright moon) through clouds made of liquid droplets.

It is possible to be high enough above the clouds or fog that your shadow is too small to see at the center of the glory. Although ice crystals often produce other halos and arcs, only water droplets form bullseyes.

Aerodynamic Factors Affecting Icing

There are various aerodynamic factors that affect the collection efficiency of an aircraft surface. Collection efficiency can be defined as the fraction of liquid water droplets that actually strike the aircraft relative to the number of droplets encountered along the flight path.

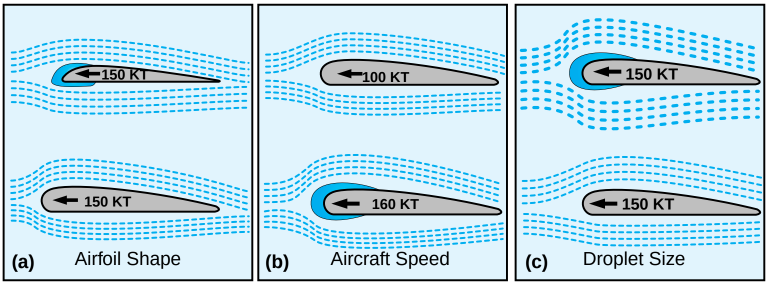


Fig. 2-5 -Variations in collection efficiency

Collection efficiency is dependent on three factors:

(a) The radius of curvature of the aircraft component. Airfoils with a big radius of curvature disrupt the airflow (like a bow wave) causing the smaller supercooled droplets to be carried around the airfoil by the air stream. For this reason, large thick components (thick wings, canopies) collect ice less efficiently than thin components (thin wings, struts, antenna).

(b) Speed. The faster the aircraft the less chance the droplets have to be diverted around the airfoil by the air stream.

(c) Droplet size. The larger the droplet the more difficult it is for the air stream to displace it.

Other Forms of Icing

(a) Freezing Rain and Ice Pellets

Freezing rain occurs when liquid water drops that are above freezing fall into a layer of air whose temperature is colder than 0°C and supercool before hitting some object. The most common scenario leading to freezing rain in Eastern Canada is "warm overrunning". In this case, warm air (above 0°C) is forced up and over colder air at the surface. In such a scenario, rain that falls into the cold air supercools, resulting in freezing rain that can last for hours. When the cold air is sufficiently deep, the freezing raindrops can freeze completely before reaching the surface causing ice pellets. Pilots should be aware, however, that ice pellets at the surface imply freezing rain aloft. Such conditions are relatively common in the winter and tend to last a little longer in valleys than over flat terrain.

(b) Freezing Drizzle or Snow Grains

Freezing drizzle is different from freezing rain in that the water droplets are smaller. Another important difference is that freezing drizzle may develop in air masses whose entire temperature profile is below freezing. In other words, freezing drizzle can occur without the presence of a warm layer (above 0°C) aloft. In this case, favourable areas for the development of freezing drizzle are in moist maritime air masses, preferably in areas of moderate to strong upslope flow. The icing associated with freezing drizzle may have a significant impact on aviation. Similar to ice pellets, snow grains imply the presence of freezing drizzle aloft.

(c) Snow
Dry snow will not adhere to an aircraft surface and will not normally cause icing problems. Wet snow, however, can freeze hard to an aircraft surface that is at subzero temperatures and be extremely difficult to remove. A very dangerous situation can arise when an aircraft attempts to take off with wet snow on the flight surfaces. Once the aircraft is set in motion, evaporational cooling will cause the wet snow to freeze hard causing a drastic reduction in lift as well as increasing the weight and drag. Wet snow can also freeze to the windscreens making visibility difficult to impossible.

(d) Freezing Spray
Freezing spray develops over open water when there is an outbreak of Arctic air. While the water itself is near or above freezing, any water that is picked up by the wind or is splashed onto an object will quickly freeze, causing a rapid increase in weight and shifting the centre of gravity. Such conditions may cause significant problems for offshore helicopter operations.

(e) Freezing Fog
Freezing fog is a common occurrence during the winter. Fog is simply “a cloud touching the ground” and, like its airborne cousin, will have a high percentage of supercooled water droplets at temperatures just below freezing (0°C to -10°C). Aircraft landing, taking off, or even taxiing, in freezing fog should anticipate rime icing.

Visibility

Reduced visibility is the meteorological component which impacts flight operations the most. Topographic features all tend to look the same at low levels making good route navigation essential. This can only be done in times of clear visibility.

Types of Visibility

There are several terms used to describe the different types of visibility used by the aviation community.

(a) **Horizontal visibility** - the furthest visibility obtained horizontally in a specific direction by referencing objects or lights at known distances.

(b) **Prevailing visibility** - the ground level visibility which is common to one-half or more of the horizon circle.

(c) **Vertical visibility** - the maximum visibility obtained by looking vertically upwards into a surface-based obstruction such as fog or snow.

(d) Slant visibility - visibility observed by looking forward and downwards from the cockpit of the aircraft.

(e) Flight visibility - the average range of visibility at any given time forward from the cockpit of an aircraft in flight.

Causes of Reduced Visibility

(a) Lithometers

Lithometers are dry particles suspended in the atmosphere and include haze, smoke, sand and dust. Of these, smoke and haze cause the most problems. The most common sources of smoke are forest fires. Smoke from distant sources will resemble haze but, near a fire, smoke can reduce the visibility significantly.

(b) Precipitation

Rain can reduce visibility, however, the restriction is seldom less than one mile other than in the heaviest showers beneath cumulonimbus clouds. Drizzle, because of the greater number of drops in each volume of air, is usually more effective than rain at reducing the visibility, especially when accompanied by fog.

Snow affects visibility more than rain or drizzle and can easily reduce it to less than one mile. Blowing snow is a product of strong winds picking up the snow particles and lifting them into the air. Fresh fallen snow is easily disturbed and can be lifted a few hundred feet. Under extreme conditions, the cockpit visibility will be excellent during a landing approach until the aircraft flares, at which time the horizontal visibility will be reduced abruptly.

(c) Fog

Fog is the most common and persistent visibility obstruction encountered by the aviation community. A cloud based on the ground, fog, can consist of water droplets, supercooled water droplets, ice crystals or a mix of supercooled droplets and ice crystals.

Photo 2-2 - Radiation fog in a valley credit: Alister Ling

(i) Radiation Fog

Radiation fog begins to form over land usually under clear skies and light winds typically after midnight and peaks early in the morning. As the land surface loses heat and radiates it into space, the air above the land is cooled and loses its ability to hold moisture. If an abundance of condensation nuclei is present in the atmosphere, radiation fog may develop before the temperature-dewpoint spread reaches zero. After sunrise, the fog begins to burn off from the edges over land but any fog that has drifted over water will take longer to burn off.

(ii) Advection Fog

Fog that forms when warm moist air moves across a snow, ice or cold water surface.

(iii) Precipitation or Frontal Fog

Precipitation fog, or frontal fog, forms ahead of warm fronts when precipitation falls through a cooler layer of air near the ground. The precipitation saturates the air at the surface and fog forms. Breaks in the precipitation usually results in the fog becoming thicker.

(iv) Steam Fog

Steam fog forms when very cold arctic air moves over relatively warmer water. In this case moisture evaporates from the water surface and saturates the air. The extremely cold air cannot hold all the evaporated moisture, so the excess condenses into fog. The result looks like steam or smoke rising from the water, and is usually no more than 50 to 100 feet thick. Steam fog, also called arctic sea smoke, can produce significant icing conditions.

(v) Ice Fog

Ice fog occurs when water vapour sublimates directly into ice crystals. In conditions of light winds and temperatures colder than -30°C or so, water vapour from manmade sources or cracks in ice-covered rivers can form widespread and persistent ice fog. The fog produced by local heating systems, and even aircraft engines, can reduce the local visibility to near zero, closing an airport for hours or even days.

(d) Snow Squalls and Streamers

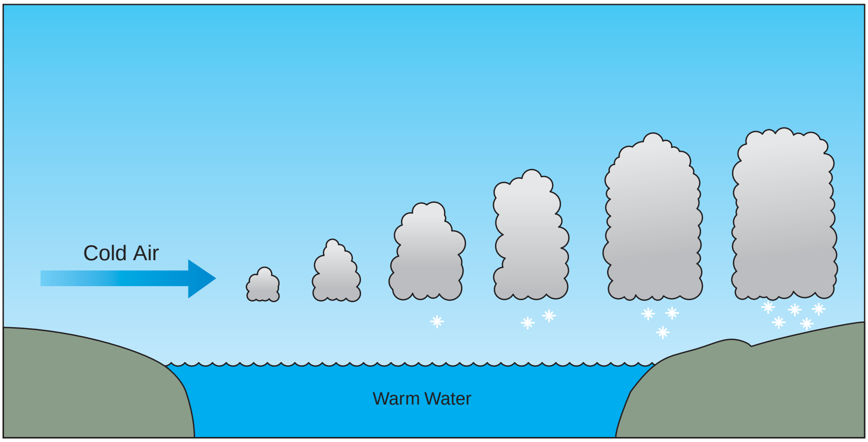


Fig. 2-6 - Snowsqualls building over open water

Snow squalls are relatively small areas of heavy snowfall. They develop when cold arctic air passes over a relatively warm water surface, such as the Great Lakes, before freeze-up. An injection of heat and moisture from the lake into the low levels of the atmosphere destabilizes the air mass. If sufficient destabilization occurs, convective clouds begin to develop with snow beginning shortly thereafter. Snowsqualls usually develop in bands of cloud, or streamers, that form parallel to the direction of flow. Movement of these snow squalls can generally be tied to the mean winds between 3,000 and 5,000 feet. Not only can snowsqualls reduce visibility to near zero but, due to their convective nature, significant icing and turbulence are often encountered within the clouds.

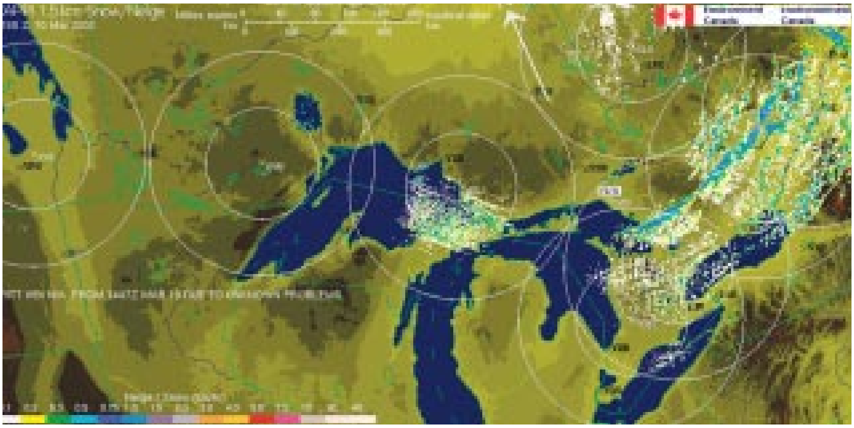


Photo 2-3 - Snowsqualls over the Great Lakes credit: Nav Canada

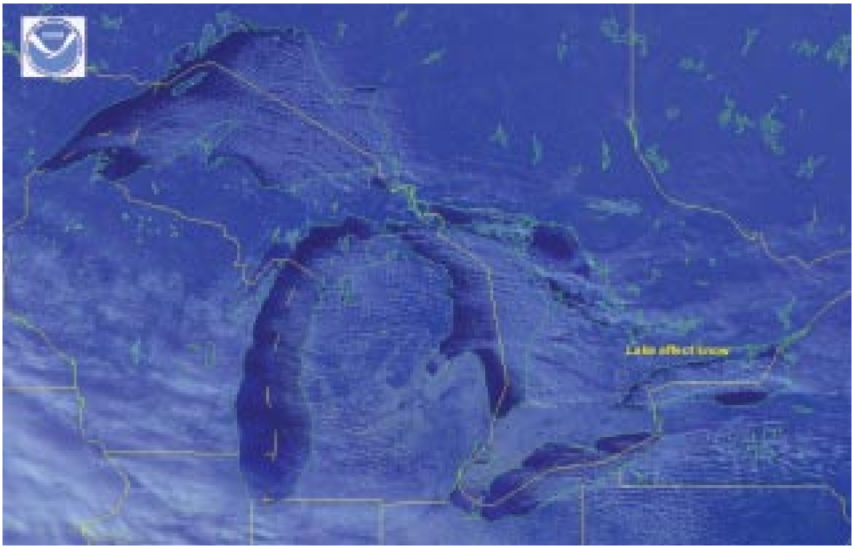


Photo 2-4 - Snowsqualls over the Great Lakes credit: NOAA

Wind, Shear and Turbulence

The “why” of winds are quite well understood. It is the daily variations of the winds, where they blow and how strong, that remains a constant problem for meteorologists to unravel. The problem becomes even more difficult when local effects such as wind flow through coastal inlets or in mountain valleys are added to the dilemma. The result of these effects can give one airport persistent light winds while another has nightly episodes of strong gusty winds.

Stability and the Diurnal Variation in Wind

In a stable weather pattern, daytime winds are generally stronger and gustier than nighttime winds. During the day, the heating from the sun sets up convective mixing which carries the stronger winds aloft down to the surface and mixes them with the slower surface winds. This causes the surface wind to increase in speed and become gusty, while at the same time reducing the wind speeds aloft in the mixed layer.

After sunset, the surface of the earth cools which, in turn, cools the air near the surface resulting in the development of a temperature inversion. This inversion deepens as cooling continues, ending the convective mixing and causing the surface winds to slacken.

Wind Shear

Wind shear is nothing more than a change in wind direction and/or wind speed over the distance between two points. If the points are in a vertical direction then it is called vertical shear, if they are in a horizontal direction than it is called horizontal shear.

In the aviation world, the major concern is how abruptly the change occurs. If the change is gradual, a change in direction or speed will result in nothing more than a minor change in the ground speed. If the change is abrupt, however, there will be a rapid change of airspeed or track. Depending on the aircraft type, it may take a significant time to correct the situation, placing the aircraft in peril, particularly during takeoff and landing.

Significant shearing can occur when the surface wind blowing along a valley varies significantly from the free flowing wind above the valley. Changes in direction of 90° and speed changes of 25 knots are reasonably common in hilly terrain.

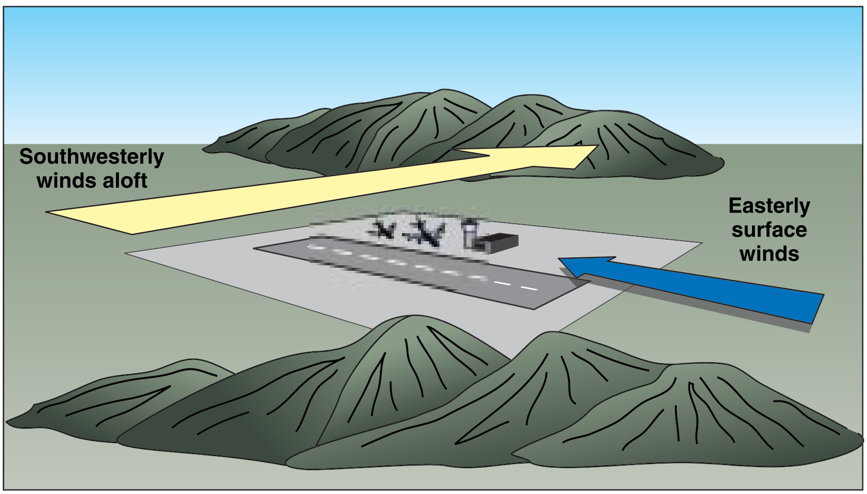


Fig. 2-7 - Wind shear near the top of a valley

Updrafts and downdrafts also induce shears. An abrupt downdraft will cause a brief decrease in the wing's attack angle resulting in a loss of lift. An updraft will increase the wing's attack angle and consequently increase the lift, however, there is a risk that it could be increased beyond the stall angle.

Shears can also be encountered along fronts. Frontal zones are generally thick enough that the change is gradual, however, cold frontal zones as thin as 200 feet have been measured. Significant directional shears across a warm front have also been observed with the directional change greater than 90 degrees over several hundred feet. Pilots doing a take-off or a landing approach through a frontal surface that is just above the ground should be wary.

Mechanical turbulence is a form of shear induced when a rough surface disrupts the smooth wind flow. The amount of shearing and the depth of the shearing layer depends on the wind speed, the roughness of the obstruction and the stability of the air.

The Relationship Between Wind Shear and Turbulence

Turbulence is the direct result of wind shear. The stronger the shear the greater the tendency for the laminar flow of the air to break down into eddies resulting in turbulence. However, not all shear zones are turbulent, so the absence of turbulence does not infer that there is no shear.

Low-Level Jets - Frontal

In developing low pressure systems, a narrow band of very strong winds often develops just ahead of the cold front and above the warm frontal zone. Meteorologists call these bands of strong winds "low-level jets". They are typically located between 500 and 5,000 feet and can be several hundred feet wide. Wind speeds associated with low-level jets can reach as high as 100 knots in more intense storms. The main problem with these features is that they can produce severe turbulence, or at least significant changes in airspeed. Critical periods for low-level windshear or turbulence with these features are one to three hours prior to a cold frontal passage. These conditions are made worse by the fact that they occur in the low levels of the atmosphere and affect aircraft in the more important phases of flight - landing and take off.

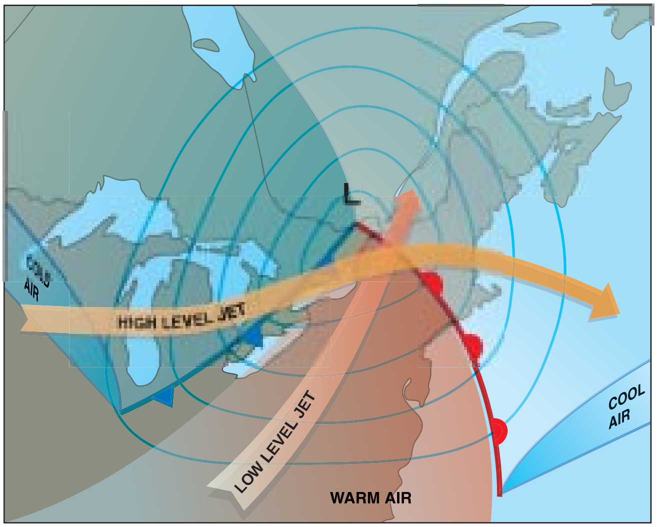


Fig. 2-8 - Idealized low and frontal system showing the position of the low-level and upper-level jet

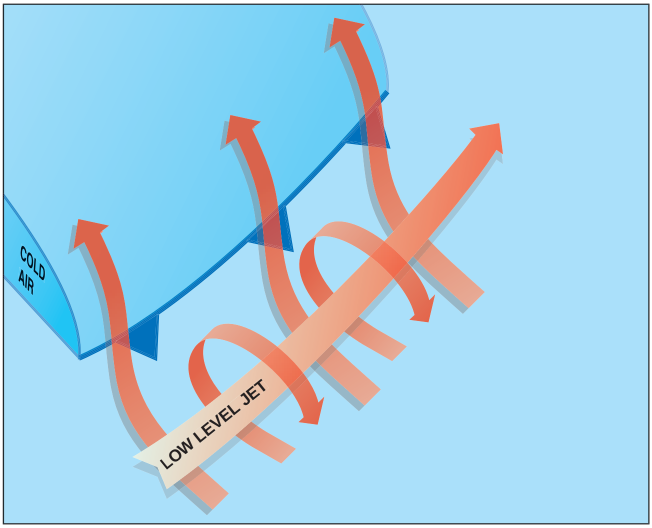


Fig. 2-9 - Complex winds around a low-level jet can result in significant wind shear and turbulence

Low-Level Jets - Nocturnal

There is another type of low-level jet known as "the low-level nocturnal jet". This jet is a band of relatively high wind speeds, typically centred at altitudes ranging between 700 and 2,000 feet above the ground (just below the top of the nocturnal inversion) but on occasion can be as high as 3,000 feet. Wind speeds usually range between 20 and 40 knots but have been observed up to 60 knots.

The low-level nocturnal jet tends to form over relatively flat terrain and resembles a ribbon of wind in that it is thousands of miles long, a few hundred feet thick and up to hundreds of miles wide. Low-level nocturnal jets have been observed in mountainous terrain but tend to be localized in character.

The low-level nocturnal jet forms mainly in the summer on clear nights (this allows the inversion to form). The winds just below the top of the inversion will begin to increase just after sunset, reach its maximum speed a couple of hours after midnight, then dissipate in the morning as the sun's heat destroys the inversion.

Topographical Effects on Wind

(a) Lee Effects

When the winds blow against a steep cliff or over rugged terrain, gusty turbulent winds result. Eddies often form downwind of the cliff face, which create stationary zones of stronger and lighter winds. These zones of strong winds are fairly predictable and usually persist as long as the wind direction and stability of the air stream do not change. The lighter winds, which occur in areas called wind shadows, can vary in speed and direction, particularly downwind of higher cliffs. Beneath the cliffs the wind is usually gusty and the wind direction is often completely opposite to the wind blowing over the top of the cliff. Smaller reverse eddies may also be encountered close to the cliffs.

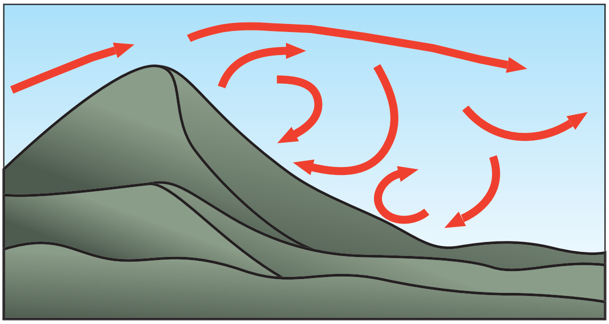


Fig. 2-10 - Lee effects

(b) Friction Effects

The winds that blow well above the surface of the earth are not strongly influenced by the presence of the earth itself. Closer to the earth, however, frictional effects decrease the speed of the air movement and back the wind (turns the wind direction counter-clockwise) towards the lower pressure. For example, in the northern hemisphere, a southerly wind becomes more southeasterly when blowing over rougher ground. There can be a significant reduction in the wind speed over a rough terrain when compared to the wind produced by the same pressure gradient over a relatively smooth prairie.

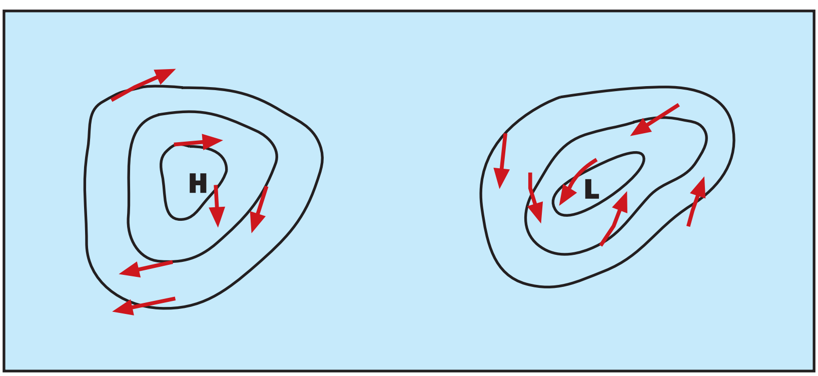


Fig. 2-11 - Friction effects

(c) Converging Winds

When two or more winds flow together or converge, a stronger wind is created. Similar effects can be noted where two or more valleys come together. Another example of this occurs along the coast when the different angles of the surface winds over land and water cause the air streams to converge. This convergence creates a band of wind that is about 25 percent stronger within a few miles of the shore.

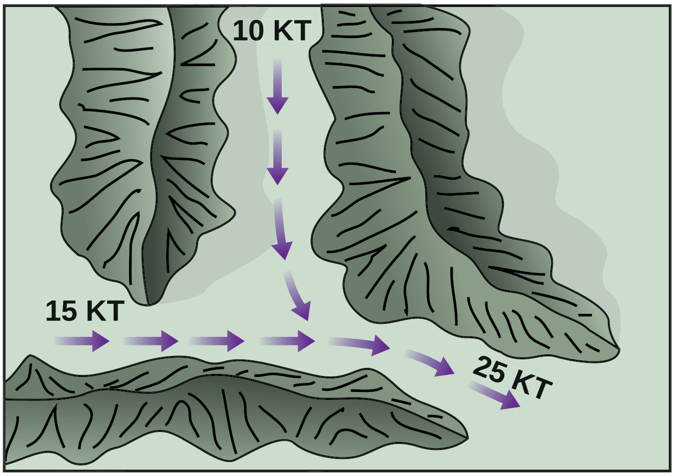


Fig. 2-12 - Converging winds

(d) Diverging Winds

A divergence of the air stream occurs when a single air stream splits into two or more streams. Each will have a lower speed than the parent air stream.

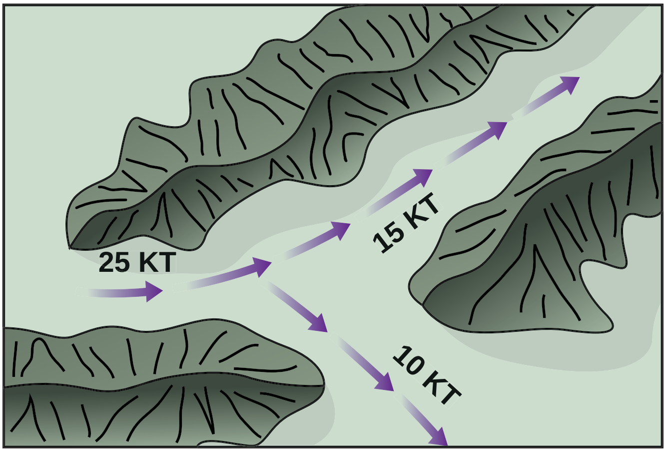


Fig. 2-13 - Diverging winds

(e) Corner Winds

When the prevailing wind encounters a headland, there is a tendency for the wind to curl around the feature. This change in direction, if done abruptly, can result in extreme turbulence.

(f) Funnelled or Gap Winds

When winds are forced to flow through a narrow opening or gap, such as an inlet or narrow section of a pass, the wind speed will increase and may even double in strength. This effect is similar to pinching a water hose and is called funnelling. It can be observed in the St. Lawrence River Valley.

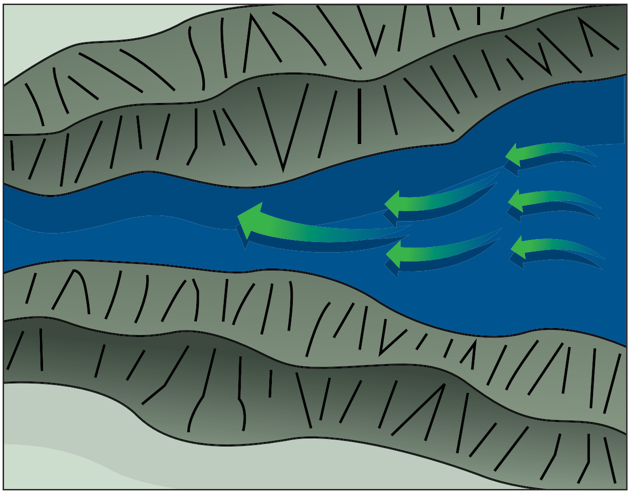


Fig. 2-14 - Funnelled winds

(g) Channelled Winds

The topography can also change the direction of the winds by forcing the flow along the direction of a pass or through a strait. This is referred to as channelling.

(h) Sea and land Breezes

Sea and land breezes are only observed under light wind conditions, and depend on temperature differences between adjoining regions.

A sea breeze occurs when the air over the land is heated more rapidly than the air over the adjacent water surface. As a result, the warmer air rises and the relatively cool air from the water flows onshore to replace it. By late afternoon, the time of maximum heating, the sea breeze circulation may be 1,500 to 3,000 feet deep, have obtained speeds of 10 to 15 knots and extend as far as 50 nautical miles inland.

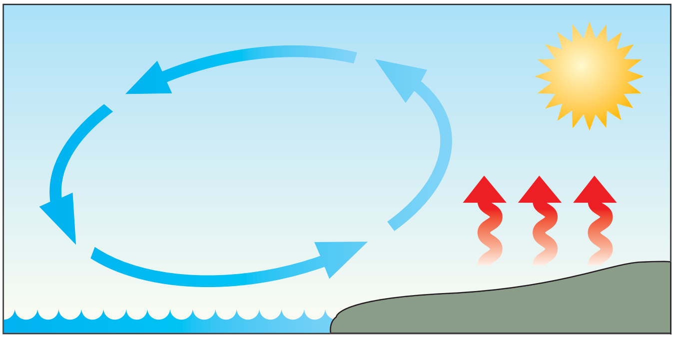


Fig. 2-15 - Sea breeze

During the evening the sea breeze subsides. At night, as the land cools, a land breeze develops in the opposite direction and flows from the land out over the water. It is generally not as strong as the sea breeze, but at times it can be quite gusty.

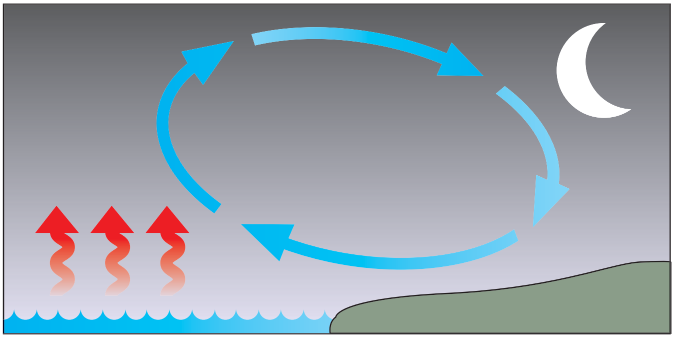


Fig. 2-16 - Land breeze

Both land and sea breezes can be influenced by channelling and funnelling resulting in almost frontal-like conditions, with sudden wind shifts and gusty winds that may reach up to 50 knots.

(i) Anabatic and Katabatic Winds

During the day, the sides of the valleys become warmer than the valley bottoms since they are better exposed to the sun. As a result, the winds blow up the slope. These daytime, upslope winds are called anabatic winds. Gently sloped valley sides, especially those facing south, are more efficiently heated than those of a steep, narrow valley. As a result, valley breezes will be stronger in the wider valleys. An anabatic wind, if extended to sufficient height, will produce cloud. In addition, such a wind offers additional lift to aircraft and gliders.

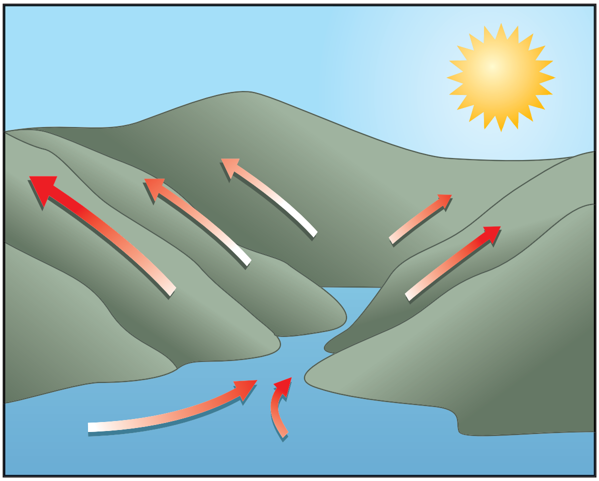


Fig. 2-17 - Anabatic winds

At night, the air cools over the mountain slopes and sinks to the valley floor. If the valley floor is sloping, the winds will move along the valley towards lower ground. The cool night winds are called drainage winds, or katabatic winds, and are often quite gusty and usually stronger than anabatic winds. Some valley airports have windsocks situated at various locations along their runways to show the changeable conditions due to the katabatic flow.

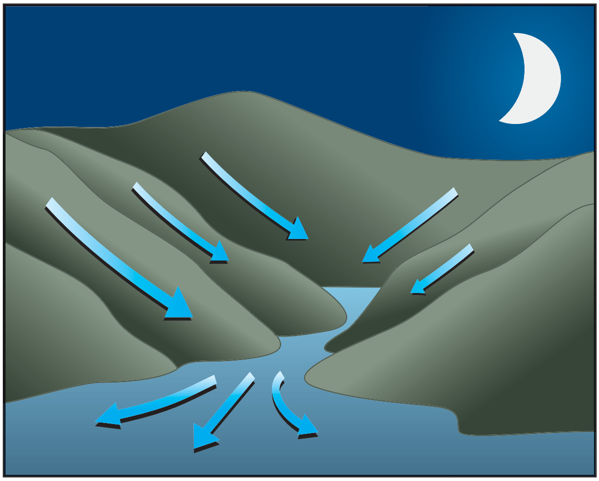


Fig. 2-18 - Katabatic winds

(j) Glacier Winds

Under extreme cooling conditions, such as an underlying ice cover, the katabatic winds can develop to hazardous proportions. As the ice is providing the cooling, a shallow wind of 80 knots or more can form and will persist during the day and night. Katabatic winds are easily funnelled resulting in winds of unexpected directions and strengths in narrow passes.

Lee Waves

When air flows across a mountain or hill, it is disturbed the same way as water flowing over a rock. The air initially is displaced upwards across the mountain, dips sharply on the lee side, then rises and falls in a series of waves downstream. These waves are called "mountain waves" or "lee waves" and are most notable for their turbulence. They often develop on the lee side of the Torngat, Long Range and Appalachian Mountains.

The Formation of Lee Waves

The development of lee waves requires that several conditions be met:

(a) the wind direction must be within 30 degrees of perpendicular to the mountain or hill. The greater the height of the mountain and the sharper the drop off to the lee side, the more extensive the induced oscillations.

(b) wind speed should exceed 15 knots for small hills and 30 knots for mountain ridges. A jet stream with its associated strong winds below the jet axis is an ideal situation.

(c) the wind direction should be constant while increasing in speed with height throughout the troposphere.

(c) the air should be stable near the mountain peaks but less stable below. The unstable layer encourages the air to ascend and the stable layer encourages the development of a downstream wave pattern.

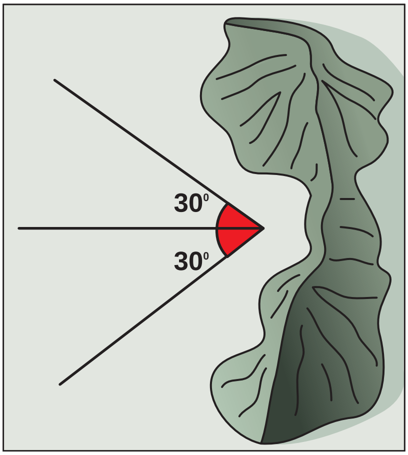


Fig. 2-19 - Angles for lee wave development

While all these conditions can be met at any time of the year, winter wind speeds are generally stronger resulting in more dangerous lee waves.

Characteristics of Lee Waves

Once a lee wave pattern has been established, it follows several basic rules:

- stronger the wind, the longer the wavelength. The typical wavelength is about 6 miles but can vary from as short as 3 miles to as long as 15 miles.
- position of the individual wave crests will remain nearly stationary with the

wind blowing through them as long as the mean wind speed remains nearly constant.

- individual wave amplitude can exceed 3,000 feet.
- layer of lee waves often extends from just below the tops of the mountains to 4,000 to 6,000 feet above the tops but can extend higher.
- induced vertical currents within the wave can reach values of 4,500 feet per minute.
- wind speed is stronger through the wave crest and slower through the wave trough.
- wave closest to the obstruction will be the strongest with the waves further downstream getting progressively weaker.
- a large eddy called a "rotor" may form below each wave crest.
- mountain ranges downstream may amplify or nullify induced wave patterns.
- downdrafts are frequently found on the downwind side of the obstruction. These downdrafts typically reach values of 2,000 feet per minute but downdrafts up to 5,000 feet per minute have been reported. The strongest downdraft is usually found at a height near the top of the summit and could force an aircraft into the ground.

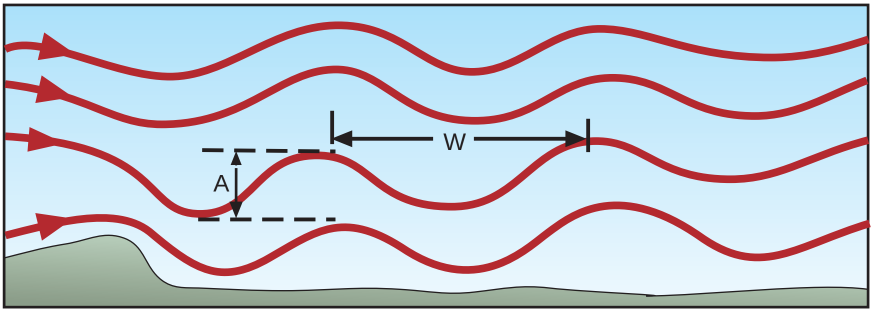


Fig. 2-20 - Amplitude (A) and wavelength (W) in lee waves

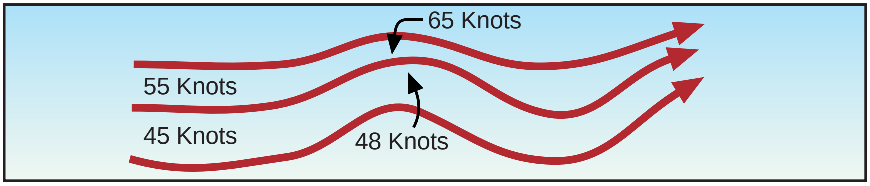


Fig. 2-21 - Stronger wind in wave crest in lee waves

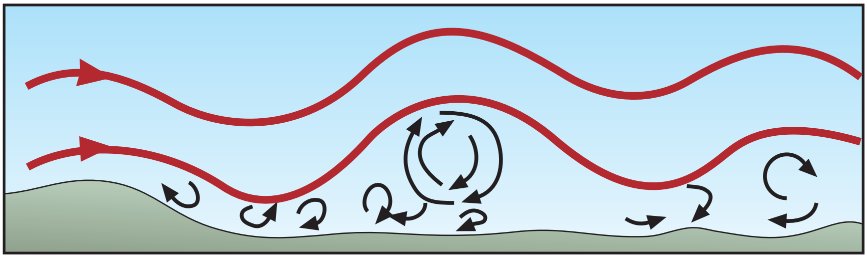


Fig. 2-22 - A rotor may form beneath wave crests

Clouds Associated with Lee Waves

Lee waves involve lift and, if sufficient moisture is available, characteristic clouds will form. The signature clouds may be absent, however, due to the air being too dry or the cloud being embedded within other clouds and not visible. It is essential to realize, nevertheless, that the absence of lee wave clouds does not mean that there are no lee waves present.

(a) Cap cloud

A cloud often forms over the peak of the mountain range and remains stationary. Frequently, it may have an almost "waterfall" appearance on the leeward side of the mountain. This effect is caused by subsidence and often signifies a strong downdraft just to the lee of the mountaintop.

(b) Lenticular clouds

A lens shaped cloud may be found at the crest of each wave. These clouds may be separated vertically with several thousand feet between each cloud or may form so close together they resemble a "stack of plates." When air flows through the crest it is often laminar, making the cloud smooth in appearance. On occasion, when the shear results in turbulence, the lenticular cloud will take on a ragged and wind torn appearance.

(c) Rotor cloud

A rotor cloud may form in association with the rotor. It will appear as a long line of stratocumulus, a few miles downwind and parallel to the ridge. Its base will be normally below the peak of the ridge, but its top can extend above it. The turbulence associated with a rotor cloud is severe within and near the rotor cloud.

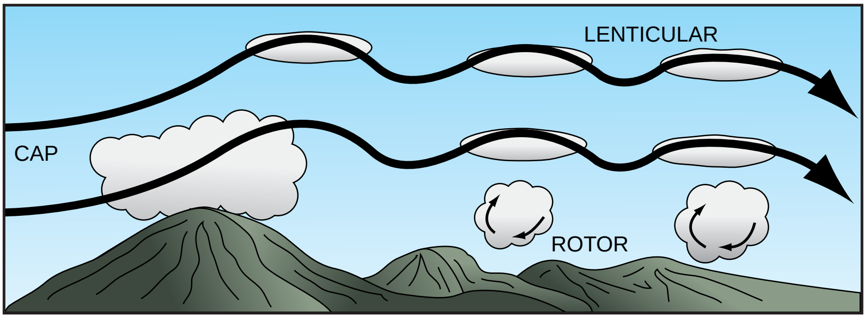


Fig. 2-23 - Characteristic clouds formed by lee waves

Fronts

A front is the transition or mixing zone between two air masses. While only the surface front is shown on a weather map, it is important to realize that an air mass is three-dimensional and resembles a wedge. If the colder air mass is advancing, then the leading edge of the transition zone is described as being a cold front. If the colder air mass is retreating, then the trailing edge of the transition zone is described as being a warm front.

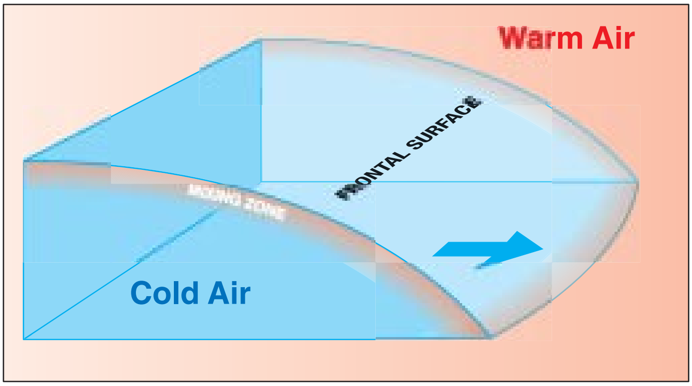


Fig. 2-24 - Cross-section of a cold front

The movement of a front is dependent on the motion of the cold air nearly perpendicular to the front, both at the surface and aloft. When the winds blow across a front, it tends to move with the wind. When winds blow parallel to a front, the front moves slowly or even becomes quasistationary. The motion of the warm air does not affect the motion of the front.

On surface charts, fronts are usually drawn as relatively straight lines. In reality, this is seldom so. Cold air flows across the surface like water. When advancing, it readily moves across level ground but in hilly or mountainous terrain it is held up until it either finds a gap or deepens to the point where it can flow over the barrier. Cold air also readily accelerates downhill resulting in rapid motion along valleys. When retreating, cold air moves slowly and leaves pools of cold air in low-lying areas that take time to modify out of existence.

Frontal Weather

When two different air masses encounter each other across a front, the cooler, denser air will lift the warm air. When this happens, the weather at a front can vary from clear skies to widespread cloud and rain with embedded thunderstorms. The weather occurring at a front depends on:

(a) amount of moisture available
Sufficient moisture must be present for clouds to form. Insufficient moisture results in "dry" or "inactive" fronts that may be marked by only changes of temperature, pressure and wind. An inactive front can become active quickly if it encounters an area of moisture.

(b) stability of the air being lifted
The degree of stability influences the type of clouds being formed. Unstable air will produce cumuliform clouds accompanied by showery weather and more turbulent conditions. Stable air will produce stratiform cloud accompanied by steady precipitation and little or no turbulence.

(c) slope of the front
A shallow frontal surface such as a warm front produces widespread cloud and steady precipitation. Such areas are susceptible to the formation of low stratus cloud and fog and may have an area of freezing precipitation. Passage of such a front is usually noted by the end of the steady precipitation, followed by a slow reduction in the cloud cover.
A steep frontal surface, such as is seen in cold fronts, tends to produce a narrow band of convective weather. Although blustery, the period of bad weather is short-lived and the improvement behind the front is dramatic.

(d) speed of the front
A fast-moving cold front enhances the vertical motion along the front, which, in turn, causes the instability to be accentuated. The result is more vigorous convective-type weather and the potential for the development of squall lines and severe weather.

Frontal Waves and Occlusions

Small-scale changes in pressure along a front can create localized alterations in the wind field resulting in a bending of the front. This bending takes on a wave-like appearance as part of the front begins to move as a warm front and another part moves as a cold front. Such a structure is known as a frontal wave. There are two types of frontal waves:

(a) Stable Waves

The wave structure moves along the front but does not develop beyond the wave appearance. Such features, known as stable waves, tend to move rapidly (25 to 60 knots) along the front and are accompanied by a localized area of heavier cloud and precipitation. The air mass stability around the wave determines the cloud and precipitation type. Since the wave moves rapidly, the associated weather duration tends to be short.

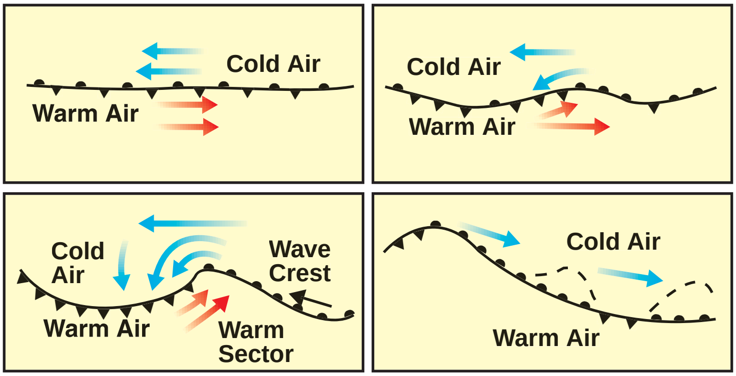


Fig 2-25 - Stable wave

(b) Unstable (Occluding) Waves

Given additional support for development, such as an upper trough, the surface pressure will continue to fall near the frontal wave, causing the formation of a low pressure centre and strengthening winds. The wind behind the cold front increases causing the cold front to accelerate and begin to wrap around the low. Eventually, it catches up with the warm front and the two fronts occlude or "close together." At this point, the low is at maximum intensity.

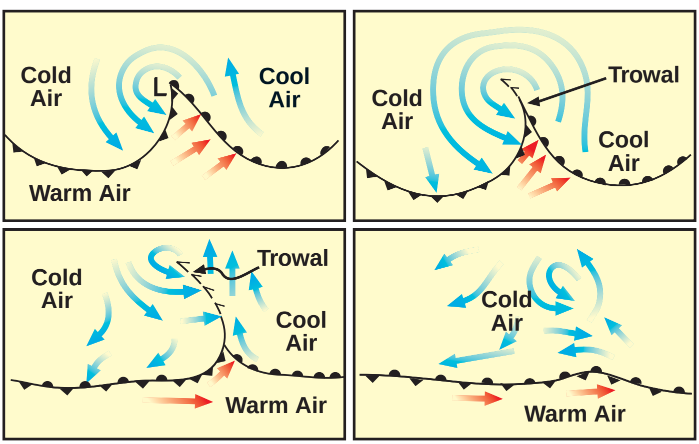


Fig. 2-26 - Formation of an occluding wave

Occlusions occur because the air behind the cold front is colder and denser than the cool air mass ahead of the warm front. Thus, it undercuts not only the warm sector of the original wave but also the warm front, forcing both features aloft. As the warm sector is lifted higher and higher, the surface portion becomes smaller and smaller. Along the occlusion, the weather is a combination of a warm front and a cold front; that is, a mix of layer clouds with steady precipitation and embedded convective clouds with enhanced showery precipitation. Such a cloud mass should be approached with caution as both icing and turbulence can be quite variable. Eventually, the frontal wave and occlusion both move away from the low, leaving only an upper frontal band curling back towards the low. This upper structure continues to weaken as it moves further and further away from the low that initially formed it .

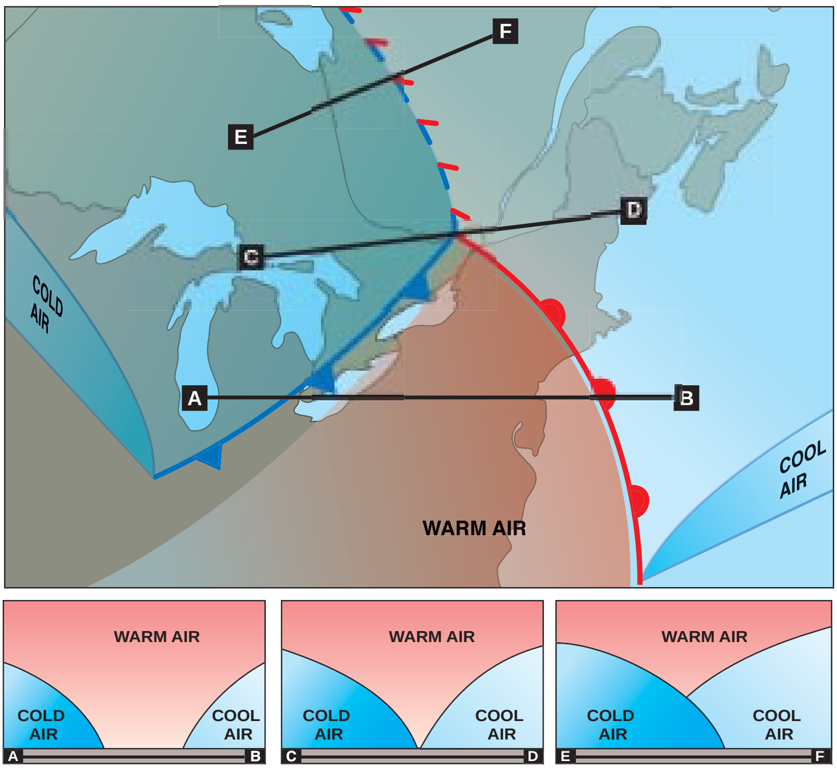


Fig. 2-27 - Frontal cross-sections

Thunderstorms

No other weather encountered by a pilot can be as violent or threatening as a thunderstorm. Thunderstorms produce many hazards to the aviation community and, since they are so common on the prairies in summer time, it is important that pilots understand their nature and how to deal with them. To produce a thunderstorm, there are several ingredients which must be in place. These include:

- an unstable airmass
- moisture in the low levels
- something to trigger them, e.g. daytime heating, upper level cooling
- for severe thunderstorms, wind shear.

The Life Cycle of a Thunderstorm

The thunderstorm, which may cover an area ranging from 5 miles in diameter to, in the extreme case, as much as 50 miles, usually consists of two or more cells in different stages of their life cycle. The stages of life of individual cells are:

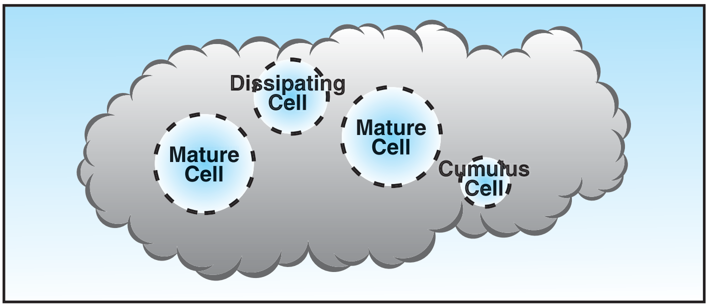


Fig. 2-28 -Top-down view of a thunderstorm "family" containing cells in different stages of development.

(a) Cumulus Stage

The cumulus stage is marked by updrafts only. These updrafts can reach values of up to 3,000 feet per minute and cause the cloud to build rapidly upwards, carrying supercooled water droplets well above the freezing level. Near the end of this stage, the cloud may well have a base more than 5 miles across and a vertical extent in excess of 20,000 feet. The average life of this stage is about 20 minutes.

(b) Mature Stage

The appearance of precipitation beneath the base of the cell and the development of the downdraft mark the transition to this stage. The downdraft is caused by water drops which have become too heavy for the updraft to support and now begin to fall. At the same time, the drops begin to evaporate as they draw in dry air from the edge of the cloud, and then fall through the drier air beneath the base of the cloud. This evaporation causes the air to cool and become denser, resulting in a downwash of accelerating cold air. Typical downdraft speeds can reach values of 2,500 feet per minute.

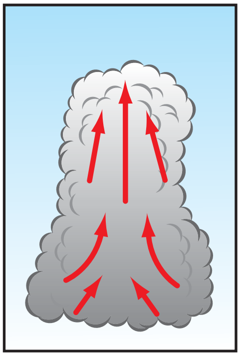


Fig. 2-29 - Cumulus stage

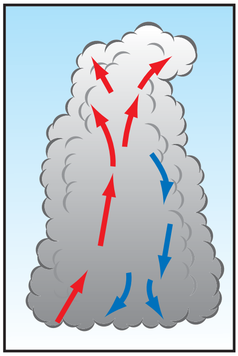


Fig. 2-30 - Mature stage

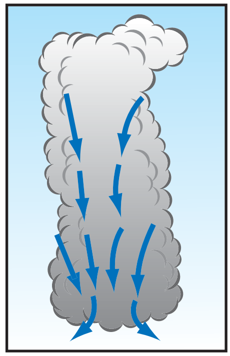


Fig. 2-31 - Dissipating Stage

The downdraft, when it hits the ground, spreads out in all directions but travels fastest in the direction that the storm is moving. The leading edge of this cold air is called the "gust front" and can extend ten to fifteen miles, or even further, when channelled along mountain valleys in front of the storm. A rapid drop in temperature and a sharp rise in pressure characterize this horizontal flow of gusty surface winds.

At the same time, the updrafts continue to strengthen until they reach maximum speeds, possibly exceeding 6,000 feet per minute. The cloud reaches the tropopause which blocks the updraft, forcing the stream of air to spread out horizontally. Strong upper winds at the tropopause level assist in the spreading out of this flow in the downwind direction, producing the traditional anvil-shaped top. This is classically what is referred to as a cumulonimbus cloud (CB).

The thunderstorm may have a base measuring from 5 miles to more than 15 miles in diameter and a top ranging from as low as 20,000 feet to more than 50,000 feet. The mature stage is the most violent stage in the life a thunderstorm and usually lasts for 20 to 30 minutes.

Near the end of the mature stage, the downdraft has increased in size so that the updraft is almost completely "choked off," stopping the development of the cell. However, at times, the upper winds increase strongly with height causing the cell to tilt. In such a case, the precipitation falls through only a portion of the cell, allowing the updraft to persist and reach values of 10,000 feet per minute. Such cells are referred to as "steady state storms" that can last for several hours and produce the most severe weather, including tornadoes.

(c) Dissipating Stage

The dissipating stage of a cell is marked by the presence of downdrafts only. With no additional flow of moisture into the cloud from an updraft, the rain gradually tapers off and the downdrafts weaken. The cell may dissipate completely in 15 to 30 minutes, leaving clear skies or patchy cloud layers. At this stage the anvil, which is formed almost exclusively of ice crystals, often detaches and drifts off downwind.

Types of Thunderstorms

(a) Air Mass Thunderstorms

These thunderstorms form within a warm, moist air mass and are non-frontal in nature. They are usually a product of diurnal heating, tend to be isolated, reach maximum strength in the late afternoon, are seldom violent, and usually dissipate quickly after the setting of the sun. There is also a second form of air mass thunderstorm that is created by cold advection. In this case, cold air moves across warm land or water and becomes unstable. Of these two, it is the movement of cold air over warm water that results in the most frequent occurrence of this type of thunderstorm. Since the heating is constant, these thunderstorms can form at any time of day or night.

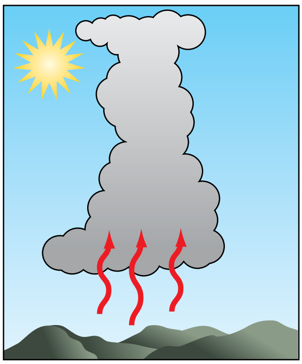


Fig. 2-32 - Air heated by warm land

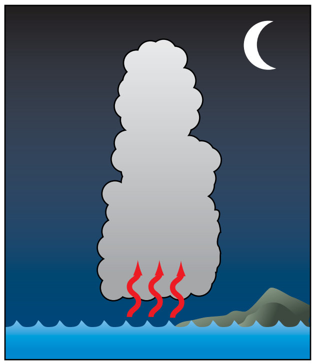


Fig. 2-33 - Cool air heated by warm water

(b) Frontal Thunderstorms

These thunderstorms form either as the result of a frontal surface lifting an unstable air mass or a stable air mass becoming unstable, as a result of the lifting. Frontal thunderstorms can be found along cold fronts, warm fronts and trowals. These thunderstorms tend to be numerous in the area, often form in lines, are frequently embedded in other cloud layers, and tend to be active during the afternoon and well into the evening. Cold frontal thunderstorms are normally more severe than warm frontal thunderstorms.

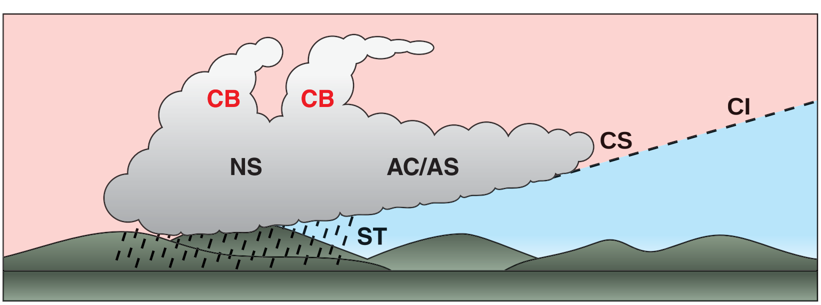


Fig. 2-34 - Warm frontal thunderstorms

(c) Squall Line Thunderstorms

A squall line (or line squall) is a line of thunderstorms. Squall lines can be several hundred miles long and have lower bases and higher tops than the average thunderstorm. Violent combinations of strong winds, hail, rain and lightning makes them an extreme hazard not only to aircraft in the air, but also to those parked uncovered on the ground.

Squall line thunderstorms are most often found 50 to 300 miles ahead of a fast-moving cold front but can also be found in accompanying low pressure troughs, in areas of convergence, along mountain ranges and even along sea breeze fronts.

(d) Orographic Thunderstorms

Orographic thunderstorms occur when moist, unstable air is forced up a hill or mountain slope. The amount of lift required varies with the amount of moisture present in the air. This type of thunderstorm is most common during the afternoon and early evening, and is usually isolated. However, on occasion, these thunderstorms will form a long, unbroken line along a mountain slope.

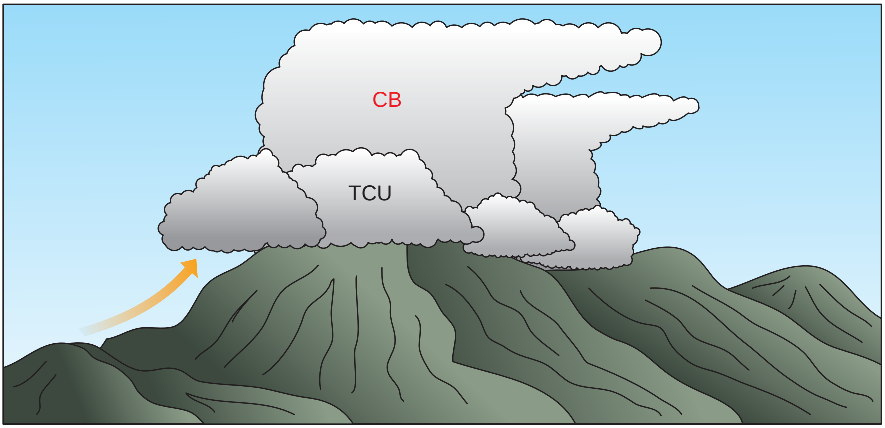


Fig. 2-35 - Orographic thunderstorms

(e) Nocturnal Thunderstorms

Nocturnal thunderstorms are those that develop during, or persist, all night. Usually, they are associated with an upper level weather feature moving through the area, are generally isolated, and tend to produce considerable lightning.

Severe Thunderstorms

The discussion of the life cycle of a thunderstorm does not fit the case of those that seem to last for extended periods of time and are most prolific in producing tornadoes and large hail. A particular type of severe thunderstorm is known as a "Supercell".

The Supercell storm typically begins as a multi-cellular thunderstorm. However, because the upper winds increase strongly with height, the cell begins to tilt. This causes the descending precipitation to fall through only a portion of the cell, allowing the updraft to persist.

The second stage of the supercell life cycle is clearly defined by the weather. At this stage, the largest hail fall generally occurs and funnel clouds are often observed.

The third and final stage of supercell evolution is the collapse phase. The storm's downdrafts increase in magnitude, and extend horizontally, while the updrafts are decreasing. It is at this time that the strongest tornadoes and straight-line winds occur.

While Supercells do occur over the Southern Prairies, Southern Ontario and Southwestern Quebec, they are rare elsewhere in Canada.

Thunderstorm Hazards

The environment in and around a thunderstorm can be the most hazardous encountered by an aircraft. In addition to the usual risks such as severe turbulence, severe clear icing, large hail, heavy precipitation, low visibility and electrical discharges within and near the cell, there are other hazards that occur in the surrounding environment.

(a) The Gust Front

The gust front is the leading edge of any downburst and can run many miles ahead of the storm. This may occur under relatively clear skies and, hence, can be particularly nasty for the unwary pilot. Aircraft taking off, landing, or operating at low levels can find themselves in rapidly changing wind fields that quickly threaten the aircraft's ability to remain airborne. In a matter of seconds, the wind direction can change by as much 180°, while at the same time the wind speed can approach 100 knots in the gusts. Extremely strong gust fronts can do considerable damage on the ground and are sometimes referred to as "plow winds." All of this will likely be accompanied by considerable mechanical turbulence and induced shear on the frontal boundary up to 6,500 feet above the ground.

(b) Downburst, Macroburst and Microburst

A downburst is a concentrated, severe downdraft which accompanies a descending column of precipitation underneath the cell. When it hits the ground, it induces an outward, horizontal burst of damaging winds. There are two types of downburst, the "macroburst" and the "microburst".

A macroburst is a downdraft of air with an outflow diameter of 2.2 nautical miles, or greater, with damaging winds that last from 5 to 20 minutes. Such occurrences are common in the summer but only rarely hit towns or airports.

On occasion, embedded within the downburst, is a violent column of descending air known as a "microburst". Microbursts have an outflow diameter of less than 2.2 nautical miles and peak winds lasting from 2 to 5 minutes. Such winds can literally force an aircraft into the ground.

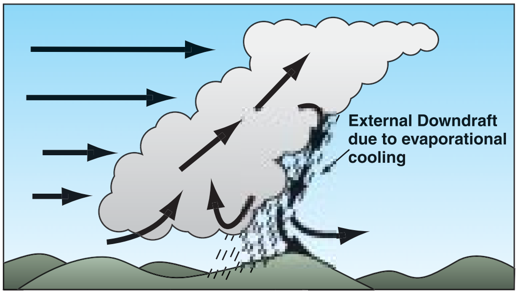


Fig. 2-36 - "Steady state" tilted thunderstorm

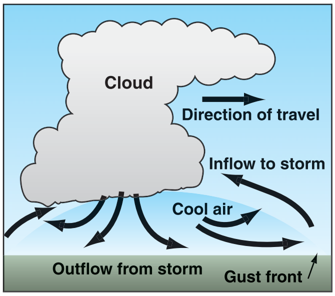


Fig. 2-37 - The gust front

(c) Funnel Cloud, Tornado and Waterspout

The most violent thunderstorms draw air into their base with great vigor. The incoming air tends to have some rotating motion and, if it should become concentrated in a small area, forms a rotating vortex in the cloud base in which wind speeds can exceed 200 knots. If the vortex becomes strong enough, it will begin to extend a funnel-shaped cloud downwards from the base. If the cloud does not reach the ground, it is called a funnel cloud. If it reaches the ground, it is refered to as a tornado and if it touches water, it is a waterspout.

Any severe thunderstorm should be avoided by a wide margin as all are extremely hazardous to aircraft.

Photo 2-5 - Severe thunderstorm credit:Alister Ling

F-Scale Number	Intensity Phrase	Wind Speed (kts)	Type of Damage Done
F0	**Gale** Tornado	35-62	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.
F1	**Moderate** Tornado	63-97	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
F2	**Significant** Tornado	98-136	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.
F3	**Severe** Tornado	137-179	Roof and some walls torn off well constructed houses; trains overturned; most trees in forest uprooted
F4	**Devastating** Tornado	180-226	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large-object missiles generated.
F5	**Incredible** Tornado	227-285	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile-sized missiles fly through the air in excess of 100 meters; trees debarked; steel re-inforced concrete structures badly damaged.

Table 2-1 - The Fujita Scale

Waterspouts tend to be a coastal phenomenon and occur more often than tornadoes because of the frequency of which cold air is projected over the warm water, enhancing the instability. The first sign that a waterspout may form is the cloud sagging down in one area. If this bulge continues downward to the sea surface, forming a vortex beneath it, water will be carried aloft in the lower 60 or 100 feet. Waterspouts are most common over the Great Lakes.

Cold Weather Operations

Operating an aircraft in extremely cold weather conditions can bring on a unique set of potential problems.

Temperature Inversion and Cold Air Outbreaks

Low-level inversions are common in most areas during the fall and winter due to very cold outbreaks and strong radiational cooling. When cold air moves out over the open water, it becomes very unstable. Cloud can be seen to almost be "boiling" off the waters surface and vortices of cloud have been witnessed to rotate upwards off the water into the cloud. Such a condition can be very turbulent and there is a significant risk of serious icing. At the same time, the convection enhances any snowfall resulting in areas of extremely poor visibility.

Looming

Another interesting effect in cold air is the bending of low angle light rays as they pass through an inversion. This bending creates an effect known as "looming," a form of mirage that causes objects normally beyond the horizon to appear above the horizon.

Ice Fog and Ice Crystals

Ice fog occurs when water vapour sublimates directly to ice crystals. In conditions of light winds and temperatures colder than -30°C or so, such as those that might be found in Labrador, water vapour from anthropogenic sources (man-made) can form widespread and persistent ice fog or ice crystals. In light winds, the visibility can be reduced to near zero, closing an airport for hours.

Blowing Snow

Blowing snow can occur almost anywhere where dry snow can be picked up by strong winds. As winds increase, the snow begins to bluster and can, in extreme conditions, reduce horizontal visibility at runway level to zero.

Whiteout

"Whiteout" is a phenomena that can occur in such places as Labrador when a layer of cloud of uniform thickness overlays a snow or ice-covered surface, such as a large frozen lake. Light rays are diffused when they pass through the cloud layer so that they strike the surface from all angles. This light is then reflected back and forth between the surface and cloud, eliminating all shadows. The result is a loss of depth perception, the horizon becoming impossible to discern, and dark objects seeming to float in a field of white. Disastrous accidents have occurred under such conditions where pilots have flown into the surface, unaware that they were descending and confident that they could see the ground.

Altimetry Errors

The basic barometric altimeter in an aircraft assumes a standard change of temperature with height in the atmosphere and, using this fact, certain pressure readings by the altimeter have been defined as being at certain altitudes. For example, a barometric altimeter set at 30.00" would indicate an altitude of 10,000 feet ASL when it senses the outside pressure of 20.00".

Cold air is much more dense than the assumed value used in the standard ICAO atmosphere. For this reason, any aircraft that is flying along a constant pressure surface will actually be descending as it moves into areas of colder air, although the indicated altitude will remain unchanged. Interestingly enough, a new altimeter setting obtained from a site in the cold air will not necessarily correct this problem and may increase the error.

Consider:

A pilot obtained an altimeter setting of 29.85" and plans to maintain a flight level of 10,000 feet enroute. As the aircraft moves into an area with a strong low-level inversion and very cold surface temperatures, the plane descends gradually as it follows the constant pressure surface corresponding to an indicated altitude of 10,000 feet. A new altimeter setting, say 30.85 inches, is obtained from an airport located in the bottom of a valley, deep in the cold air. This new setting is higher than the original setting and, when it is entered, the altimeter will show an increase in altitude (in this case the change is one inch and so the altimeter will show an increase from 10,000 to 11,000 feet). Unaware of what is happening, the pilot descends even further to reach the desired enroute altitude, compounding the height error.

If the aircraft were operating in cloud-shrouded mountains, an extremely hazardous situation can develop. There is no simple solution to this problem, other than to be aware of it and allow for additional altitude to clear obstacles.

Volcanic Ash

A major, but fortunately infrequent, threat to aviation is volcanic ash. When a volcano erupts, a large amount of rock is pulverized into dust and blasted upwards. The altitude is determined by the severity of the blast and, at times, the ash plume will extend into the stratosphere. This ash is then spread downwind by the winds aloft in the troposphere and the stratosphere. The dust in the troposphere settles fairly rapidly and can limit visibility over a large area.

Of greater concern is the volcanic ash that is ingested by aircraft engines at flight level. Piston-driven engines have failed due to plugged air filters while turbine engines have "flamed out."

The volcanic dust also contains considerable pumice material. Leading edges such as wings, struts, and turbine blades can all be abraded to the point where replacement becomes necessary. Windscreens have been abraded until they become opaque.

For the most part, volcanic ash is not a problem in Eastern Canada. On occasion, the ash from an eruption in Iceland will drift eastward along the easterly branch of an upper trough or "cut-off" low over the North Atlantic.

Deformation Zone

A deformation zone is defined as "an area in the atmosphere where winds converge along one axis and diverge along another. Deformation zones (or axis of deformation as they are sometimes referred to) can produce clouds and precipitation." More simply put, we are referring to areas in the atmosphere where the winds flow together (converge) or apart (diverge), resulting in areas where air parcels undergo stretching along one axis and contraction along another axis. Meteorologically, this is an area where significant cloud amounts, precipitation, icing and turbulence can occur to in the induced vertical currents.

For meteorologists, the most common form of deformation zones are the ones associated with upper lows. Northeast of the upper low, a deformation zone usually forms in which the air is ascending. In this area, thick cloud layers form giving widespread precipitation. Depending on the temperatures aloft, this cloud may also contain significant icing. During the summer, the edges of this cloud area will often have thunderstorms develop in the afternoon. If this area of cloud is slow moving, or should it interact with terrain, then the upslope areas can see prolonged precipitation. Winds shear in the ascending air will often give turbulence in the middle-and higher-levels.

A second deformation zone exists to the west and northwest of these lows. In this case the air is descending, so that widespread higher clouds usually only consist of whatever cloud is wrapped around the low. Precipitation here tends to be more intermittent or showery. Wind shear can also cause turbulence but most often it is confined to the low-levels.

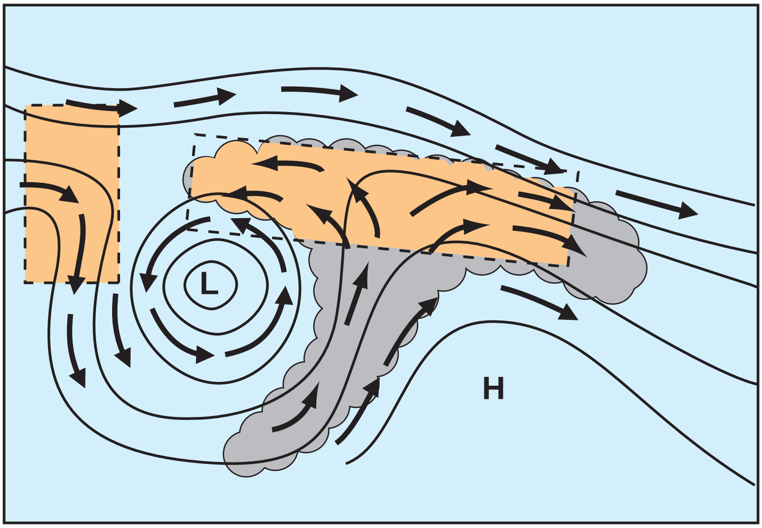


Fig. 2-38 - Deformation zones

Notes

Chapter 3

Weather Patterns of Ontario and Quebec

Introduction

"Weather is what you get; climate is what you expect."

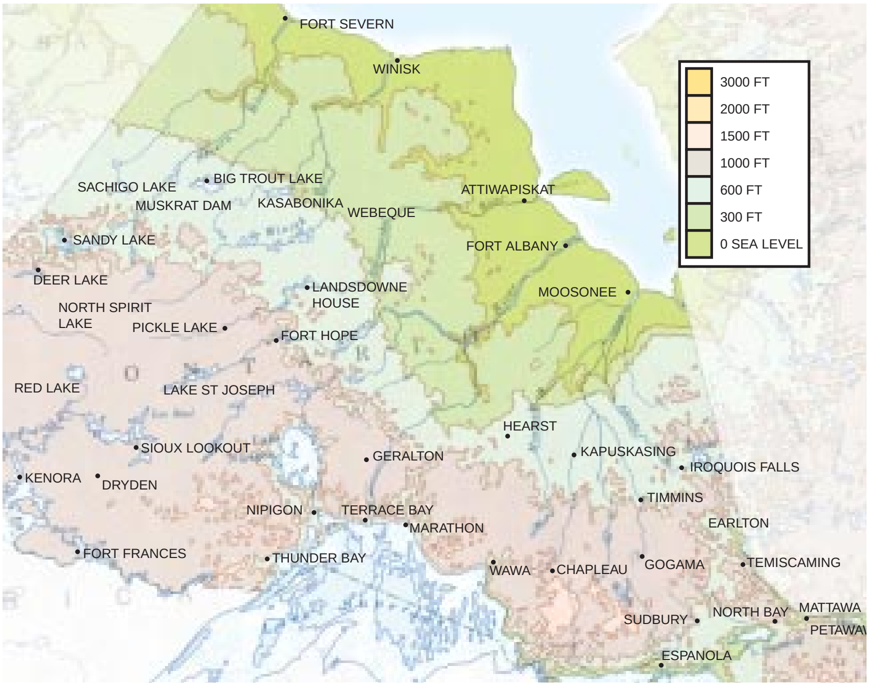
Most of us if asked to describe a particular location would include a comment about it being warm or cold, cloudy and wet or dry and sunny and maybe, windy or calm. We tend to think in terms of the north as cold, the south as warm, coastal areas as wet and cloudy and interior plains as dry and sunny. Viewed in this way, we are in a sense talking about climatology, taking an historic look at values of temperature, rainfall and cloud cover and recognizing that these values differ due to factors associated with geographic location.

Climatology can't tell us if it is currently raining in Toronto, snowing in Timmins or foggy in Montreal. Weather is dynamic, and its patterns transient. Meteorologists must combine knowledge of climate with an understanding of weather to forecast tomorrow's conditions. Add to this the effects of large bodies of water and elevated terrain and the task can be daunting.

Map 3-1 - Topography of the GFACN33 Domain

Geography

Northern Ontario



Map 3-2 - Northern Ontario

Northern Ontario borders the southern shores of Hudson Bay in the west and James Bay in the east. These are vast areas of relatively shallow inland sea, more than three times the combined area of the Great Lakes. James Bay contains many islands; Akimiski, the largest, has a length of 53 nautical miles. The bays remain largely free of ice from mid July through mid October, after which ice begins to form around the shores. The ice builds outward from the shore, frequently shifting and moving with changes in wind direction, until there is little or no open water remaining after mid December. These waters have a strong influence on flying conditions in this region, due to their comparatively cold temperature in summer and warm temperature in winter.

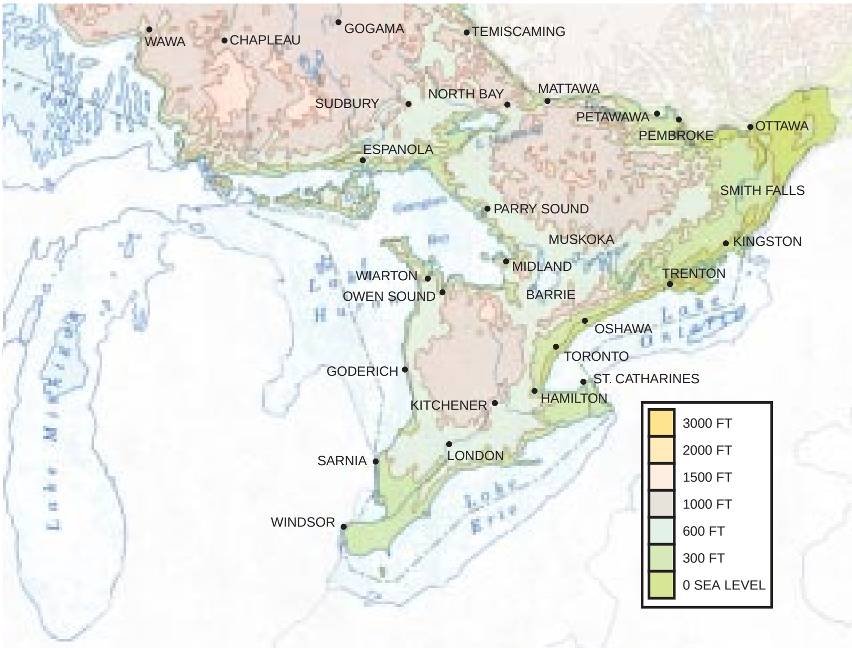
Rising gently from Hudson Bay and James Bay, the lands of northern Ontario form a broad drainage basin known as the Hudson Bay Lowlands. The Severn and Winsk Rivers flow northeastward across the lowlands into Hudson Bay, while the Ekwan, Attawapiskat, Albany, Missinaibi, and Abatibi flow into James Bay. Almost flat, there is little variation in elevation to the terrain across this region. A narrow band of flat treeless tundra rims the lowlands northern boundary with Hudson Bay, blending into boggy low terrain, or muskeg dotted with short sparse conifers that become progressively taller and more widespread to the south. The lowlands extend roughly 100 to 200 miles inland, gradually transitioning into the more rugged elevated terrain of the Canadian Shield.

The Canadian Shield, an enormous exposed outcropping of Precambrian rock, arcs across the bulk of northern Ontario, sweeping from the northwest south of the Hudson Bay lowlands, around the Great Lakes, and eastward to form the Laurentian Mountains of southern Quebec. This upland region is pitted with a maze of innumerable lakes and covered in needle leaf forest that gradually gives way to taller trees and more broadleaf species across the south.

While relatively low in elevation over northwestern Ontario near the Manitoba border, the Canadian Shield rises to the southeast, reaching heights just over 2,200 feet ASL near the Wisconsin border, west of Thunder Bay. This rugged higher terrain divide undulates as it arches eastward around the north of Lake Superior, Lake Huron, and Georgian Bay. Approximately 50 nautical miles north of the city of Sudbury, in Lady Evelyn-Smoothwater Provincial Park, it reaches its highest point, and also the highest elevation in Ontario, at 2,275 feet ASL, then falls away to the east and the Ottawa River Valley.

The Ottawa River Valley, oriented northwest to southeast from Lake Timiskaming through to the city of Ottawa, cuts deeply into the Canadian Shield and marks a political boundary between Ontario and Quebec. To the west of the Ottawa River Valley, the higher terrain of the Shield falls slowly southeastward to the Mattawa River, then rises again forming a broad roughly triangular outcropping of ridges and lakes set to the east of Georgian Bay and north of Lake Ontario. Geologists refer to this section of the Canadian Shields as the Frontenac Axis. It divides the Saint Lawrence lowlands to the southeast of the Ottawa River, from the Great Lakes lowlands to the southwest. Within the northern half of this region lies Algonquin Park.

Southern Ontario



Map 3-3 - Southern Ontario

South of Ottawa, the Ottawa River Valley fans out in low rolling hills that ease into the still broader, more gently sloping lowlands of the upper St. Lawrence River Valley of southeastern Ontario. The state of New York borders the southern shore of the St. Lawrence and, still farther south across the river valley, the terrain rises to meet the Appalachian Mountains. Near Kingston, at the eastern end of Lake Ontario, the river channel broadens, cutting through a low section of the Canadian Shield, leaving a collection of outcroppings known as the Thousand Islands. An irregular series of low prominences, bays and channels mark the northern shoreline of Lake Ontario, between Kingston and Trenton. The shoreline then becomes more regular, with inland terrain rising gently across rolling hills of glacial moraine. The most prominent of these, known as the Oak Ridges Moraine, extends roughly from a point just northwest of Trenton to the city of Caledon, just northwest of Toronto. Beyond the crest of the western end of the Oak Ridges Moraine, the lands slopes more gently downward toward Lake Simcoe, then across a rolling plain north of Barrie, to the southern shores of Georgian Bay.

A most prominent feature of the Great Lakes Lowlands is the Niagara Escarpment. A line of limestone cliffs rimming the edge of the Escarpment extend from Niagara Falls, just south of St. Catharines and Hamilton, northward across the Bruce Peninsula to the Manitoulin Islands in Lake Huron. The southern third of the escarpment area forms a gently rolling plain, sloping south and southwest toward Lake Erie and Lake St. Clair. The bulk of the northern part of the escarpment slopes westward toward Lake Huron.

Quebec

Nunavik

Map 3-4 - Nunavik

The vast territory of northern Quebec is now known as Nunavik. It covers an area of more than 217,000 square miles, which extends from the eastern shore of Hudson Bay, to the Quebec/Labrador border in the east, and from approximately 55°N in the south to the Hudson Strait in the north. Lake-studded plains share the territory with mountainous terrain. The latter is mostly concentrated on the Ungava Peninsula, along large rivers, along Ungava Bay, and in the Torngat Mountain Range. Villages are dispersed along the coastline, separated by distances averaging 60 nautical miles. Another geographical feature of note is the tree line, which extends from Flat Point (approx 50°N 69°W), to the northern shore of Lac À L'Eau Claire, then to the southern shore of Guillaume-Delisle Lake.

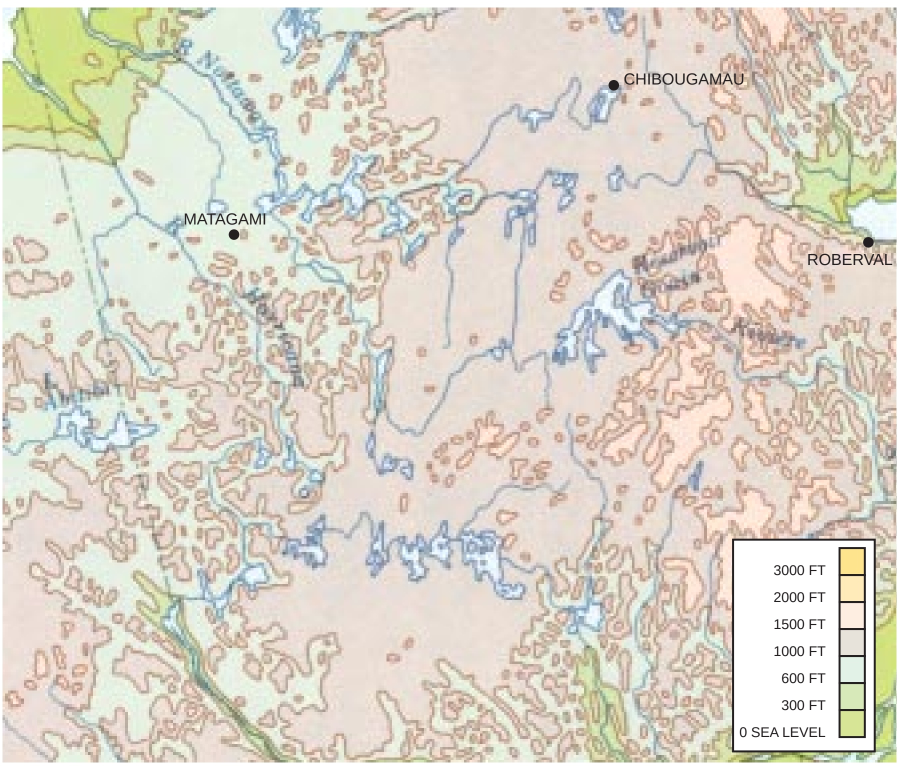
James Bay and Matagami - Mistassini Area

Map 3-5 - James Bay and Matagami - Mistassini Area

The James Bay region includes, on one hand, the eastern shoreline of James Bay, and, on the other hand, the flat landscape to the east, where vast hydroelectric reservoirs and large dams can be found along two of the largest rivers: the "La Grande" River and the Eastmain River. Just to the west of La Grande Airport, there is a sharp drop in topography, which varies between 500 and 1,000 feet ASL. East of La Grande Airport, the land rises slowly and gradually. To the south of Eastmain River, toward its head, there is a small mountain range called the Otis Range. This mountain range is oriented in a southwest to northeast line, with its highest peak culminatingat 3,725 feet ASL.

Marshland can be found to the south of James Bay. The land rises slowly toward the south and the east. At the head of the Nottaway River, Lake Matagami can be found, with the Matagami village and airport just to the southwest of the lake. Farther to the east, there is a series of lakes, in the midst of which lies the Chibougamau airport. To the northeast of Chibougamau, is one of the largest lakes in the province of Quebec, Lake Mistassini. Around Chibougamau, the land is relatively flat with scattered hills but the airport is surrounded by several hills, the highest being 1,950 feet. The terrain becomes rugged and desolate to the east of Lakes Mistassini and Chibougamau, carved by rivers flowing in canyons toward Lake Saint-Jean. There is one hydroelectric dam set at the mouth of Lake Peribonca, with a private airfield named Chute-des-Passes. To the northeast, the White Mountain Range peaks at 3,400 feet ASL. The White Mountains are surrounded by the “Riviere des Montagnes Blanches” to the west, the Manouanis River to the south, the Outardes River to the east, Pletipi Lake to the northeast, and the “Lac aux Deux Decharges” to the north. The area is rugged with very narrow river valleys.

Northwestern Quebec



Map 3-6 - Northwestern Quebec

This vast area starts at the Ontario border and goes to the west of Lake St-Jean basin. It includes the Abitibi, Temiskaming, Upper Laurentians, Mauricie and the

Gouin Reservoir areas. Most of the region is part of the Canadian Shield and resembles a ridge. Elsewhere, the terrain is mountainous, extending to the city of Gatineau, and almost reaching Montreal. It is covered with lakes and rivers, with narrow valleys. Terrain elevations generally vary between 1,000 to 2,000 feet, with the highest elevation, 3,175 feet, in the St-Jovite area.

Saguenay River Valley, Lake Saint-Jean, Laurentides Wildlife Reserve, and Mount Valin Highlands

Map 3-7 - Saguenay River Valley, Lake Saint-Jean, Laurentides Wildlife Reserve, and Mount Valin Highlands

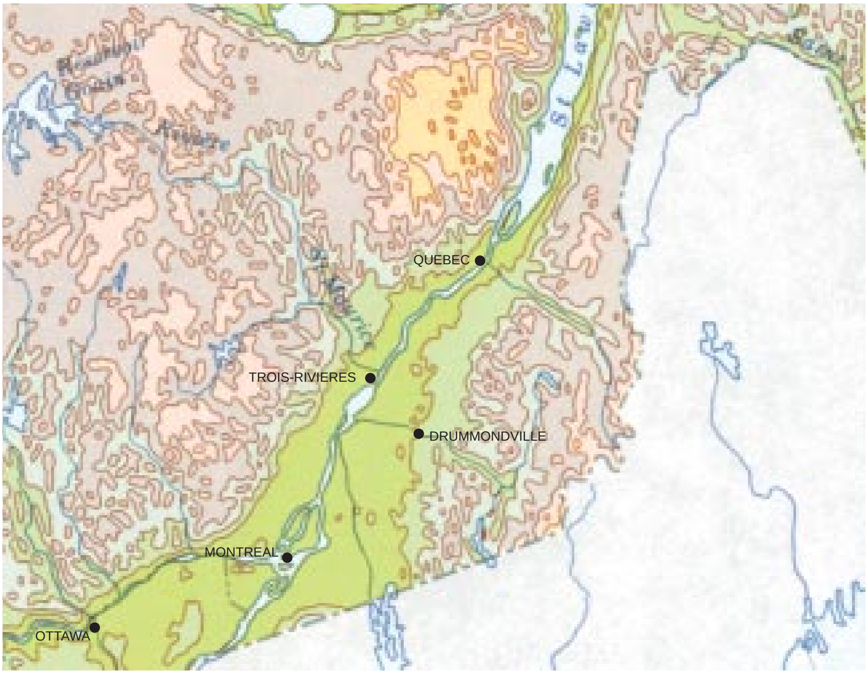
Lake Saint-Jean and the upper half of the Saguenay River are surrounded by farmlands in a valley, nestled in the Canadian Shield. There are approximately 300,000 inhabitants living in this region. Lake Saint-Jean is a large lake (26 nautical miles long and 17 nautical miles wide) with many tributaries coming from the surrounding mountains. The lake is shallow, however, and usually freezes in early December. The valley forms an asymmetrical funnel, oriented in a west-southwest to east-southeast direction. To the east of Chicoutimi, the river widens and deepens, while the valley narrows rapidly. The lower third of the Saguenay River is nested in a steep-sided canyon carved into the Canadian Shield. The geography of this portion of the river is very similar to Scandinavian fjords and, for this reason, the lower tier of the Saguenay River is usually called "Saguenay Fjord."

The section of the Canadian Shield, which lies between the Saguenay River and

Quebec City, is now known as the "Laurentides Wildlife Reserve." It also used to be called the "Laurentides Park". The area is rugged with peaks up to 3,825 feet ASL, rivers, and a multitude of lakes. The tops of the mountains have been rounded by erosion and, in many sections of the Reserve, the forests have been harvested, exposing the granite rock underneath. The section of the Shield, which forms the north shore of the Saint Lawrence River between Beaupre and the mouth of the Saguenay River, is known as "Charlevoix."

The section of the Canadian Shield lying to the north of the Saguenay River is known as the Mount Valin Highlands. Mount Valin, which gives its name to the area, is the highest peak at 3,548 feet ASL and lies close to the Saint-Honore Airport, along the southwestern edge of this mountainous terrain. The topography of the Mount Valin Highlands is similar to the Laurentides Wildlife Reserve. The most rugged terrain continues toward the northwest, up to the Nestaocano River, although the average elevation diminishes.

St. Lawrence River Valley

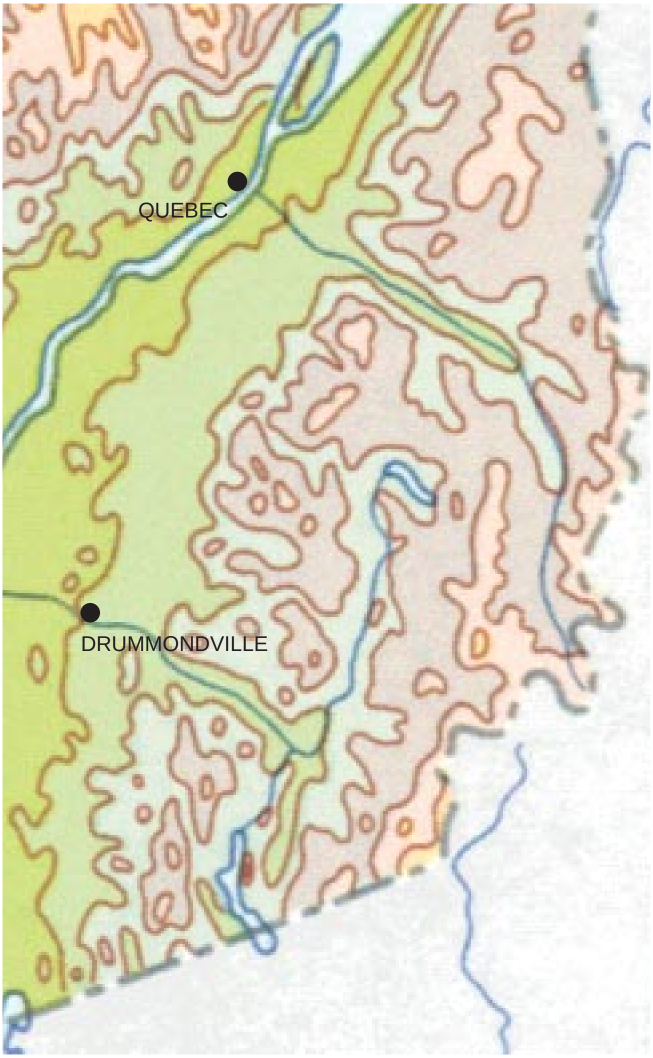


Map 3-8 - St. Lawrence River Valley

The St. Lawrence River has a southwest to northeast orientation from Lake Ontario to where it originates in the Gulf of St. Lawrence. The valley is wide near the Ontario-Quebec border and narrows toward Quebec City. Further east, the width of the valley remains almost constant, although the river itself widens gradually as it flows downstream. The section of the Saint Lawrence River between the Isle of Orleans and Tadoussac is often called the "middle estuary", while the section between Tadoussac and Pointe-des-Monts is usually called the "maritime estuary." Both sections combine to form the "Saint Lawrence Estuary", one of the longest (215 nautical miles) and one of the deepest (from approximately 160 feet near the Isle of Orleans to 300 feet just west of the Saguenay River, and 1,150 feet from then on) in the world. Its width goes from one nautical mile, in the west, to 27 miles by the time it reaches the Gulf. Exposed to northeasterlies, amongst the predominant winds, the Estuary acts as a funnel and, under the right conditions, wind speeds in excess of 60 knots have been reported. Due to its depth, high salt content, and frequent occurrences of high winds, the Estuary takes a long time to freeze over. It usually takes an outbreak of very cold arctic air for at least a week. Any onset of mild temperatures and strong southwesterlies often results in the ice breaking up.

The Canadian Shield bounds the St. Lawrence River Valley to the north. In the Montreal area, the land rises rapidly, but gradually, toward the Shield. This area is generally called the Lower Laurentian Highlands. By the time the river reaches Quebec City, the Canadian Shield gets very close to the rivers northern shore, then it hugs the shore further to the east. South of the river, however, the land remains flat for a good distance, and then the ground rises gradually until the Appalachian Mountains foothills are reached, where the land rises sharply and where the valley ends. Although the slope is gentler to the south, some rivers, like Chaudiere, flow in deep and narrow gorges. The St. Lawrence River dominates the valley and some of its tributaries, like the north - south Richelieu River, the Yamaska, the Saint-Maurice, and the Chaudiere River.

Eastern Townships and Beauce



Map 3-9 - Eastern Townships and Beauce

The Eastern Townships and the Beauce regions are located to the south of the Saint Lawrence River Valley, along the Canada-United States border. Both of these contiguous regions straddle the Appalachian Mountains foothills. The highest hill, Mount Megantic, peaks at 3,640 feet ASL. The largest lakes and most important rivers are deeply encased by mountains. Furthermore, rivers in these two regions flow to the north and are prone to ice jams and flooding in the spring.

Mean Atmospheric Circulation

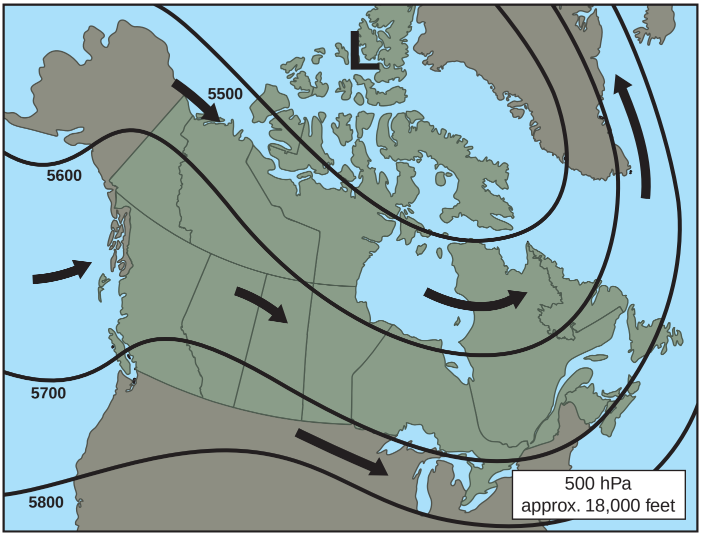


Fig. 3-1- Mean Summer Upper Winds

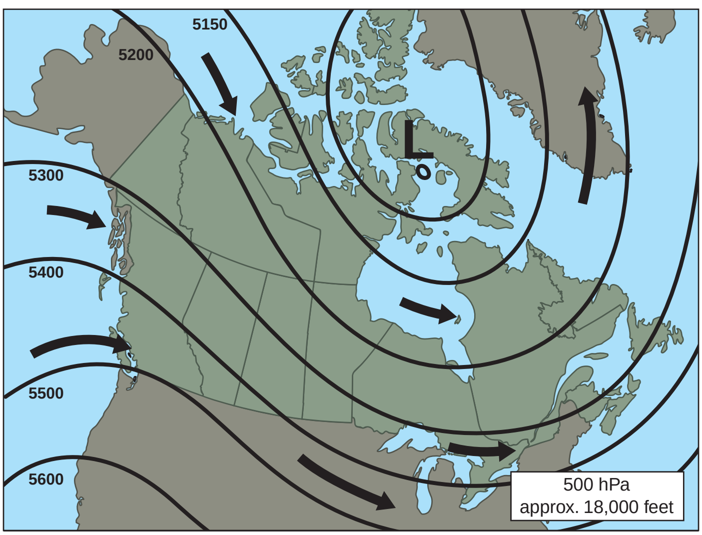


Fig. 3-2 - Mean Winter Upper Winds

The mean atmospheric circulation over Ontario and Quebec is from west to east, but shows a distinct seasonal shift. A good indicator of this shift can be seen in the jet stream, a relatively rapid flowing ribbon of air embedded in the general circulation, generated by temperature differences along the boundary between polar and tropical air masses. During the summer months, as polar air begins to retreat, the jet stream weakens and migrates northward, oscillating between 45 and 60 degrees north latitude. The mean position of the jet stream parallels the mean summer circulation pattern of the upper atmosphere, as it arcs gently northward from the Pacific to the central Prairies, then southward across Ontario and Quebec.

In winter, the polar air mass deepens, the temperature gradient between polar and tropical air increases, and the jet stream migrates southward and strengthens. Upper level winds in winter can be as much as 60 percent stronger than in summer months. The jet stream arcs sharply northward over the west coast, southward across the Prairies and eastern Canada, sometimes dipping as far south as Florida. The large-scale trough created in the mean flow over eastern Canada during the winter months contributes to the development of surface pressure systems that move across Ontario and Quebec.

Upper Troughs and Upper Ridges

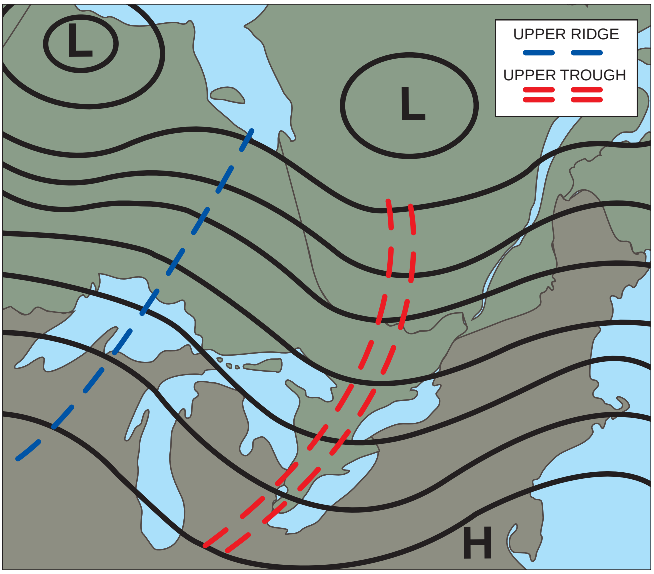


Fig.3-3 - Typical winter pattern with upper troughs and ridges added

The most common features moving in the upper flow are upper ridges and upper troughs. Upper ridges are usually associated with good or improving weather conditions, while upper troughs are usually associated with weather that is poor or deteriorating.

That being said, the position of the upper ridge plays a significant role on the impact it has on weather. When an upper ridge lies in the path of a low, it may force the approaching system to be deflected to the north or south. The air mass beneath the ridge may become stagnant, with light winds at all levels causing air pollutants to linger, producing haze. Upper ridges often bring periods of dry weather, leading the way for sunny skies and hot temperatures in summer or sunny days, and clear cold nights in winter.

Semi-Permanent Surface Features

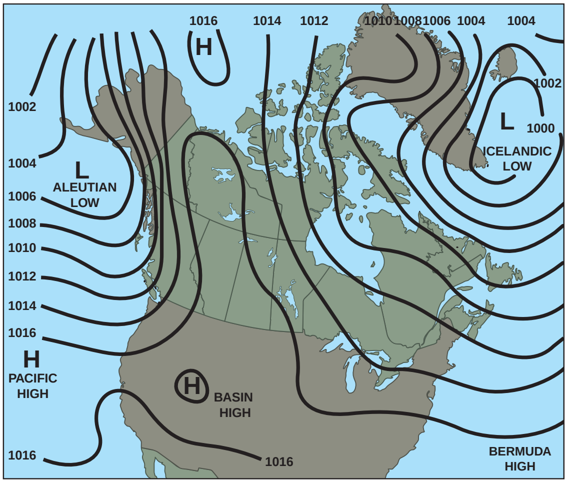


Fig. 3-4 - January mean sea level pressure

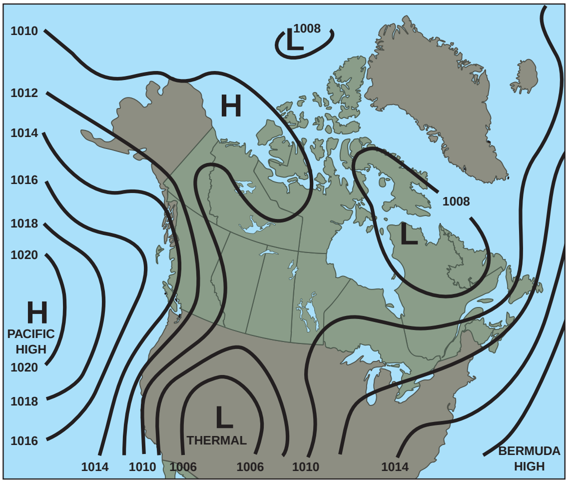


Fig. 3-5 - July mean sea level pressure

An examination of the average sea level pressure distribution over a number of years reveals the presence of relatively fixed features in the winter and summer pressure patterns. One of these is the Icelandic low located near or just west of Iceland. It is commonly associated with a trough of low pressure extending from Scandinavia southwestward to the Davis Strait. Migratory low-pressure systems, deepening and moving northeastward in the north Atlantic, eventually occlude, decelerate significantly, and may become almost stationary for extended periods of time. They account for the presence of the Icelandic Low, a semi-permanent area of low pressure, much deeper and more extensive in the winter than the summer.

The Bermuda High, or Azores High, on the other hand, is a semi-permanent area of high pressure elongated along an east-west axis near 35ºN. During the winter, it weakens and shifts eastward to lie near the Azores. Drifting westward and becoming more prominent in its summer position near the Bahamas, this feature plays a significant roll in directing occasional surges of humid tropical air northeastward, across the eastern seaboard into southern Ontario and Quebec.

Migratory Systems

The semi-permanent features seen in the mean surface patterns discussed above are in essence composites arising from the common and frequent motion of individual low and high pressure systems. Low-pressure systems can be classified as extra-tropical (systems originating over the mid-latitudes) and tropical (those that develop near the tropics). Of these, it is the extra-tropical lows that most frequently and significantly impact the GFACN33 region. The majority of these lows develop in areas well to the west or southwest and, steered by the upper flow pattern, track east or northeastward into Ontario and Quebec. Less common, and usually less severe, are storms arriving from the southeast that began over the Atlantic Ocean and moved inland losing much of their moisture and energy.

Passage over the Great Lakes or Hudson Bay can re-energize migratory systems, but eventually they slow and continue to occlude. Infrequently, they may even "retrogress" (move slowly westward).

Winter Storms

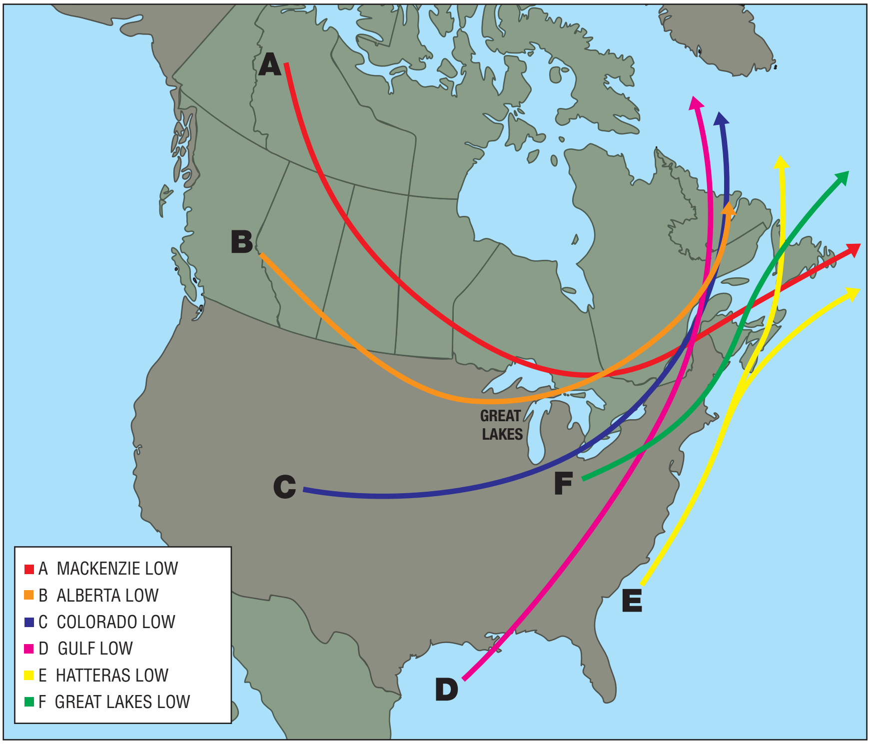


Fig. 3-6 - Winter storm tracks

More frequent and usually more intense than their summer counterparts, due to the strong winter temperature gradient between northern an southern latitudes, winter storms favor some locations for their formation and development. Moving along one of several common storm tracks, these systems frequently generate broad areas of cloud, snowfall, rain, high winds and, at times, freezing precipitation. Winter storms produce some of the worst flying conditions across the GFACN33 region.

Summer Storms

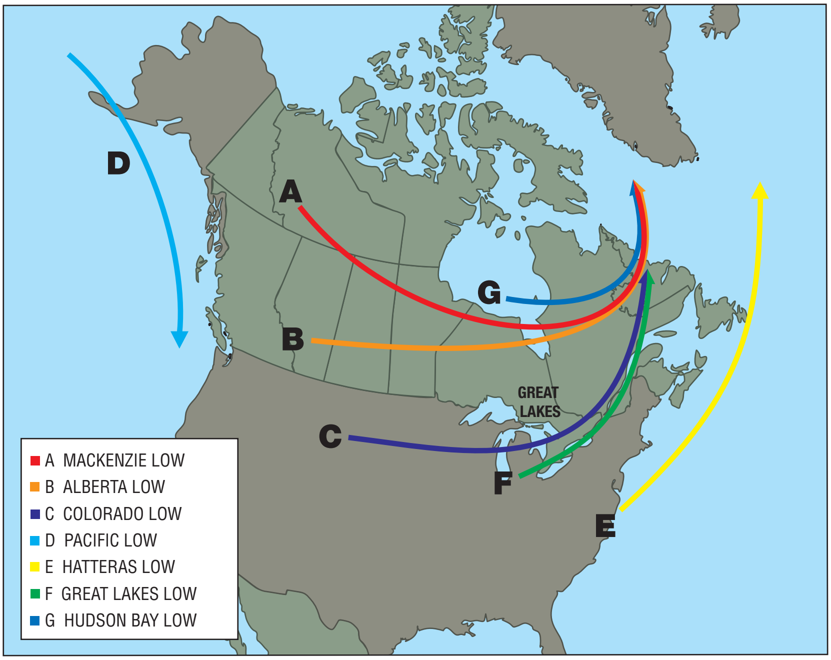


Fig. 3-7 - Summer storm tracks

With the approach of summer, the polar air mass becomes shallow and begins to retreat northward and, correspondingly, the severity and frequency of extra-tropical storms declines.

Alberta Lows (Alberta Clipper)

The Alberta Low forms to the lee of the Rocky Mountains in Alberta. Moving along a southeasterly track, this low often dips into the Plains of the northern US during the winter months, eastward across the Great Lakes, southern Ontario, Quebec and on to the north Atlantic. During the summer months the storm track shifts northward. The point of origin remains to the lee of the Rocky Mountains in Alberta, however, the lows tend to move eastward across the Canadian Prairies, northern Ontario and northern Quebec.

Alberta Lows, while not generally associated with heavy precipitation, are sometimes invigorated by an inflow of relatively warm moist air moving up the Atlantic seaboard. Under such conditions, these storms can then rapidly intensify, bringing heavy winter snowfall to southern Ontario and Quebec.

Colorado Lows

These lows develop to the lee of the Rocky Mountains, frequently forming over southern Colorado, during the winter, and somewhat farther north during the summer. They tend to track northeastward, intensify over the Great Lakes, and can bring heavy snowfalls and strong winds as they continue eastward across southern Ontario and Quebec. Colorado lows may also track eastward across the US, diminishing in strength then re-develop over the warm waters of the Gulf Stream, becoming Hatteras Lows that then track northeastward into the Maritimes.

Great Lakes Lows

The Great Lakes are yet another area of development for low-pressure systems. Acting as a reservoir, the lakes transfer stored heat and moisture into the lower atmosphere. Under favorable conditions, a thermal trough or thermal low will form and last for days, due to the effect of cold air over warm water. This may be enough to initiate the formation of a new low or serve to intensify a passing system. Lows forming over the Great Lakes tend to be less vigorous than their Atlantic counterparts but can still generate a significant amount of cloud, precipitation and strong gusty winds. Upon development, Great Lakes lows most frequently follow one of two routes, either wrapping northeastward across eastern Ontario, Quebec and Labrador, or a more easterly course to the Atlantic, where they may re-intensify off the east coast of the United States.

Hudson Bay Lows

Lows developing or re-forming over Hudson Bay frequently migrate eastward across Quebec and Labrador. They tend to be less intense than Great Lakes lows, affect mainly the northern areas and can occur in both summer and winter. In winter, the air mass associated with these systems is usually very cold and dry, allowing areas of low ceiling and visibility to improve rapidly in their wake. Much more moisture is available to the lower atmosphere during the summer, allowing areas of low cloud and showers to become more widespread and linger well after the low has left the region.

Polar Lows

By definition, the Polar Low is a small scale, but often intense, maritime cyclone ranging in size from 60 to 600 nautical miles across, carrying surface winds in excess of 30 knots. These lows form over coastal waters during outbreaks of very cold arctic air, where the air-sea temperature difference exceeds 20 degrees Celsius. Found most frequently over the Labrador Sea, but also forming over Hudson Bay, mature Polar Lows can give poor visibility in heavy snow showers, strong shifts in wind direction, occasional lightning and severe aircraft icing. They are difficult to forecast, since they mature rapidly over open water then quickly dissipate upon moving over ice or land, and frequently last less than 24 hours.

Hatteras Lows (or Eastern Seabord Bombs)

Hatteras Lows develop just off the coast of Cape Hatteras, North Carolina. Here, the Gulf Stream, a warm water current, hugging the coastline up to that point starts moving off toward the northeast, eventually reaching the Shetland Islands, off Scotland. In winter, when very cold arctic air pushes south into the Southeastern American states, a strong temperature gradient develops off the Carolina coast, thus generating fast moving and fast developing weather systems. These Hatteras Lows move very rapidly north along the American seaboard and, as they deepen so quickly, they are generally referred to as “bombs”. These lows can follow either one of two typical trajectories: they either move over Nova Scotia and Newfoundland or they can move across New England, Quebec Eastern Townships, toward Ungava Bay. Like the Polar Lows, these storms are difficult to forecast.

Highs

During the winter months, cold domes of polar air form areas of high pressure, or anti-cyclones, over the northern continental regions. From time to time, this very cold arctic air mass will flow southeastward across Ontario and Quebec, clearing skies and bringing chilling temperatures in the wake of transient low-pressure systems. Gradually shifting southward, these cold highs tend to persist with greater frequently over the Quebec region during the mid-winter months, a time when the semi-permanent Bermuda High, so dominant throughout the summer, has shifted south-eastward to lie near the Equator. In the summer months, the Bermuda High migrates northwestward to lie over the island for which it is named, and builds toward North Carolina. The polar air masses gradually retreat from Ontario and Quebec, replaced by warmer air out of the southwest and, at times, hot humid tropical air masses with origins in the Mexican Gulf. The path of highs, or anti-cyclones, across Ontario and Quebec shows a corresponding northward shift during the summer months.

Tropical Depressions, Tropical Storms and Hurricanes

From late summer to early fall, tropical cyclones, named after their place of origin in the tropical latitudes, migrate westward with the trade winds, accelerate in a northward arc off the east coast of North America and weaken as they begin to encounter the cooler waters of the North Atlantic. These Atlantic Ocean systems, broadly termed tropical cyclones, are referred to as “tropical depressions” when sustained winds achieve 20 to 33 knots, “tropical storms” when sustained winds reach 34 to 63 knots, and “hurricanes” when sustained winds attain or exceed 64 knots. Having reached hurricane strength, a storm is classified according to the Saffir-Simpson scale (see Glossary).

Statistics tell us that, on average, one tropical storm can be expected to reach Quebec every 6.6 years and Ontario every 11.1 years. These low numbers reflect the fact that most tropical cyclones gradually enter the decaying stage of their life cycle as they move northward, leaving the warm (at least 26° C) tropical waters of their origin. Having made landfall and begun to move inland, the cyclone's source of energy is removed and further decay of the system is accelerated due to frictional drag with the earth's surface. Often no longer visible as a feature on the weather map, the dissipated energy of these storms may continue to move through the atmosphere, with very moist tropical air generating heavy rainfall on the surface and strong winds persisting aloft.

Tropical storms and hurricanes present a subject of continuing scientific interest and research. To this end, regular data reconnaissance flights are fully planned and carefully executed. However, with practically every known aviation weather hazard present within these storms, they are clearly not the place for general or commercial aviation. In addition, precautions for strong winds and heavy precipitation are advisable for aircraft on the ground.

Cold Lows

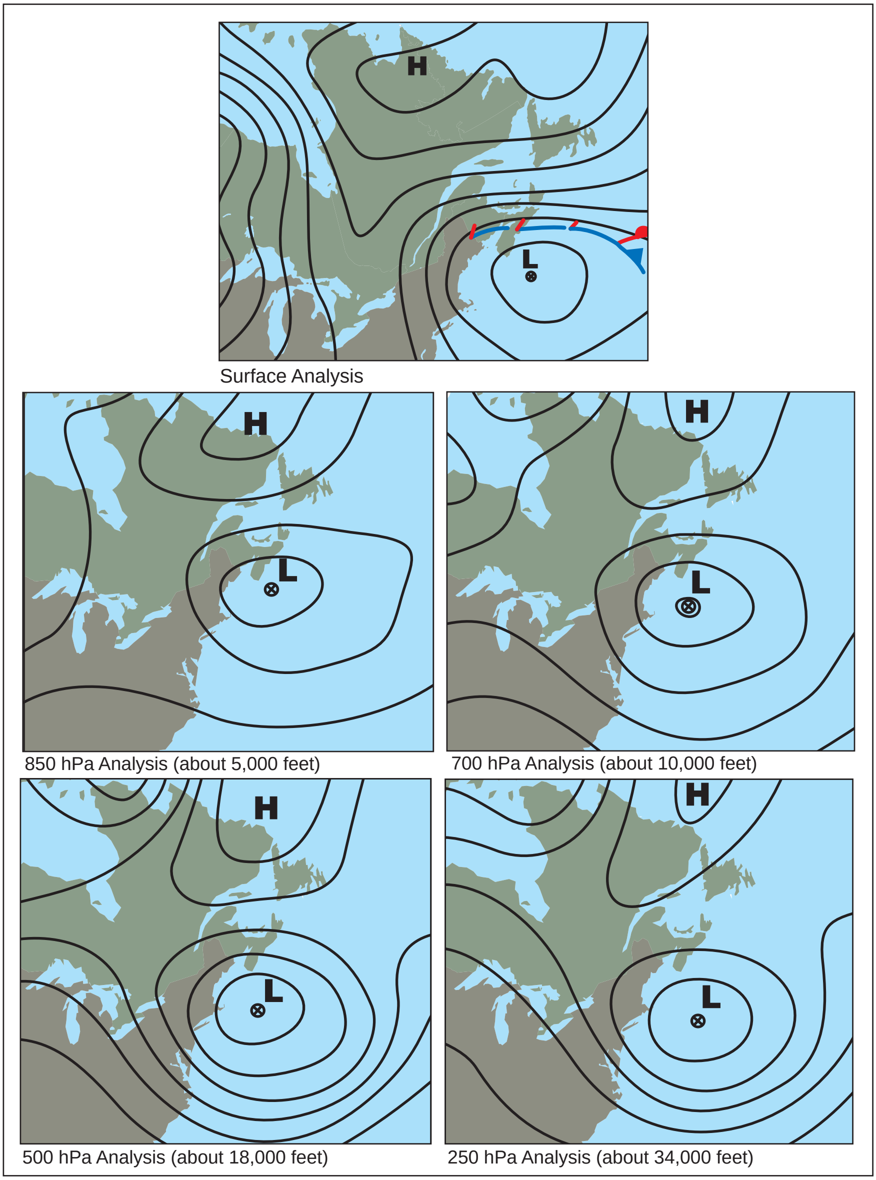


Fig. 3-8 - Typical MSL surface and upper cold low pattern.

The term cold low or "cut-off low" refers to a final stage of development in the lifecycle of a low-pressure system, but this stage is not reached by all storms. Occurring at any time of the year, they tend to develop more frequently over the northern latitudes in summer and southern latitudes in spring. They are often difficult to forecast, typically approaching along the common storm tracks out of the southwest, and look much like any other low, until becoming “cut-off” from the prevailing upper circulation.

Cold lows may or may not produce recognizable centres of low pressure at the surface; therefore they are more easily identified on upper charts where they take on a circular appearance, forming a column through the atmosphere in which temperatures become colder toward a central core. Once formed, cold lows tend to be persistent, moving slowly or lingering in one location for prolonged periods of time. The cool and unstable air mass with which they are associated often generates broad bands of cloud, embedded convection, and precipitation, culminating at times in thunder-showers. For this reason, cold lows are favored locations for the development of aircraft icing, particularly throughout the northeast quadrant of the low, where enhanced lift usually produces thicker cloud and more widespread steady precipitation.

Seasonal Migratory Birds

Indirectly associated with seasonal changes in weather, large flocks of migratory birds fly across the GFACN33 region. Impact with birds can present a serious hazard to aviation. A four-pound bird striking an aircraft traveling at 130 knots exerts a localized force of more than 2 tons. An aircraft traveling at 260 knots and hitting a bird of the same size would receive a localized force of 9 tons.

Spring

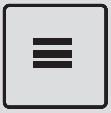
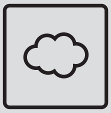
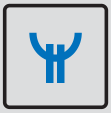
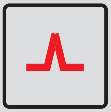
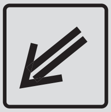
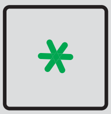
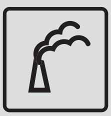
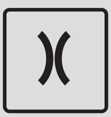
Normally, migratory birds leave their staging areas between dusk and midnight, and during the first three hours after dawn: however, they may leave at any hour of the day or night, particularly after long periods of poor weather. They will not leave a staging area against surface winds in excess of 10 knots. Major movements, involving hundreds of thousands of birds, often follow the passage of a ridge of high pressure.

Autumn

Geese, swans and cranes normally move south with favourable winds. They depart from staging areas 12 to 24 hours after the passage of a cold front, especially if there is rapid clearing and there are strong northerly winds behind the front. The birds take off from the staging areas in the late afternoon for night flights. Occasionally, however, they may fly by day as well.

Notes

Table 3: Symbols Used in this Manual

	**Fog Symbol (3 horizontal lines)** This standard symbol for fog indicates areas where fog is frequently observed.
	**Cloud areas and cloud edges** Scalloped lines show areas where low cloud (preventing VFR flying) is known to occur frequently. In many cases, this hazard may not be detected at any nearby airports.
	**Icing symbol (2 vertical lines through a half circle)** This standard symbol for icing indicate areas where significant icing is relatively common.
	**Choppy water symbol (symbol with two wavelike points)** For float plane operation, this symbol is used to denote areas where winds and significant waves can make landings and takeoffs dangerous or impossible.
	**Turbulence symbol** This standard symbol for turbulence is also used to indicate areas known for significant windshear, as well as potentially hazardous downdrafts.
	**Strong wind symbol (straight arrow)** This arrow is used to show areas prone to very strong winds and also indicates the typical direction of these winds. Where these winds encounter changing topography (hills, valley bends, coastlines, islands) turbulence, although not always indicated, can be expected.
	**Funnelling / Channelling symbol (narrowing arrow)** This symbol is similar to the strong wind symbol except that the winds are constricted or channeled by topography. In this case, winds in the narrow portion could be very strong while surrounding locations receive much lighter winds.
	**Snow symbol (asterisk)** This standard symbol for snow shows areas prone to very heavy snowfall.
	**Thunderstorm symbol (half circle with anvil top)** This standard symbol for cumulonimbus (CB) cloud is used to denote areas prone to thunderstorm activity.
	**Mill symbol (smokestack)** This symbol shows areas where major industrial activity can impact on aviation weather. The industrial activity usually results in more frequent low cloud and fog.
	**Mountain pass symbol (side-by-side arcs)** This symbol is used on aviation charts to indicate mountain passes, the highest point along a route. Although not a weather phenomenon, many passes are shown as they are often prone to hazardous aviation weather.

Chapter 4

Regional Weather and Local Effects

Introduction

This chapter delves into the local weather hazards and effects that are commonly observed in the GFACN33 area of responsibility. Listed here are the most common and verifiable weather hazards identified through extensive discussion with weather forecasters, FSS personnel, pilots and dispatchers.

While most weather hazards are described simply by applying symbols to the accompanying maps followed by brief sections of text, some of the more complex weather phenomena are detailed more fully. Table 3 provides a legend for the various symbols used throughout this chapter.

Map 4-1 - Topographic overview of the GFACN33 Domain

Ontario

(a) Summer

Summer offers some of the best flying weather as it brings a decrease in both the number and intensity of storms affecting the GFACN33 domaine. The upper winds diminish in strength, air masses tend to linger and weather in general becomes more persistent. Tropical air masses do make regular intrusions into southern Ontario during the summer. They often bring high temperatures, humidity and afternoon thunderstorms.

Thunderstorms are more prevalent in the south, occurring on average 25 days each year, often triggered by the passage of a cold front in the spring or summer. That number rises to as many as 35 days per year in the corridor through Windsor and London, in southwestern Ontario. Some of the worst thunderstorms, mainly those in the southwest, may be accompanied by tornadoes. Thunderstorm numbers drop to the north, falling to 5 days or less along the shores of Hudson Bay.

Prevailing winds tend to be light in summer and generally they flow out of the southwest. Land and lake breezes are common around the shores of the Great lakes, blowing off the water during the day and off the land at night.

Haze, formed from high concentrations of aerosol and particulate pollutants, is a chronic problem in the summer. With the airmass being cooled from below by the Great Lakes, a haze trapping inversion forms. This haze layer can extend as high as 8,000 feet ASL and lower the visibility to 2 to 3 statute miles.

Summer fog is more common across northern Ontario than in the south, where the foggiest season is the fall and winter. Fog tends to form during the early morning hours with light winds and nighttime cooling of the land. Later in the season steam fog forms over lakes blanketed by cold dry air.

With the approach of fall, the number and vigor of migratory low pressure systems begins to increase, as the region lies in the path of one of the North America's major storm tracks. At this time of year, it is not uncommon for remnants of tropical hurricanes to push northeastward up the Atlantic coast and affect southern and central Ontario with strong winds and periods of moderate or heavy rain. Across the north, where summers are shorter, fall brings colder temperatures and eventually the first accumulations of snow.

(b) Winter

As winter settles in, prevailing winds begin to shift to northwest. The storm track moves southward to lie across the Great Lakes and storms further increase in both frequency and strength. At the same time, cold, dry, Arctic air moves into the northern sections of the domain and makes periodic intrusions into the south, modified by passage over the warmer waters of the Great Lakes.

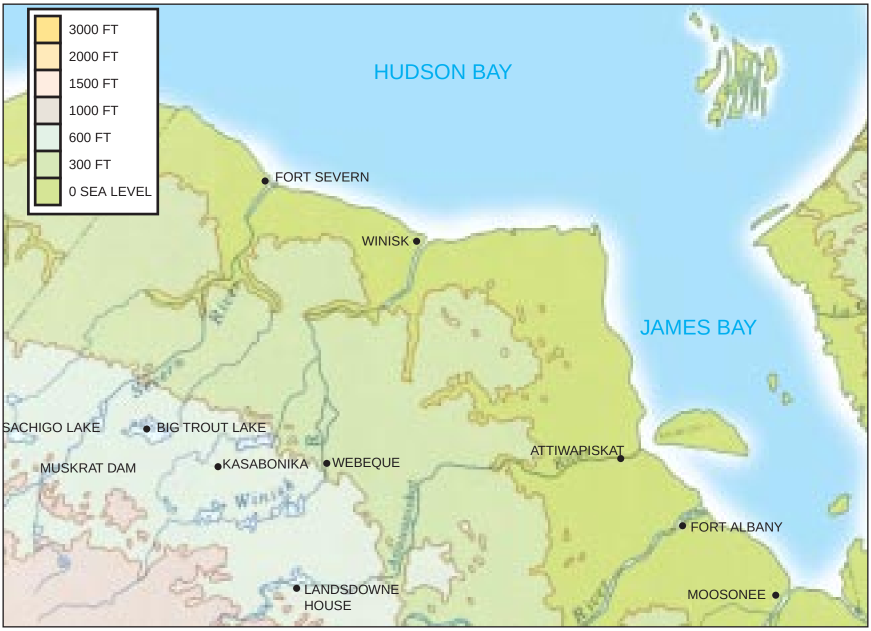
Fog occurs more frequently in the central areas of Ontario, during the fall and winter, than in the north or south. Sudbury and North Bay respectively average 69 and 63 days of fog per year. Locations like Red Lake and Pickle Lake in the northwest average close to 15 days, while 35 days of occurrence are typical across the of south. In spring, fog will sometimes form over lakes, as the cold lake waters cool warm moist air passing over its surface. Fog may continue to develop later in the season if there is overturning of colder water from lower depths.

The first snowfalls usually occur in the Winsk and Severn River areas of northwestern Ontario, in late October or early November, and spread across Lake Superior eastward to Sudbury by mid month. Much of southern Ontario, from London through Kingston, receives snowfall early in December and the extreme southwest, near Christmas. Heavy snowbelts occur along the upland slopes of the Canadian Shield facing Lake Huron, Georgian Bay and Lake Superior where cold air, after picking up heat and moisture from long fetches of open water, is forced to rise over the highlands. These lake effect snowbelts also occur in the vicinity of Parry Sound, to the south of Owen Sound, northeast of Sault Ste Marie, near London and along the St. Lawrence River.

Freezing precipitation can occur throughout the winter months but is most often encountered in the early part of the season. Usually developing ahead of an approaching warm front, freezing precipitation can produce some of the most hazardous of icing conditions. Frequency of occurrence is 5 to 10 days per year across the north and up to 20 days per year in the south.

Local Effects

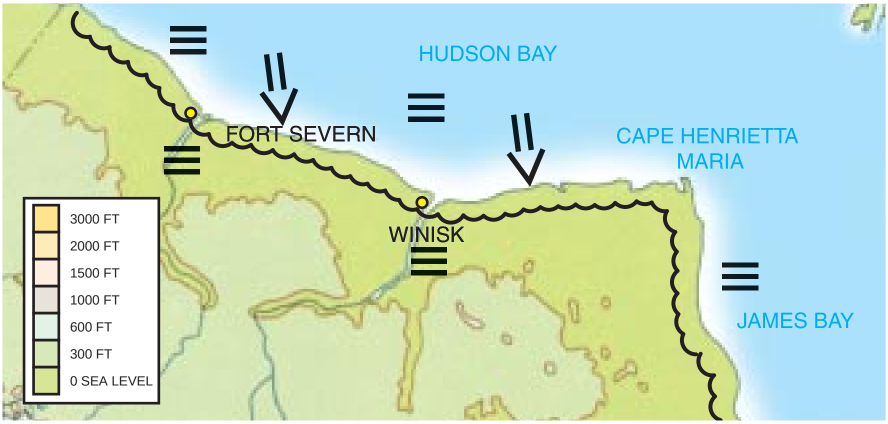
Hudson Bay Coast and Lowlands Fort Severn - Moosonee



Map 4-2 - Hudson Bay Coast and Lowlands Fort Severn - Moosonee

This vast section of the GFACN33 region is one of the most isolated and desolate areas in Canada. The northern coastline of Ontario stretches from the Manitoba border southeastward to Cape Henrietta Maria, south to the mouth of the Attiwapiskat River near Akimiski Island, then southeastward again to the Quebec border on the Ministikawatin Peninsula. A handful of small widely dispersed communities dot the coastline near the mouths of the major rivers which bear their name; Fort Servern, Winisk, Attawapiskat, Fort Albany, Moosonee and Moose Factory.

Fort Severn – Cape Henrietta Maria



Map 4-3 - Fort Severn – Cape Henrietta Maria

This section of coastline and adjacent lowland runs from the Manitoba border east southeastward. Well drained, raised beaches and grass covered tidal flats line much of the coast, which is almost treeless for the first 5 to 10 miles inland from the shore. Further inland, the landscape is relatively flat, with areas of tundra and poorly drained bogs and marshes giving way to sparse trees. The area is home to two small communities, located on the banks of the Severn and Winsk Rivers, just inland from the coast. Prevailing winds across the region are generally from the northwest.

During the summer, when Hudson Bay is ice-free, fog banks and low stratus are common over the cold water. Winds out of the north will often bring these conditions inland causing low ceilings and poor visibility. While fog will sometimes persist along the coastline throughout the day, stratus that has pushed inland will often break up during the afternoon with daytime heating.

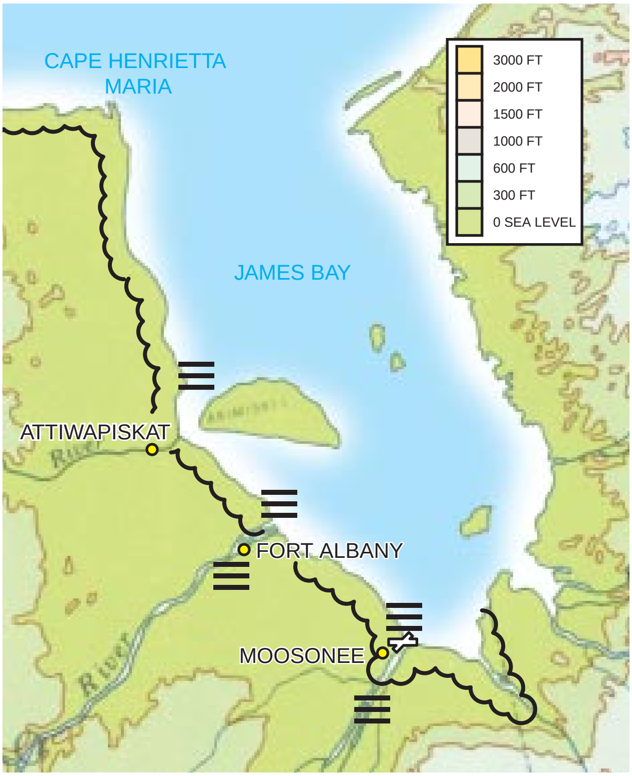
Snow squalls are common during the fall, often developing as cold arctic air (-8°C or less) flows over the open and warmer waters of the Hudson Bay. Ceilings and visibility can be locally reduced to near zero at times in snow squalls, but these conditions are not usually persistent.

During winter, large sections of Hudson Bay begin to freeze over and flying conditions generally improve, as is often the case in January and February. Weather here can change rapidly, however. The passage of frontal systems can bring on periods of snow, strong winds, and sometimes blizzards or whiteout conditions.

Under light winds or in still cold air, ice fog can form and sometimes become persistent near settlements and airstrips, its formation triggered by exhaust from aircraft engines or community chimneys.

With the arrival of longer and warmer days of spring and summer, the last of the ice usually melts off of Hudson Bay by late June or early July.

Cape Henrietta Maria – Moosonee



Map 4-4 - Cape Henrietta Maria – Moosonee

This area of coastline lies along the western side of James Bay. Its sloping shores rise to meet flat, low terrain inland that is sparsely treed within one to five miles of the coast. Farther inland, the landscape gradually becomes more thickly forested and dotted with muskeg and marshes. Several small communities are located near the mouths of the major rivers in the area. They include Attawapiskat, Kashechewan, Fort Albany and Moosonee.

James Bay becomes free of ice between mid June and early July. Summers are short and freeze up generally occurs between mid December or early January. Prevailing winds across the region are generally from the northwest.

Areas of fog and low stratus are common over the cold water waters of James Bay during the summer. Winds out of the northeast will sometimes bring these conditions inland causing low ceilings and poor visibility. Fog will sometimes persist along the coastline throughout the day while stratus that has pushed inland will often break up during the afternoon, with daytime heating.

Snow squalls tend to occur in the fall under a cold north, or northeast, flow over the warmer waters of James Bay. While they can locally reduce visibility and ceilings, they seldom persist for more than a few hours.

By mid winter (January and February) most of James Bay has frozen and, in the absence of open water, flying conditions often improve. Local occurrence of ice fog is not uncommon but, when it does happen, it can be persistent. Ice fog often forms near settlements and airfields where exhaust from aircraft or the moisture from household heating systems can trigger its formation.

Winter weather across this region often changes rapidly, usually with the passage of frontal systems, which can bring periods of snow, strong winds, and sometimes blizzards or whiteout conditions.

Northwestern Ontario

Map 4-5 - Northwestern Ontario

Northwestern Ontario is a vast area, much of which lies on the gently inclining, rocky and forested terrain of the Canadian Shield. A myriad of lakes cover the region and pilots flying it for the first time often find it disorienting, saying that after a period of time "it can all start to look the same." Broad sections of the Shield are also subject to cloud development under conditions of upslope flow and, while much of the terrain is low in elevation, cloud can engulf power lines and communication towers perched atop the higher hills making them difficult to see.

Convective cloud is common in summer and early winter, especially during the afternoon. Pilots have commented that "this is one of the bumpiest regions to fly across on a convective day" and that " the prolonged jostling can be exhausting."

Convection at this time of year is due, in part, to stronger daytime heating and the fact that moisture is readily available from warm open lakes and rivers. The frequency of thunderstorms is generally lower in northern Ontario than it is in the south

Red Lake – Pickle Lake - Sandy Lake – Big Trout Lake

Map 4-6 - Red Lake – Pickle Lake - Sandy Lake – Big Trout Lake

A north or northwest flow is upslope across much of this region, and at Pickle Lake this is also true for winds out of the west. Winds from these directions can often generate broken cloud cover in the absence of larger scale weather systems. This is frequently the case in late summer or early winter when prevailing winds begin to favour the west or northwest and moisture is still freely available from open water. In addition, because of upslope, this region is often slow to clear following the passage of frontal systems under a west or northwest flow.

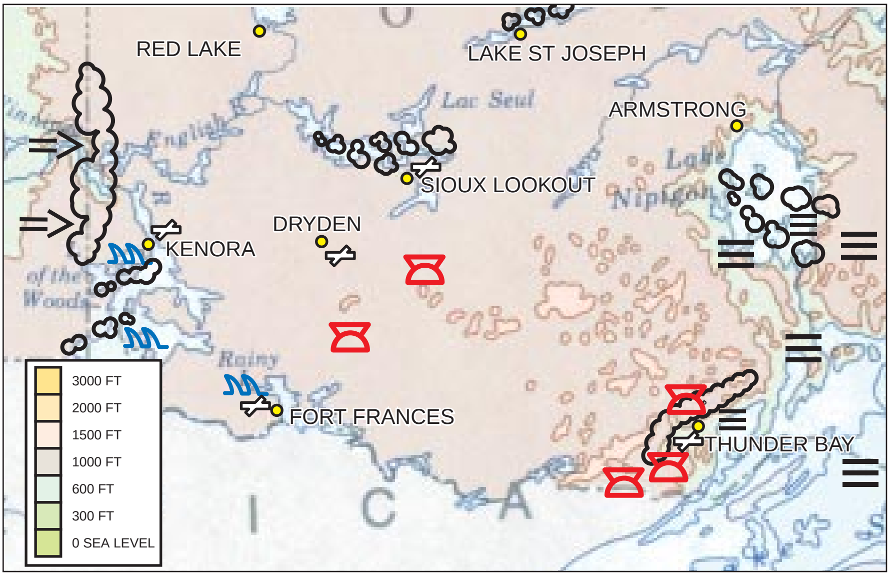
Lake effect convection and precipitation is common to the lee of some of the larger lakes where wind direction favours airflow over longer fetches of open water. This is most pronounced in the late summer and early winter. Lake effect convection can cause marked reduction in local ceilings and visibility, due to showers. Local reports of one half mile to one quarter mile visibility in lake effect snow showers occur relatively frequently and these conditions can persist over several hours.

Thunderstorms, on average, occur 15 to 20 times per season. They commonly develop throughout the summer, peak in frequency during July, and rarely occur outside the period between May and September. Widely spaced air mass thunderstorms are common, however, more organised lines of thunderstorm activity often accompany the passage of cold fronts.

Fog does make an appearance but usually only reduces visibility to less than half a mile 2 or 3 times per month. The occurrence of fog is higher in late summer and early winter while lakes and rivers remain open and much less frequent after freeze up. Radiation fog is the most common, often generating poor visibility within a few hours of sunrise, and rarely lasts until the afternoon. Ice fog will sometimes occur near these communities in the winter, developing from moisture associated with chimney smoke that forms into ice crystals under cold, calm conditions. Aircraft engine exhaust can also quickly trigger local ice fog development and temporarily restrict airport visibility, until ice crystals gradually settle out.

Blowing snow is not a common occurrence but does occur with greater frequency at some of the more exposed sites, like Big Trout Lake.

Kenora – Fort Frances – Dryden -Sioux Lookout – Thunder Bay



Map 4-7 - Kenora – Fort Frances – Dryden -Sioux Lookout – Thunder Bay

The Canadian Shield gradually rises to form a rim, or divide, around the northern shores of Lake Superior. As a result, this section of northwestern Ontario has some of the regions highest and most rugged terrain, reaching elevations of 2,225 feet ASL about 30 nautical miles west of Thunder Bay. Broadly speaking, winds from the southwest through northeast tend to be upslope but, owing to the orientation of terrain, become downslope and subsident at Thunder Bay and other locations around the northwest shore of Lake Superior.

Upslope winds can often generate broken cloud cover and obscure higher terrain in the absence of larger scale weather systems. In addition, they can often delay the improvement of flying weather west of Lake Superior following passage of a frontal sysem. Subsident flows, on the other hand, as is the case with northwest winds at Thunder Bay, tend to dissipate layers of broken cloud and fog that may otherwise delay the onset of low flying conditions.

Lake effect convection and precipitation is common to the lee of some of the larger lakes, including Lake of the Woods and Rainy Lake, especially where wind direction favours airflow over the longer fetches of open water. It is most pronounced in the late summer and early winter, when air temperatures begin to fall but lakes waters remain relatively warm. Lake effect convection can cause marked reduction in local ceilings and visibility due to showers. Local reports of one half mile to one quarter mile visibility in lake effect snow showers are common.

There are, on average, 25 to 35 thunderstorms in this area each year. They tend to develop throughout the summer, peak in frequency during July and August and rarely occur outside the period between April and October. Widely spaced air mass thunderstorms are the most common, however, more organised lines of thunderstorm activity often accompany the passage of cold fronts. During the summer, when the air mass is sufficiently unstable, easterly lake breezes will give rise to thunderstorms along the upslope terrain northwest of Lake Superior. As a result, thunderstorms are a common occurrence to the northwest of Thunder Bay. Some of the heaviest thunderstorm activity in this region occurs along the corridor of upslope terrain, extending from Fort Frances through just south east of Sioux Lookout.

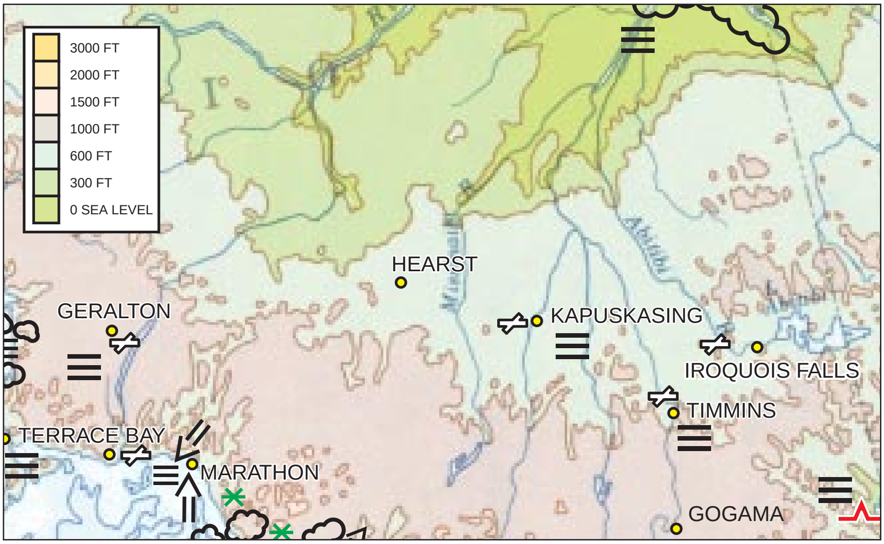
North of Lake Superior, fog, on average, reduces visibility to less than half a mile 2 to 4 times per month. The occurrence of fog is higher in late summer and early winter, while lakes and rivers remain open, and becomes much less frequent after freeze up. Fog occurs more often at Thunder Bay and around the northern shore of Lake Superior where, on average, it occurs 2 to 6 times per month, with the highest rate of occurrence in the summer.

Northeastern Ontario

Map 4-8 - Northeastern Ontario

Northeastern Ontario, like much of the northwest, is a vast and sparsely populated land that gently rises out of the Hudson Bay lowlands to the higher elevations of the Canadian Shield to the south. The land to the north is generally flat, covered in scrub forest, dotted with shallow lakes and muskeg and drained by numerous branching rivers. Farther south, the land is more heavily forested and marked by low rolling hills and rocky outcroppings, but is again interspersed with lakes, rivers and scattered marshes. Pilots have commented that "a handful of power lines and the tracks of the Ontario Northern railroad linking the communities of Moosonnee and Timmins are sometimes the only northern man-made linear landmarks recognizable from the air." Much of this region, while gently sloping, is subject to cloud development under conditions of upslope flow, even in the absence of larger scale weather systems. Pilots have cautioned against complacency while flying south after long flights over the low, unobstructed terrain in the north. As you move south, the terrain rises so that cloud can engulf power lines and communication towers perched atop the higher hills in the south, making them difficult to see.

Kapuskasing – Timmins - Geralton



Map 4-9 - Kapuskasing – Timmins - Geralton

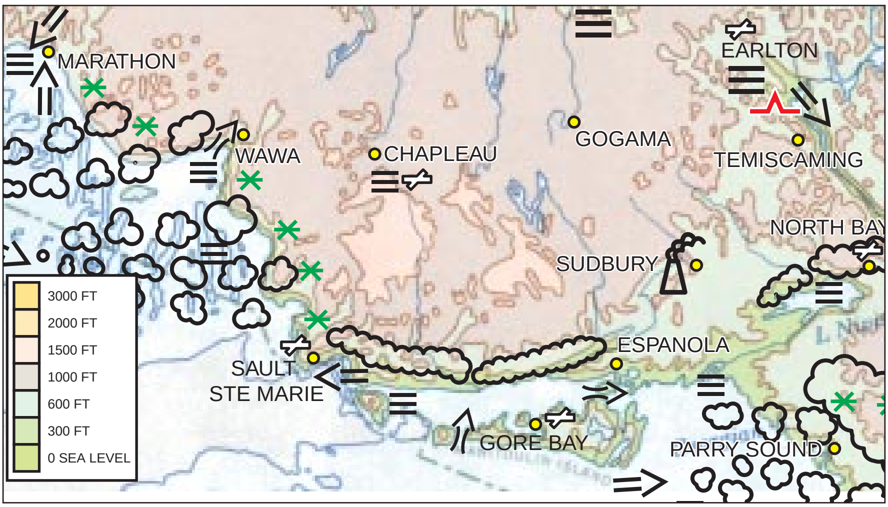
North or northwest winds are generally upslope across northeastern Ontario and can often give rise to areas of broken cloud even in the absence of large-scale weather systems. This is often the case in late summer or early winter when prevailing winds begin shift to the northwest and moisture is still freely available from open water. This can also make the region slow to clear following the passage of frontal systems under a northwest flow.

Lake effect convection and precipitation is common to the lee of some of the larger lakes, where wind direction favours airflow over longer fetches of open water. This is especially true of the area around Lake Nipigon, to the west of Geralton, and to a somewhat lesser extent of the area around Lake Abitibi, east-northeast of Timmins. Lake effect convection and precipitation is most pronounced in the late summer and early winter while lakes are open and their water remains relatively warm in comparison to falling air temperatures. Lake effect convection can cause marked reduction in local ceilings and visibility, due to showers. Local reports of one half mile to one quarter mile visibility in lake effect snow showers are all too common and can persist for several hours.

Thunderstorms, on average, occur 16 to 20 times per season. They commonly develop throughout the summer, peak in frequency during July, and rarely occur outside the period between May and September. Widely spaced air mass thunderstorms are common, however, more organised lines of thunderstorm activity often accompany the passage of cold fronts.

Fog that reduces the visibility to less than half a mile occurs 2 or 3 times per month, on average. The occurrence of fog is higher in late summer and early winter, while lakes and rivers remain open, and much less frequent after freeze up. Radiation fog is the most common, while ice fog will sometimes occur near these communities in the winter under cold calm conditions. Aircraft engine exhaust can quickly trigger local ice fog development and temporarily restrict airport visibility.

North Bay – Sudbury - Sault Ste. Marie – Wawa – Marathon



Map 4-10 - North Bay – Sudbury - Sault Ste. Marie – Wawa – Marathon

The Canadian Shield gradually rises in the south, forming a rim or divide around the northern shores of Lake Superior, Lake Huron and Lake Nipissing. This rugged higher terrain extends eastward toward the Quebec border, where it is deeply cut by the Ottawa River Valley. The highest elevation in Ontario, 2,275 feet ASL, occurs approximately 45 miles to the north of Sudbury.

Broadly speaking, winds out of the northern quadrants are upslope north of the divide, while winds from the southern quadrants are upslope to the south of the divide. Upslope flows frequently generate a broken cloud cover over this higher terrain. Lee subsidence is most pronounced to the south of the divide under a northerly flow and will often cause cloud and fog to dissipate along a corridor to the south of North Bay, through to Sudbury and Sault Ste. Marie. Subsidence effects are much less pronounced at Marathon and Wawa, which are more frequently subject to periods of persistent low cloud and fog.

Prevailing winds are generally from the west or southwest during the summer and shift to northwest in winter, while easterly winds are the least frequent and lighter. A noted exception in this pattern occurs at Sault Ste. Marie where winds are channelled between the rising terrain to the northwest of the airport and the St. Mary's River to the south. This results in both higher wind speeds and a prevailing wind direction out of the east.

Another noted case of channelling winds occurs along the narrowing valley corridor surrounding Lake Timiscaming. Under a northwest flow of 10 to 15 knots at Earlton, pilots will report winds of 25 knots or more and occasional moderate turbulence near the south end of lake as it narrows into the Ottawa River.

Lake effect convection and precipitation can be very strong to the lee of the Great Lakes, especially where prevailing wind direction favours airflow over long fetches of open water. This open water can produce a thermal low or thermal trough where convergence helps create long duration snow showers. This is the case along the northeastern shores of Lake Superior, to the north of Sault Ste. Marie (which receives in excess of 300 centimetres of snowfall annually) and over the rising terrain to the east of Georgian Bay. To a lesser extent, lake effect convection and precipitation occurs along the northern shores of Lake Huron and Lake Nipissing under a south or southwest flow. This pattern will often result in low ceilings and poor visibility from North Bay through to Sault Ste. Marie, with numerous reports of one half mile to one quarter mile visibility in showers and snow showers.

Thunderstorms are more frequent here than in the areas to the north and, on average, occur about 25 times per season. They tend to develop throughout the summer, peak in frequency during July and August and rarely occur outside the period between April and October. During the summer, when the air mass is sufficiently unstable, lake breezes frequently generate convective cloud over the Upper Michigan Peninsula near Sault Ste. Marie and along the upslope terrain to the north of Lake Huron and Lake Nipissing, as well as east of Georgian Bay. Thunderstorms are common to these areas during the afternoon and early evening but usually dissipate by sunset. More widely spaced, air mass thunderstorms usually occur with daytime heating over the northern part of the region, while organised lines of thunderstorm activity often accompany the passage of cold fronts.

The area around the northern and eastern shores of Lake Superior and Lake Huron, as well as the adjacent upslope terrain, is prone to periods of low stratus and fog. On average, fog reduces visibility to less than half a mile 4 to 8 times per month at Marathon and Wawa. The highest rate of occurrence is in late summer and early winter and the fog can be persistent. Fog will typically form over the water of Lake Superior as air temperatures begin to fall in winter. Lake breezes tend to pack fog in along the shore and the rising terrain inland. This is often the case at Marathon and Wawa where visibility less than one miles and ceilings of less than five hundred feet can persist throughout the day, while both forecasters and pilots await expected clearing. Cold, dry katabatic winds flowing downslope and out flowing through valleys overnight tend to erode away areas of fog inland from the lake, but will often cause fog to thicken and bank along the shore, only to be carried inland by lake breezes developing the following day.

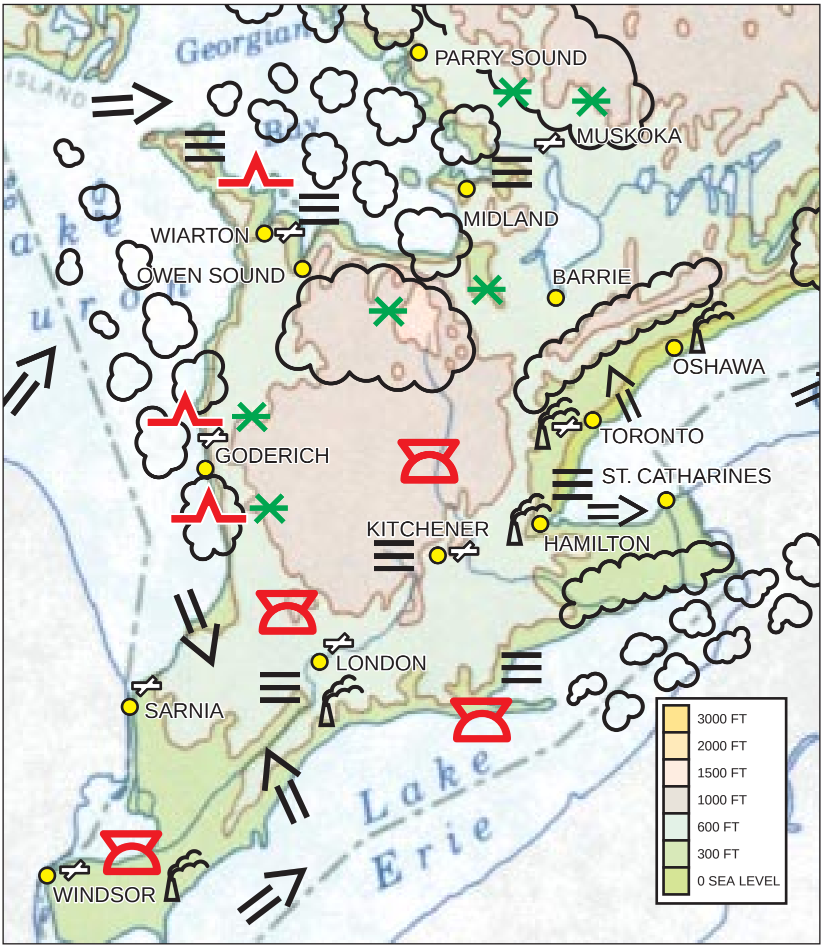
Eastern sections of the region from North Bay through Mattawa have a high occurrence of freezing rain. Typical freezing rain events involve the prior establishment of cold polar air near the surface flowing out from an area of high pressure centred over southern Quebec and along the Ottawa and Mattawa Valleys. With the cold air firmly entrenched, and sustained by surface winds, freezing rain will sometimes develop and persist for several hours as warm air is wedged over subfreezing surface layers ahead and along the frontal boundary of warm fronts.

Southern Ontario

Map 4-11 - Southern Ontario

Southern Ontario shows little of the terrain relief associated with the Canadian Shield northeast and northwest of Lake Superior. Most of the southern region is nearly level or consists of gently rolling hills having little elevation. In fact the only two upland areas rise much above fourteen hundred feet. They are the Ontario Highlands just east of Lake Huron (elevations to 1,790 feet ASL) which includes the ski hills near Collingwood and a section of the Canadian Shield to the east of Georgian Bay, home to Algonquin Park (elevations to 1,925 feet ASL). While the south is fairly densely populated and highly industrialized, offering pilots numerous landmarks, the area of the Canadian Shield in the vicinity of Algonquin Park contains sections of rugged wilderness and few roads or communities. Pilots have commented that one of the most striking and recognizable features of Southern Ontario, both from the ground and air, is the Niagara escarpment. Its bluffs parallel the southern shores of Lake Ontario through to Hamilton, then northward to Collingwood, west to Owen Sound, and north along the Bruce Peninsula to Manitoulin Island. The greatest single influence on weather across the region is the presence of the Great Lakes.

Windsor – London – Hamilton – St. Catharines – Buttonville – Muskoka



Map 4-12 - Windsor – London – Hamilton – St. Catharines – Buttonville – Muskoka

During the winter, lake effect convection and precipitation frequently develops across the upslope terrain to the southeast of Lake Huron and Georgian Bay. Under a northwest flow, before the freeze up of the lakes, these areas can receive periods of heavy snowfall, often in excess of 75 snow days annually. Airports like Muskoka and Barrie lie within this snow belt and pilot reports of visibility less than one half mile in snow showers are common under these conditions. Areas to the lee of the lakes but on the downslope side of higher terrain, such as the eastern half of Algonquin Park toward Pembroke, Toronto and Hamilton, are sometimes subjected to lake effect snowfalls under a strong northwest flow. This occurs much less frequently, however, and these downslope areas tend to receive less than half the annual snowfall of

Muskoka and Barrie. This is also the case for St. Catharines, which, while only thirty miles from Buffalo, receives significantly less snowfall.

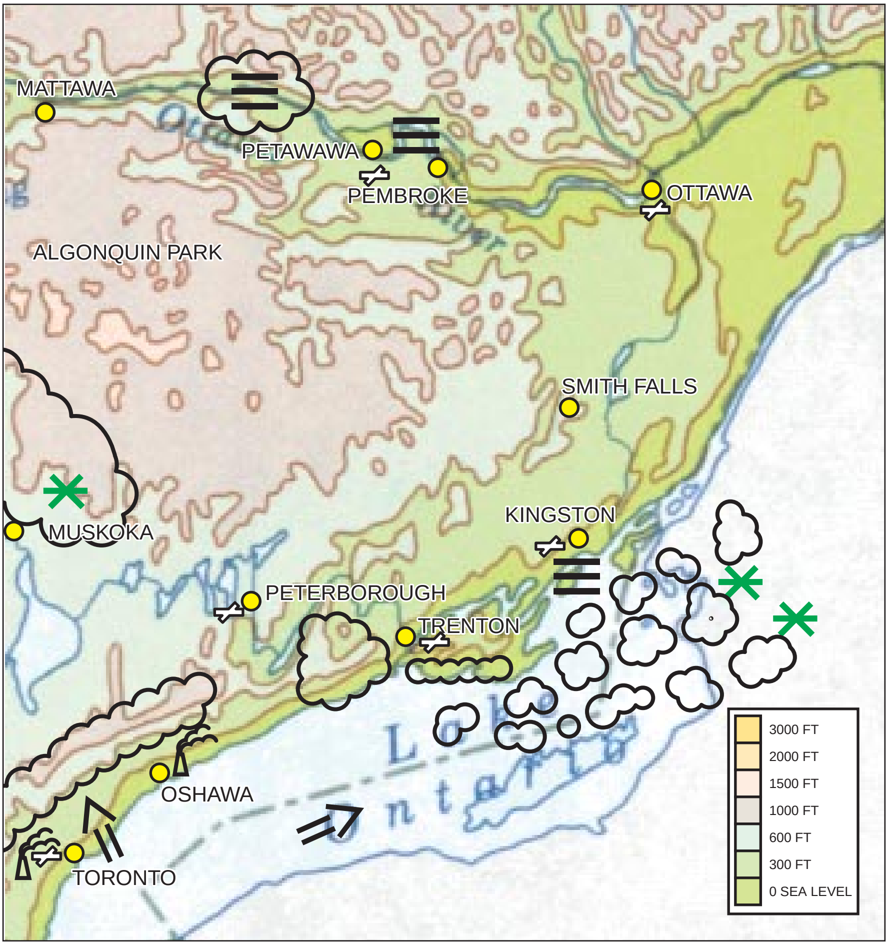
Low ceilings due to stratus cloud tends to prevail in the upslope flow north and east of London. Flights between London and Toronto often encounter lower than expected ceilings as the elevation rises while both Toronto and London are reporting good ceilings and visibility.

Thunderstorms occur more frequently over southwestern Ontario than anywhere else in the region, generally averaging 25 to 30 occurrences per season, and 35 per season along a corridor extending from Windsor through London, to just west of Toronto. Thunderstorms often form in association with lake breeze fronts, as cold lake air along the frontal boundary sweeps inland, lifting the warmer air residing over the land. Lake breeze fronts arriving from Lake Erie to the south and Lake Huron to the north frequently converge over southwestern Ontario, giving rise to the high number and sometimes severe nature of thunderstorms in this area. They tend to develop throughout the summer, peak in frequency during June and July and rarely occur during the rest of the year. Throughout the height of the convective season, severe thunderstorms accompanied by tornados occur here more frequently than anywhere in Canada. Waterspouts also occur, especially over Lake Erie, and are more common in late August and September than any other time of the year. In fact, they are almost unheard of in July.

Haze is a regular occurrence over this region during the summer, frequently reducing visibility to less than 5 miles. Haze often develops under a persistent ridge of high pressure when weak air mass circulation leads to industrial and automotive aerosols and particulates pooling in the stable air overlying the cool waters of Lake Ontario and Lake Erie. Lake breezes carry haze inland and can generate poor visibility while nightime land breezes generally bring some improvement. Haze is usually at its worst after a period of prolonged high pressure and conditions usually improve considerably following the passage of a frontal system. A good example of the hazard that haze can present comes from a pilot who, in flying along the northern side Lake Erie under worsening haze conditions, reported following the Long Point shoreline (south of London) out over the centre of the lake where he lost contact with the surface. This "whiteout" condition occurs when the water and sky become indistinguishable, leading to a loss of horizon.

Fog is at its worst in the late summer and early winter, usually accompanying frontal precipitation or the result of radiation cooling. On average, fog restricts visibility at the region's airports to less than half a mile, 2 to 5 time per month. Steam fog frequently occurs over the lakes with the arrival of cold, dry winter air masses. In addition, fog will sometimes develop over the lakes in spring with warm moist air becoming chilled by cold lake waters.

Peterborough – Trenton – Kingston – Ottawa



Map 4-13 - Peterborough – Trenton – Kingston – Ottawa

Winter can be a nasty time in this part of Ontario. Freezing rain develops infrequently throughout the region of the Great Lakes, usually in the period between December and March and rarely outside of November and April. Almost half of all freezing rain events are of light intensity, relatively large in area, last only an hour or two, and are associated with the passage of a warm front. However, the hazard associated with aircraft icing can be severe. In Ontario, freezing rain occurs most often along a corridor extending form the St. Lawrence Valley through the southwest to the vicinity of Windsor. Within this corridor, the eastern section from Ottawa through to Kingston has the distinction of having highest rate of freezing rain occurrence and the greatest number of prolonged freezing rain events.

While several different scenarios can result in freezing rain, the most common in this region involves the prior establishment of cold air near the surface flowing out from an area of high pressure centred over southern Quebec. As a result, surface winds will usually flow out of the east or southeast, spilling cold air along the St Lawrence and Ottawa Valleys, while winds south of the region will be from the south or southwest. The next step in the scenario involves the approach of a warm front, associated with a migratory low pressure system, arriving along the winter storm track out of the southwest. When a warm front approaches from the southwest, ahead of a migratory low pressure system, freezing rain will usually develop in the vicinity and to the north of the warm frontal boundary.

Several factors are considered to contribute to the more frequent and prolonged freezing rain events over southeastern Ontario, as compared to other areas. To begin with, there is often less moisture available for widespread precipitation across the west, due to the fact that the source of low-level moisture for lows approaching from the southwest is the distant Gulf of Mexico. Secondly, lows arrive over the Great Lakes will often slow, drawing heat and low level moisture from the open water of the Lakes or from the Atlantic coast. This moisture is then fed into the warm frontal airmass rising over air pooling in the St. Lawrence and Ottawa Valleys, prolonging the periods of freezing rain. Finally, both the Ottawa River Valley and St. Lawrence Valley, with the rising Appalachian Mountains to the south, tend to dam and channel the polar air, sustaining the subfreezing surface layer in which freezing rain occurs east of Lake Ontario.

Lake effect convection and precipitation can be very pronounced to the east of Lake Ontario, under a west or southwest flow. Under these conditions, the rising terrain between Cobourg and Trenton as well as much of Prince Edward County to the southeast of Trenton, will often have lower ceilings and poorer visibility in snow showers. This is also the case for the rising terrain to the northeast of Trenton as well as north and northwest of Kingston. The areas where lake effect snow produces the heaviest accumulation and presents the greatest problems to aviation in terms of low ceiling and poor visibility, however, lie to the south of the Canadian border, near Syracuse and Watertown in upstate New York.

Summer brings the return of thunderstorms which occur an average of 24 to 30 times per season across southeastern Ontario. Thunderstorms generally peak in number during July and August and rarely develop between the months of October to April. During this time, lake breezes will frequently initiate an upslope flow along the northern shore of Lake Ontario giving rise to afternoon convective cloud development. When the air mass is sufficiently moist and unstable, afternoon thunderstorms will often develop along the Oak Ridges Moraine and the rising terrain to the northwest of Trenton through Smith Falls. Westerly winds generally cause cells to drift eastward throughout the afternoon. Thunderstorms generally dissipate within a few hours of sunset. Nocturnal thunderstorms are usually associated with the nighttime passage of cold fronts. Pilots have commented that on convective days a fairly clear corridor will generally remain open to east west flight along the shore of Lake Ontario, while flying north will often involve detouring around CBs.

Haze is a common summer occurrence over this region, but is usually worst near the industrial centres along the north shore of Lake Ontario and the St Lawrence. Haze will occasionally reduce visibility to less than five miles but only infrequently to less than three. It usually develops with a persistent ridge of high pressure, when weak air mass circulation leads to industrial and automotive aerosols and particulates pooling in the stable air overlying the cool waters of Lake Ontario, and in the confines of the St. Lawrence Valley. Lake breezes carry haze inland and often cause some of the poorest visibility during the afternoon. Land breezes will generally bring some improvement overnight. Haze is usually worst after a period of prolonged high pressure and conditions will usually improve considerably following the passage of a frontal system.

Fog is at its worst in the late summer and early winter, usually accompanying frontal precipitation or the result of radiation cooling. On average, fog restricts visibility at the regions airports to less than half a mile 2 to 5 time per month. Steam fog frequently occurs over the lakes with the arrival of cold, dry winter air masses. In addition, fog will sometimes develop over the lakes in spring with warm moist air becoming chilled by cold lake waters.

The Great Lakes

Map 4-14 - The Great Lakes

As discussed in Chapter 3, the Great Lakes Basin is one of the more active regions for migratory low pressure systems and, as such, the Great Lakes and the adjacent terrain is home to a great deal of system related weather. The strongest winds over and around the lakes are associated with the more intense lows developing in April and May and again later on in September through November. These lows typically approach from the southwest, deepen over the lakes and produce very strong pressure gradients and active fronts.

Frontal systems are usually the most active over the Lower Lakes in the spring and the Upper Lakes in the fall. Active spring lows passing over Lake Huron carrying warm and cold fronts will often initiate strong southerly winds with their approach and rapidly deteriorating ceilings and visibility in showers and mist. A sharp wind shift to the southwest and improvement in ceilings and visibility typically marks the passage of the warm front. Several hours may pass before squall lines with thunderstorms and strong gusting winds herald the onset of an active trailing cold front. The cold front itself will usually bring further convective cloud, showers and a sharp shift to strong northwest winds. Passage of a cold front over the lakes may not bring the improvement in aviation weather often expected to follow frontal passage over land. With intense fall storms, strong surges of cold polar air behind a cold front can bring some of the storm's greatest winds. In addition, strong convection will often develop as cold polar air sweeps over long stretches of warm open water. This can generate strong turbulence, low ceilings and poor visibility in lake effect snowfall that may extend miles inland downwind of the lakes.

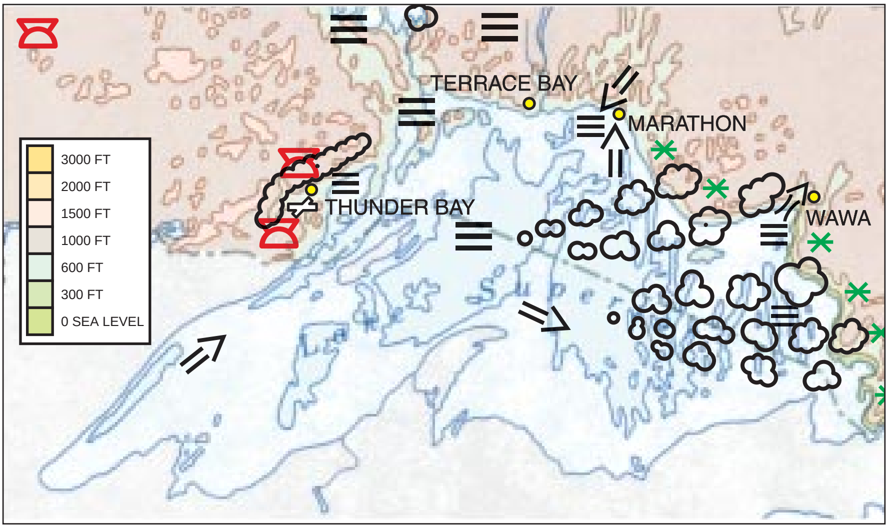
The single weather phenomena most often credited with hampering aviation operations near and around the Great Lakes is fog. From April through November the Great Lakes Basin is affected by fog arising from different processes. Advection or sea fog is the most common, forming when warm, moist air condenses over cold water. This type of fog frequently occurs over Lake Superior and Lake Huron, whose deep waters remain cold throughout the summer due to upwelling. Heavy banks of advection fog tend to form around Lake Superior well into the summer. West or southwest winds will frequently bring these fog banks onto the northern and eastern shore, plaguing locations like Terrace Bay, Marathon and Wawa. Advection fog may persist for several days even under moderate winds but will usually lift following passage of a cold front.

Frontal fog forms in the moist airmass trapped beneath a warm frontal inversion. It is often worse in the more moist air over the lakes than over the surrounding land. Local pilots recommend caution when flying across the lakes from nearby airports under conditions of minimum visibility. Frontal fog will often lift within a few hours following passage of a warm front.

During the winter, usually from mid December through February, steam fog will frequently accompany very cold arctic air as it moves out over open water. Steam fog, also referred to as arctic sea smoke, can extend several hundred feet off the water surface.

Pilots have made the comment that, most of the time, sea smoke hugs the surface and can be avoided but, forced to fly through it by low ceilings, sea smoke can quickly result in visible icing.

Lake Superior



Map 4-15 - Lake Superior

Lake Superior, with a surface area of over 82,000 square kilometres, is the largest and deepest of the Great Lakes. Over the western section of the lake, from Isle Royale to Deluth, prevailing winds are out of the northeast or southwest. The central and eastern sections of the lake from Thunder Bay to Whitefish Bay are subject to prevailing winds out of the northwest. Superior is the coldest of the Great Lakes with water temperatures that warm to only 10 to 14 degrees C°. Fog is common over the cold lake surface throughout the summer, often drifting inland under lake breezes to plague surrounding airports. Fog is at its worst in June with fog banks becoming an almost permanent feature around the lake from Thunder Bay to Sault St Marie.

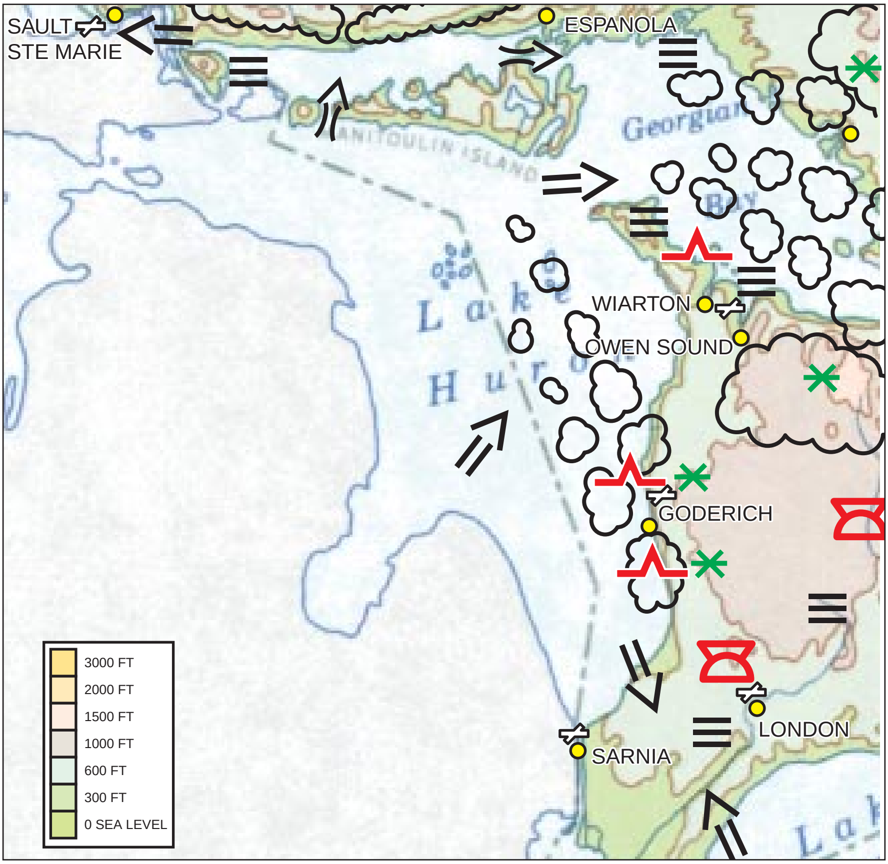
In fall and winter, the winds around the lake are often 10 to 15 knots stronger than over the land, driven by convection developing above the comparatively warm lake surface.

Interacting with the steep rugged terrain of the Canadian Shield rising around the lakeshore, moderate to strong winds will often give rise to areas of low-level mechanical turbulence.

Thunderstorms, while not uncommon across Lake Superior, are usually associated with the passage of cold fronts. Thunderstorms tend to lose their strength or die out entirely as they move off the warmer land and out over the cooler waters of the lake.

Convection along cold fronts, typically moving from west to east across the lake, will usually be much weaker by the time the front reaches the eastern shore.

Lake Huron



Map 4-16 - Lake Huron

Lake Huron has a surface area of over 59,000 square kilometres. Its eastern shores, along Georgian Bay, are dotted with small communities while inland lies the cottage country of Muskoka. Prevailing winds over Georgian Bay are northwesterly but, because of the many islands, channels and inlets near and along the shoreline, local winds show tremendous variability. Wind speeds within the Thirty Thousand Islands often exceed those over the open water, due to funnelling and channelling effects between the islands.

The entrance to Georgian Bay, between Manitoulin and Tobermory, is an area often affected by strong westerly winds, which tend to be funnelled through the channel. The cold waters of the deep central section of the lake frequently generate heavy fog in this area during the spring and summer.

Rugged cliffs mark the eastern side of the Bruce Peninsula down to Wiarton and Owen Sound which lie at the end of deeply cut bays. Strong southwest winds can make a flight over this area fairly bumpy due to low-level mechanical turbulence.

In winter, the upslope areas inland from the south end of Georgian Bay between Meaford and Collingwood through Midland to Parry Sound are subject to strong lake effect snowfalls, low ceilings and poor visibility under a northwest flow.

Thunderstorms over Georgian Bay usually develop in association with the passage of cold fronts. Outbreaks of cold air between August and October may also bring the development of waterspouts.

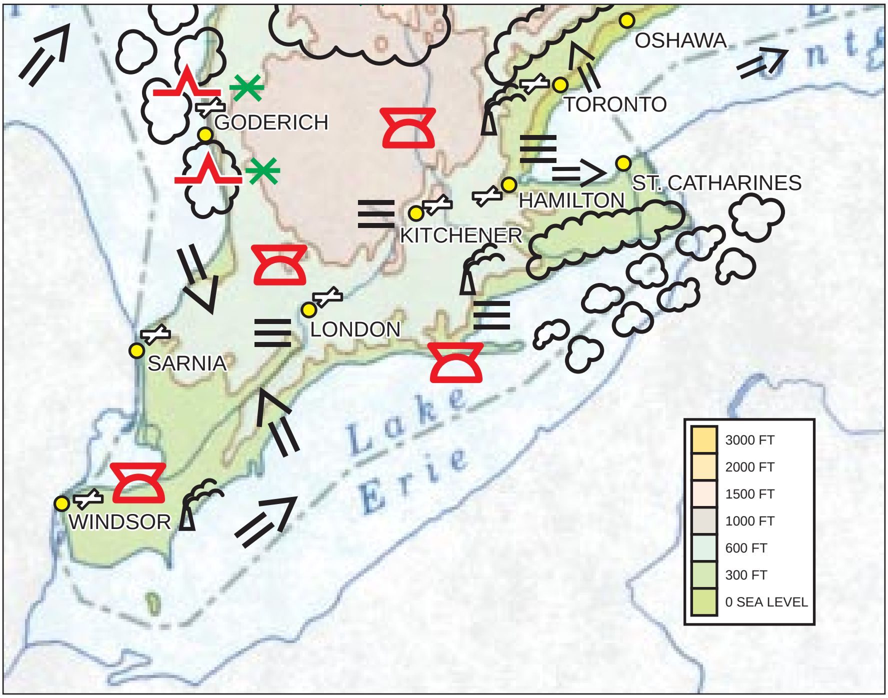
Prevailing winds over Southern Lake Huron are south or southwesterly. The lakeshore from Sarinia through Goderich, Port Elgin and northward along the Bruce Peninsula is exposed to large fetches of the lake. Summer wind speeds average 15 knots but winds may reach as high as 50 knots with the more intense storms of winter. Flights along the coast under strong winds can be bumpy due to low level mechanical turbulence.

Thunderstorms occur more frequently in the area of southern Lake Huron and, due to warmer water temperatures, they tend to maintain most of their intensity. Water spouts are common from August through late October, usually accompanying convection in outbreaks of cold air.

The cold waters of Lake Huron create another interesting effect. For a distance of 20 miles inland from the east shore of Lake Huron, during the late spring and early summer, a lake "shadow" will exist where little cumulus cloud will form, due to the dome of cold air that slides in off the water. Along the eastern edge of this dome, cumulus will begin to form and areas to the east of this line will often see broken cloud, while areas to the west of the line will see scattered or no cloud. Similarly, precipitation is less within the lake shadow during May and June, while the reverse happens in the fall months.

The North Channel and Manitoulin Island are subject to prevailing westerly winds. Winds funnelled through the narrowing terrain between the island and mainland increase significantly in the area around Espanola. This is also the case through Mississagi Strait and Detour Passage of Manitoulin Island; areas surrounded by higher terrain shorelines. Fog is less extensive over the North Channel than over northern Lake Huron, throughout the spring and summer, due to warmer water temperatures. While diminishing the effects of fog, warmer water temperatures support more intense convection and thunderstorms are more common here than over the cold waters of the central sections of the lake.

Lake Erie

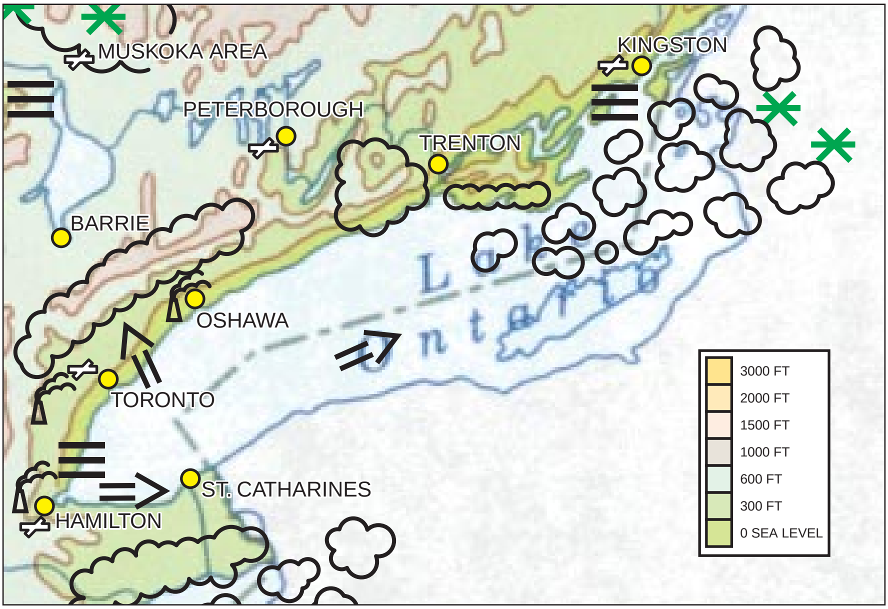


Map 4-17 - Lake Erie

Lake Erie is slightly larger than Lake Ontario but it is much shallower and far warmer. Water temperatures near the western end of Lake Erie can exceed 24 degrees C. The gently rising terrain on either side of the lake tends to channel winds along its length from west-southwest to east-northeast. As a result, prevailing winds are out of the southwest. The prevailing year round wind speed is 10 to 15 knots, however, funnelling causes winds to be stronger at the eastern end of the lake. Lakeshore convergence also causes the easterly wind along the north shore and the westerly wind along the south shore to be stronger than the prevailing wind.

Severe weather is more common across Lake Erie than on any of the other Great Lakes. Severe thunderstorms occur on 8 to 10 days each summer and waterspouts 4 to 6 days per year from late July through October, most toward the southwest end of the lake. On the positive side, because it warms quickly, Lake Erie has less fog than the other lakes and little of that occurs throughout the summer after June. The area around Long Point and the Inner Bay is subject to frequent summer thunderstorms and is a common location for waterspouts.

Lake Ontario



Map 4-18 - Lake Ontario

With a surface area of almost 19,000 square kilometres, Lake Ontario is the smallest of the Great Lakes. It does not freeze over completely in winter and its long fetches of open water often result in heavy lake effect snowfalls to the lee of the lake in Syracuse and Watertown, during the winter. Pronounced lake breezes tend to develop along Lake Ontario's shoreline, especially in the Toronto area, where strong temperature differences develop between the heat island of the city and cool lake waters.

Under stable conditions, such as beneath a strong ridge of high pressure or with the influx of tropical air moving up from the Gulf of Mexico, pollutants and humidity will build up in the cool stagnant air over the lake, reducing visibility. On clear calm nights, cold air drainage will set up a light northerly flow to the east of the Niagra Escarpment.

The western end of Lake Ontario includes the population and industrial centres of Hamilton, Burlington and St. Catharines. Westerly winds tend to be channelled along the southern shore of the lake and upslope along the rising terrain and steep bluffs of the Niagara Escarpment, from Burlington to Beamsville. Thunderstorms often develop in this area during the summer and drift out over the lake.

In the Dundas Valley near Hamilton, prevailing fall westerlies and the easterly winds prevailing in spring are commonly funnelled through the valley, increasing wind speeds near Hamilton by roughly 50 percent over those in surrounding areas.

Visibility in the region is frequently reduced by haze, often to less than 5 miles in the vicinity of Hamilton.

During the winter, an easterly wind off Lake Ontario can give significant snowfalls to areas downstream of the lake. In the spring, these same easterly winds can cause poor visibility in fog to persist over the western end of the lake for extended periods.

The eastern end of Lake Ontario, near the mouth of the St. Lawrence River, is dotted with islands. The most prominent local effect is the channelling of winds to the southwest and northeast along the St. Lawrence Valley. Fog is common throughout the spring and often reduces visibility. Lake breezes occur frequently throughout the summer, often initiating the upslope flow that in combination with daytime heating leads to afternoon thunderstorms over the heated slopes around the lake. Cornering winds and gusty lee eddies are common within the Thousand Islands between Brockville and Kingston.

Quebec

Nunavik

Map 4-19 - Nunavik

Weather conditions across Nunavik are strongly influenced by the large saltwater bodies of Ungava Bay, Hudson Bay and Hudson Strait, as well as mountains and river gorges. Ungava Bay usually freezes over in late October or early November and remains covered until the pack ice goes in late July. From 1997 to 2000, however, the bay froze later and never froze completely during the winter of 2001. During the same four years, the pack ice was gone at the beginning of July and the remainder (small floes; grounded ice chunks) by mid-July, one month early. Hudson Bay freezes much later, usually by the end of December, but never does so completely as the ice shifts continuously under the influence of the wind. Near the coastline, however, the ice usually melts in late June or early July with the rest of the ice not breaking up until much later in the summer. As for the Hudson Strait, the water usually freezes by the end of November and remains so until the pack ice goes away in mid-July, leaving floes and small bergs that finally clear out of the strait by the end of July.

(a) Ice-covered season

So far north, traditional seasons are less relevant to flying conditions than ice-free, ice-covered or transition periods. Once the ice pack is well established, flying conditions tend to become more favourable, both in terms of ceiling and visibility. This is especially true for the months of February, March and April. Typically, during this time of year, a localized high pressure system establishes itself over Ungava Bay giving clear skies and good visibilities. This did not happen in 2001, however. The area is still exposed to synoptic-scale weather systems that move generally from west to east or from southwest to northeast. In such a case, weather conditions that hit the eastern shore of Hudson Bay usually reach Ungava Bay 24 hours later.

Whiteout conditions can develop without warning and last for several days. Whiteouts are frequent north of the tree line, since there are few visual markers and the horizon is easily lost. Whiteout conditions become generalized as soon as the land is covered by low stratus cloud. Nowhere is it as frequent as the Raglan Plateau, which is at 1,900 feet ASL.

Due to usually stronger winds at this time of the year, turbulence becomes more frequent both over and in the lee of mountainous terrain. On the Raglan Plateau, lenticular clouds (SCSL or ACSL) are frequently observed at altitudes of 6000 to 7,000 feet ASL, indicating the presence of severe lee wave turbulence. Moderate to severe mechanical turbulence is common with northwesterly winds of 30 knots or more developing after the passage of a cold front. It is also frequent throughout the Ungava Peninsula when the upper winds at 3,000 feet are 30 knots or more. Severe mechanical turbulence reported further south that is associated with a 40 to 45 knot low-level jet stream often extends to 58°N, and sometimes to 60°N.

Icing may become an issue as most flights are short “hops” between neighbouring villages and tend to be conducted at altitudes of less than 3,000 feet ASL. Significant amounts of ice can then accumulate over aircraft surfaces over long periods of time. Fog, producing significant icing and zero ceilings and visibilities, forms over any open water and drifts inland, pushed by the wind during colder months. Ice fog also tends to form over villages as soon as there is a little wind mixing the air, due to the humidity contained in the smoke from house and building chimneys.

On very cold and clear days, drifting snow or blowing snow is common. The weather can rapidly change to whiteout conditions as visibilities fall drastically in ice crystals in the lowest thousand feet of the atmosphere. The Inuit call this phenomenon “natarluk” (the “r” is pronounced like a “k”).

(b) Late spring and early summer

The arrival of warmer air over ice- or snow-covered surfaces generally results in the formation of thick fog or low stratus cloud. As a result, low ceilings, low visibilities, and light to moderate rime or mixed icing are common. Conditions improve once the snow melts and the pack ice moves away. The top of the fog layer may reach 500 feet AGL. It generally stays over water during the day but it can move inland as the ground, and air, temperature warms up. For example, it is common to see the fog moving inland along the southern shore of Ungava Bay around 5 pm in early May and around 7 pm by early June.

(c) Ice-free season

Fog is the dominant weather maker once the ice is completely gone and the water starts to warm up. This is advection fog, giving either zero or near zero ceilings and visibilities. It is generally so thick; that pilots may not see their own aircraft propeller. The months of July and August are generally the worst. Advection fog is usually observed along the entire coast line, from Killinek to Kuujjuaq, to Ivujivik, then to Kuujjuarapik.

Rain is generally observed with the passage of a weather system. Thunderstorms, on the other hand, are rarely observed over northern Nunavik. When observed, they are usually associated with a trowel crossing Hudson Bay from the west and are found at higher altitudes, embedded in nimbostratus clouds.

Strong southerly winds (20-30 knots) are often observed during the summer months, bringing in warmer air masses. Lee wave turbulence and lenticular clouds are frequently observed over the Ungava Peninsula, especially over the Raglan Plateau, during the time.

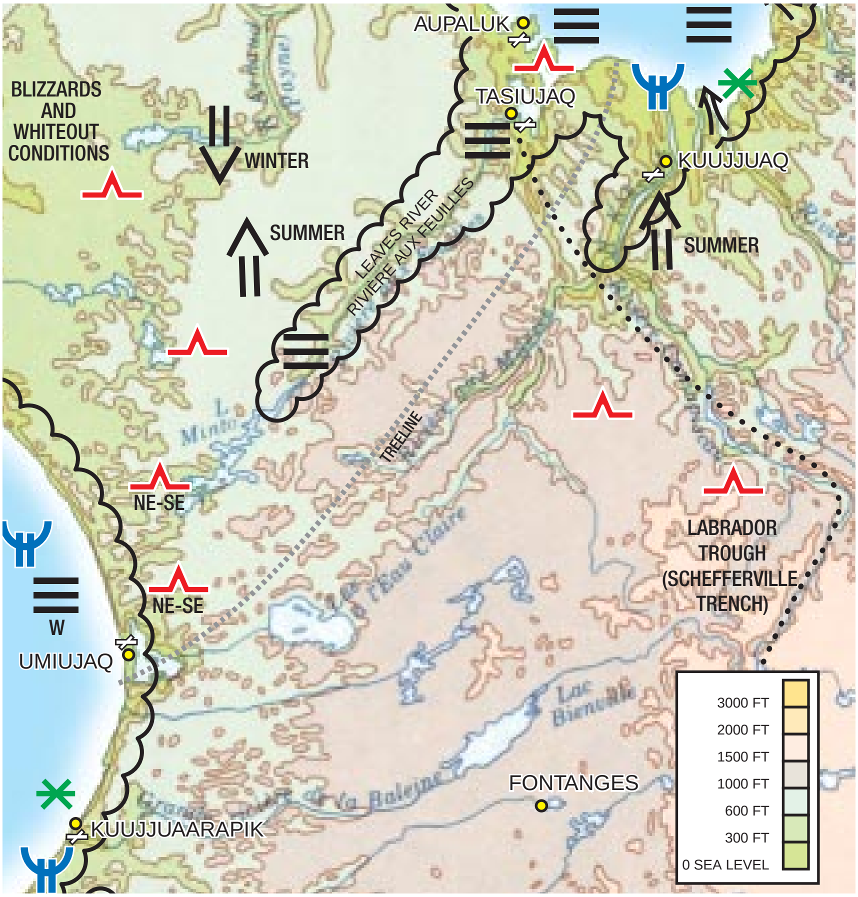
(d) Fall transition from mid-September to mid-November

Fog becomes less dominant as the land cools down. On the other hand, cooling lands favour the production of freezing drizzle, depending on weather systems. Freezing drizzle then tends to form in onshore / upslope flow off the sea. Icing is common over water and along the coast line. Conditions get better further inland.

Photo 4-1 - Advection fog and 500-foot stratus ceiling near Leaves Passage

copyright: Peter Duncan, Nunavik Rotors Inc.

Kangiqsualujjuaq to Kuujjuaq

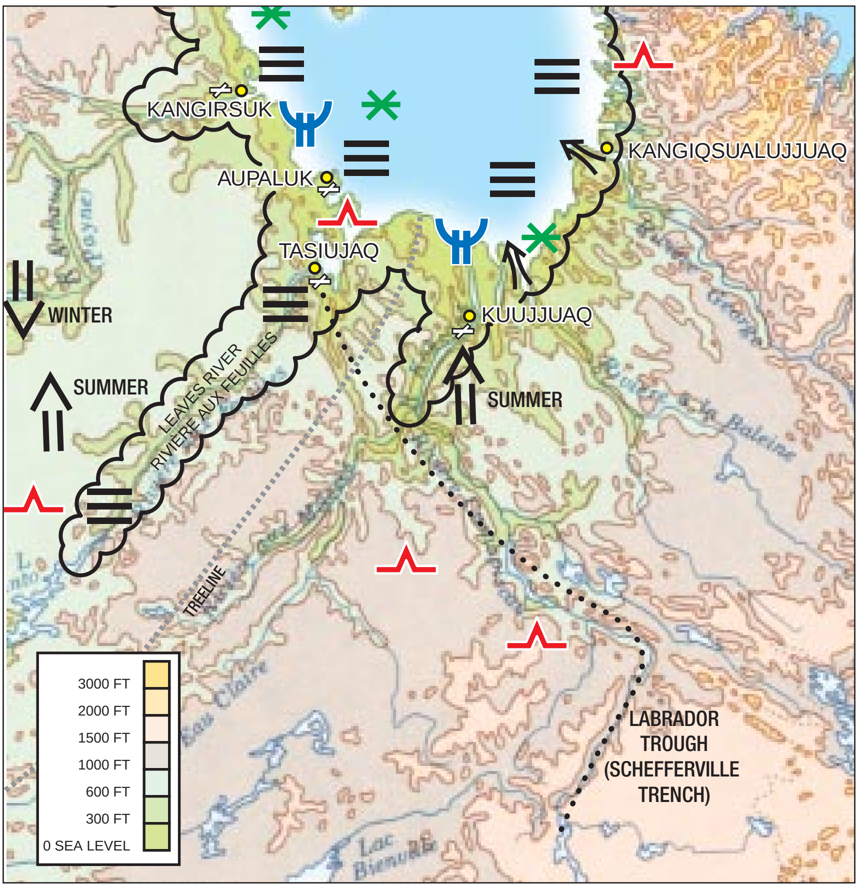


Map 4-20 - Kangiqsualujjuaq to Kuujjuaq

During the warmer months, onshore circulation results in persistent zero ceilings and visibilities in advection fog. Trapped under an inversion, this fog will not lift, regardless of how strong the sun. The worst conditions are generally encountered between the coast and the bank of the George River.

During cooler months, icing can also be expected in the fog. During the coldest months, numerous snow squalls will develop over the bay and move onshore, pushed by dominant northwesterly winds. Severe turbulence and icing, along with whiteout conditions, are usually encountered in these squalls. Strong turbulence can be expected when the wind runs crosswise to the fjord. It will be smoother when a strong, but steady and stable, wind is coming down the fjord. Additionally, strong katabatic winds, which have reached 80 knots on occasions, sometimes developed in various fjords at night.

Labrador Trough (also called Schefferville Trench)



Map 4-21 - Labrador Trough (also called Schefferville Trench)

The Labrador Trough starts at Tasiujuaq, goes to the Koksoak River, then follows the Caniapiscau River and continues on toward Schefferville. The trough is approximately 45 nautical miles wide. Moderate mechanical turbulence occurs frequently over this mountainous area throughout the year.

Riviere aux Feuilles (Leaves River)

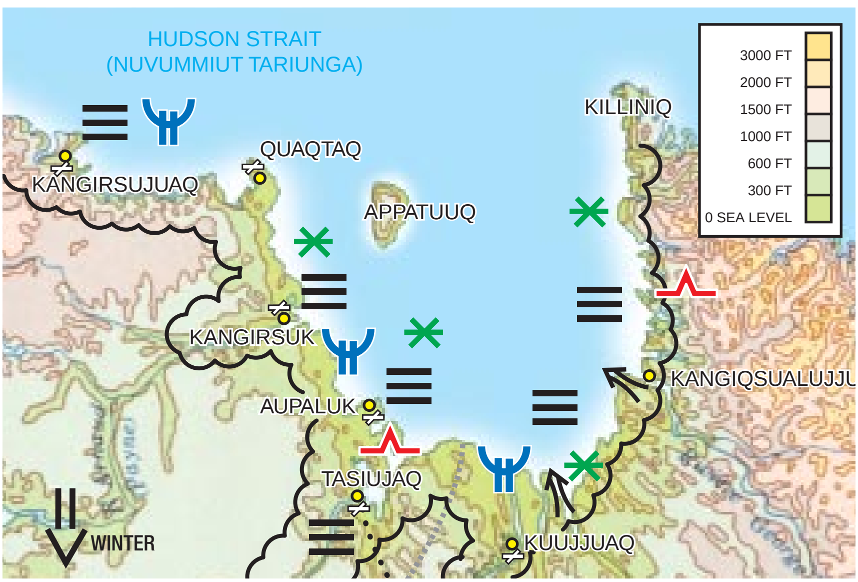
Leaves River, that is the area within 20 to 30 nautical miles either side of the river, is usually wrapped in fog or very low-level stratus cloud. The cloud cover occurs occasionally in summer but it is more generalized and persistent in the spring and the fall.

Tasiujuaq Area

Tasiujuaq is at the end of a very large bay, surrounded by mountains. Due to the geography, this area is subjected to some of the highest tides in Canada. At low tide, the water withdraws almost completely from Dry Bay and Whales Bay. While the bays do freeze up, Leaves Passage never freezes in winter. As a result northeast winds result in extensive advection fog, giving near zero ceilings and visibilities, or very low level stratiform clouds.

In winter, the passage of a cold front brings arctic sea smoke and ice fog. Additionally, strong northwesterly winds may result in moderate mechanical turbulence near the surface.

Aupaluk Area



Map 4-22 - Aupaluk Area

Aupaluk is well exposed to the waters of Ungava Bay. The land surrounding the aerodrome is composed of low lying marshes and, as a result, any wind coming from the northwest, the north or the northeast will bring in advection fog or very low stratus clouds. The fog and stratus clouds are usually extensive and tend to persist, especially in late spring or fall. Even southeasterly winds will push fog and stratus over the low-lying area toward the aerodrome.

This area of the bay usually freezes late in January, although freezing occurred later over the last few years. Light to moderate rime or mixed icing is frequent in the fog and stratiform clouds in cooler months, especially during the two transition periods. The cooler months will see more snow, which will give low visibilities when the circulation comes from the bay. Like Tasiujuaq, the passage of a cold front often brings northwesterly winds of 20 to 30 knots. These winds are perpendicular to the runway axis, making landing and take off problematic.

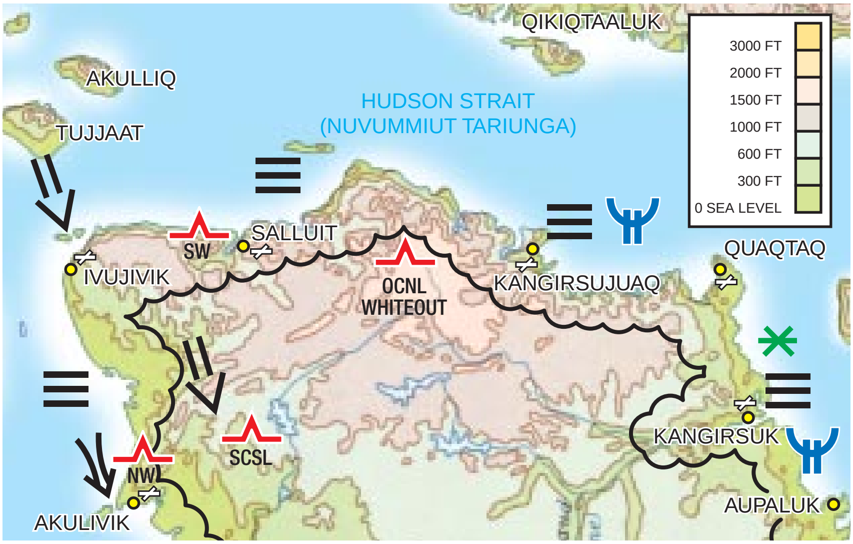
Kangirsuk

Kangirsuk is situated near the mouth of the Payne River, on its northern shore. The runway is located at an altitude of 383 feet ASL.

While the river eventually freezes in winter, Payne Bay does not and the limit of the ice usually ends only a few miles from the aerodrome. East or northeast winds continuously bring moisture and very low stratiform clouds with bases between 200 and 300 feet AGL. This results in the runway being in the cloud itself due to the runway elevation, with zero visibilities.

In late spring, the arrival of warm air while the ice has not yet cleared the coastal area of Ungava Bay, results in local cooling and poor ceilings and visibilities.

Area from Quaqtaq to Salluit to Ivujivik



Map 4-23 -Area from Quaqtaq to Salluit to Ivujivik

There are four aerodromes which are found along the Hudson Strait coast line. They are Quaqtaq (elevation 95 feet ASL), Kangiqsujuak (elevation 511 feet ASL), Salluit (elevation 742 feet ASL), and Ivujivik (elevation 137 feet ASL).

North of 60°N, strong coastal winds are common. In the depth of winter, violent winds from the southeast, in excess of 50 knots, are observed when an intense low pressure system moves from Hudson Bay to northern Baffin Island. After the passage of a cold front, northwesterly winds of 50 to 60 knots are often observed, mostly at night. Such winds usually generate significant mechanical turbulence along the coast, especially in Kangiqsujuak and Salluit, due to the high elevation of their respective runways.

Quaqtaq is situated on the north-western tip of Cape Hopes Point. It is surrounded from most directions by the waters of Hudson Strait. As a result, Quaqtaq experiences extensive fog or low stratus (ceilings 400 to 500 feet AGL) during the ice-free season, with a temperature-dew point spread of only one degree for long periods of time. An inversion tend to persist over the area due to the cold temperatures of the land and water so that Quaqtaq tends to remain shrouded in fog banks even with high winds.

Spring arrives very late, usually in the latter half of June, several weeks after surrounding localities. Icebergs can sometimes be found stuck between Quaqtaq and Hearn Island, or in Diana Bay. On the other hand, turbulence occurs very rarely in Quaqtaq.

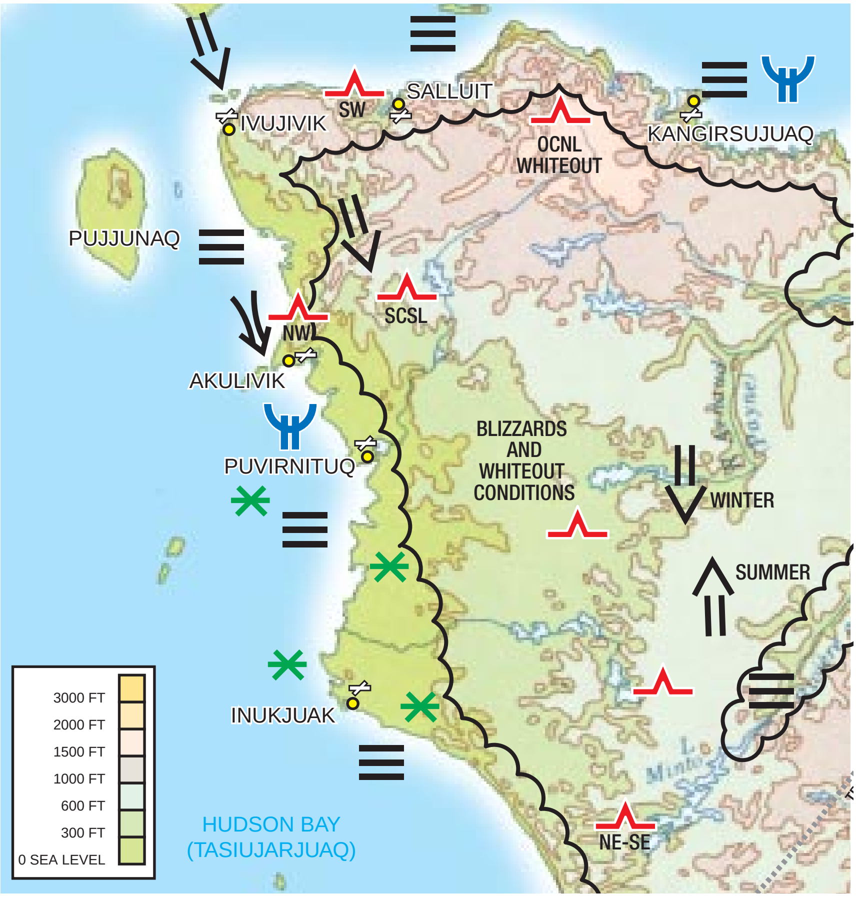
Salluit aerodrome is located on top a cliff, approximately 740 feet above the actual village, on the east side of Sugluk Inlet. Dominant winds are from the northwest, perpendicular to the inlet and to the runway. For their part, northeasterly winds are rare and usually occur with speed of 2 knots or less. In Salluit, the turbulence generated in summer or fall by winds of 20 knots or more, from a direction varying from southwest to west, is often too strong to allow for passenger flights.

With northwest winds, the village often experiences a 500-foot stratus ceiling while the runway is shrouded in thick fog. Such a situation can last for three to four days, until the wind direction changes. This occurs throughout the year.

In Ivujivik, the aerodrome is surrounded by flat land to the south and the east, and with water to the north and west. Fog is frequent during the ice-free months.

The waters along the coast line freeze solid by end-January. For the following months (February through May), flying conditions are excellent with the best conditions in April, and the air temperature is in the -30°C to -35°C range. Ivujivik is subjected to very strong northwesterly winds, especially behind a cold front. It is worth noting that it usually takes about three hours for the weather conditions at Ivujivik to move to Salluit (with a front moving at 20 knots).

Akulivik and Puvirnituq
(northern section of the east shore of Hudson Bay)



Map 4-24 - Akulivik and Puvirnituq

Akulivik and Puvirnituq are separated by approximately 54 nautical miles and, as such, their weather tends to be quite similar. Akulivik is situated on Chanjon Point, on the western tip of the d'Youville Mountain Range. Puvirnituq, on the other hand, is surrounded by flat lands to the east and the Povungnituk Bay to the west. In this area the waters of Hudson Bay freeze for a good distance to the west.

The predominant winds are from the northwest and low stratus cloud (ceilings 500 to 600 feet) is common. Additionally, north or northwest winds usually cause moderate mechanical turbulence in Akulivik, due to a mountain to the north and the runway axis (NE - SW) respectively.

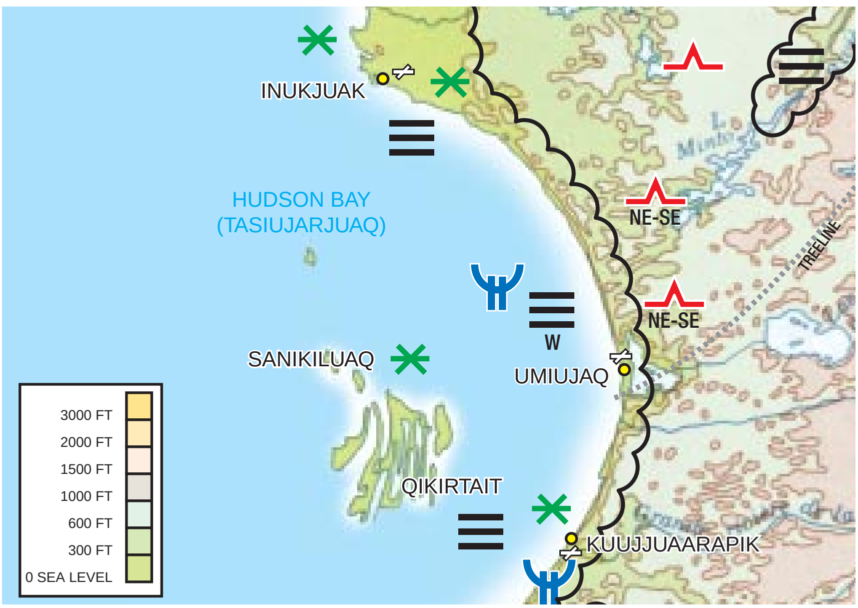
Inukjuak

During the ice-free season, fog banks and stratus are common, whenever the wind comes from any direction between south and west. When this happens, near zero ceilings and visibilities are frequently encountered.

During the fall, when arctic air (air temperature of -8°C or less) invades over still warm waters, snow squall activity becomes prevalent giving near zero ceilings and visibilities, along with moderate turbulence and icing.

Once the eastern section of Hudson Bay freezes over, flying conditions become favourable when the wind dies down, especially in January and February. As soon as the wind picks up, blizzard conditions and whiteout can be expected. The ice is usually present on the eastern Hudson Bay until mid-July. As long as the ice lasts, the fog that does advect in off Hudson Bay usually only moves inland about 10 miles.

Umiujaq



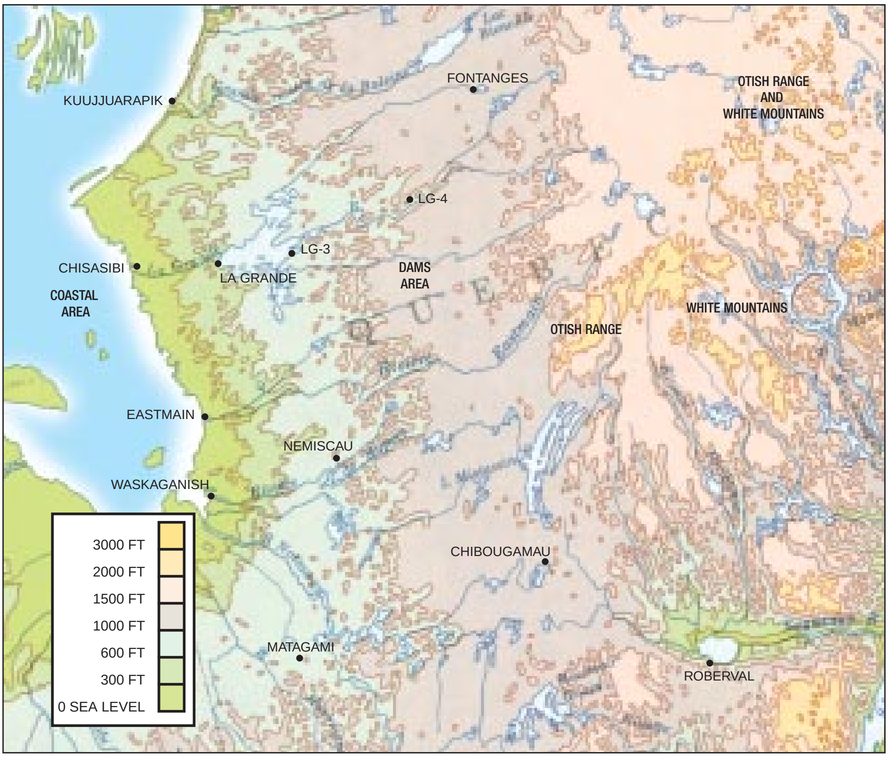
Map 4-25 - Umiujaq

Umiujaq is situated on the coast of Hudson Bay and abutted against a narrow north to south hill range to the east of the aerodrome, culminating at 1,415 feet ASL in its immediate vicinity. A chain of flat islands, the Nastapoka Islands, runs parallel to the coast, separated from it by a narrow sound.

Orographic effects create particular weather-related problems for flight operations. Winds coming from any direction between northeast and southeast, over the hills, generate significant mechanical turbulence over the runway. During the ice-free season and the fall transition period, westerly winds generate combined onshore and upslope flows, which produce very low stratus clouds, with ceilings of 200 to 300 feet, and visibilities of less than one mile in drizzle and mist (or fog). When the air temperature hovers just below freezing, the precipitation may be freezing drizzle and significant icing should be expected.

Once the ice sets on the Bay, the stratus ceiling tends to rise to 500 feet and the visibility improves. Being north of the tree line, there are no easy visibility markers beyond the runway for a plane on final approach, during the winter and early spring season. As with aerodromes further north, Umiujaq can be subjected to snow squall activity in the fall.

James Bay Region



Map 4-26 - James Bay region

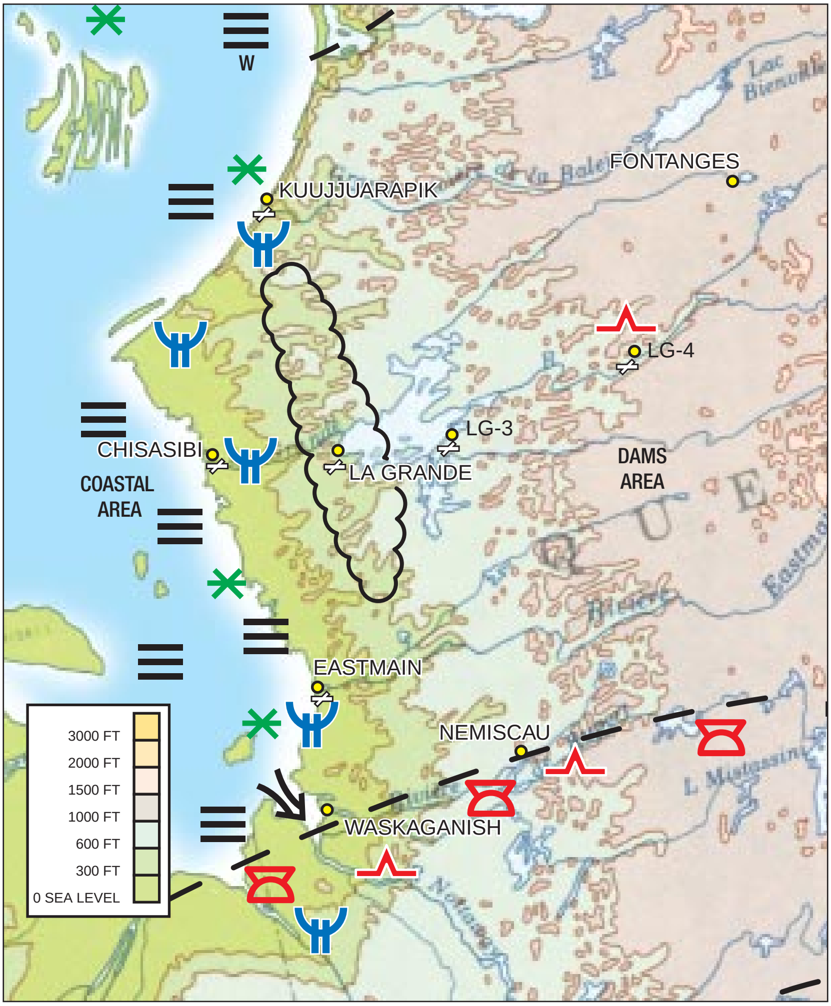
James Bay, its seawater either frozen or open, is the major controlling element of weather in this area. When open, between June and December, James Bay is a major source of low cloud, fog and icing. Frozen over the rest of the year, the area resembles a frozen desert. To further complicate this area, the large reservoirs of Hydro-Quebec dams, rivers, and a multitude of lakes all add their own effects to the local weather.

The winter weather in this area is typical of this latitude. Long periods of cold and clear weather occur when the frigid air covers the region. The most active weather tends to occur in the transition seasons, spring and fall, when larger weather systems move across the area.

Summer is a time of convection. Turbulence, sufficient to affect passenger flights, remains a rare occurrence and, when it happens, it is usually associated with thunderstorm activity. Most of the larger convection occurs south of a line from Moosonee to Waskaganish to Nemiscau, although individual cells are sometimes observed north of that boundary. South of the boundary, thunderstorms usually travel in bands from west to east. Hydro-Quebec flights, returning from any airports in the James Bay Area to Montreal, Quebec City, or Bagotville, usually encounter thunderstorm activity along a specific line around 3 to 4 p.m. during the summer. These cumulonimbus clouds travel along the same trajectory day in and day out. This trajectory, a general east to west line, passes approximately 7 nautical miles south of Matagami, to approximately 13 nautical miles south of the Chibougamau NDB, to approximately 23 nautical miles south of the Chute-des-Passes NDB, then continuing on eastward.

Local effects

Coastal Area



Map 4-27 - Coastal Area

(a) Winter and spring

Flying conditions are usually good along the coast in winter and early spring. On very cold winter days (and nights), the visibility can rapidly be reduced to 1/2 to 3/4 statute miles by ice crystals. Chisasibi, like Kuujjuarapik, are particularly prone to this phenomenon.

Turbulence is seldom encountered at this time of the year and when it does occur it tends to be localized, generally associated with surrounding topography. As for icing, it is very rare once James Bay is frozen. It does occur, however, over a two-week period when the air starts to warm up and before the ice goes, usually in May. Freezing drizzle and SLD icing, due to liquid phase low stratus clouds, are sometimes observed along the coast in late spring. It is a lesser problem in the fall since the air temperature near the surface is usually above freezing. In late spring, fog starts to form offshore over the ice. It is inclined to remain there but Eastmain Airport, being situated on a piece of land protruding farther into the bay, is more often affected by the fog, with visibilities around 1/2 to 1 statute mile.

(b) Summer

Flying conditions are generally favourable. Light westerly and northwesterly winds may bring in fog from the bay, but it does not stay long during the daytime. The fog moves in at sunrise and it usually lifts between 9 and 10 a.m. It also comes ashore during the late afternoon, usually between 5 and 6 p.m., and stays throughout the evening, before lifting after midnight. Visibilities are sometimes restricted in smoke from forest fires. Along the coast, Waskaganish is the airport most affected by smoke.

(c) Fall

Like Nunavik, flying conditions are more challenging during the fall transition period. The most dangerous icing conditions are associated with low-level stratiform cloud forming in the onshore and slightly upslope flow. These clouds consist mainly of large cloud drops, producing freezing drizzle and significant icing. These clouds usually top between 4,000 and 5,000 feet, where the icing is the most severe. The problem is further accentuated when the air temperature at the surface is between 0°C and -5°C. Several of the local carriers provide special training to their pilots, who will be operating into the coastal sites, on how to handle these conditions.

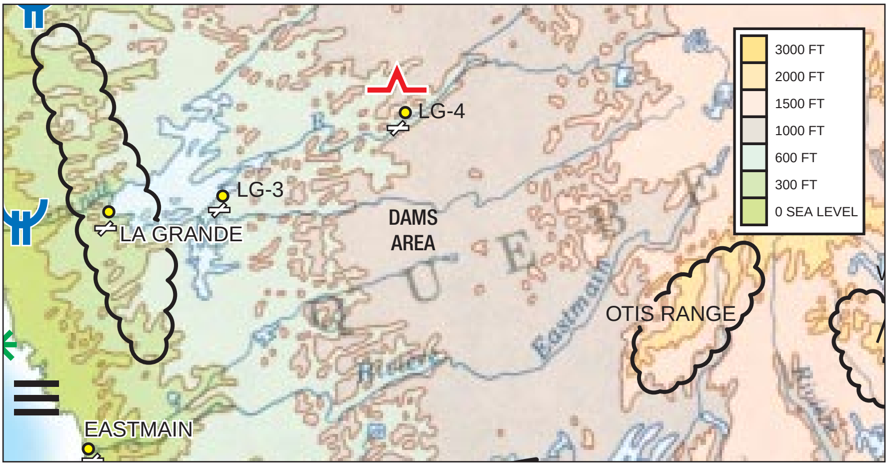
Although significant turbulence remains a rare occurrence in the fall, this is the season when it is the most frequent. Even scheduled flights are cancelled 3 or 4 times in the fall, usually in October or November, due to the dangerous turbulence associated with strong winds along the coast.

Low level clouds usually occur throughout the year. The associated ceilings are usually above 1,000 feet. Precipitation is more common in the afternoon than at any other time. Visibilities of 1/2 statute miles are frequent in precipitation, regardless if it is rain or snow. These lower visibilities are usually associated with westerly to northwesterly winds. Southerly winds in the summer generally result in higher values.

Wind shear layers are very rarely observed in the James Bay Area, regardless of the time of year. One problem area is Waskaganish, where northwesterly winds tend to be faster than anywhere else. Typically, Waskaganish may experience 30 knot winds while they may be 20 knots elsewhere. This is likely due to the localization of the airport deep in Rupert Bay, the latter acting like a funnel, accelerating the wind.

This phenomenon is less common in summer, due to the higher frequency of southerly winds. Speeds up to 50 knots have, however, been observed with northwesterlies in summer, when the air temperature reaches 28 to 30°C. This is likely due to a combination of funnelling and the stark temperature contrast between hot land and cold water temperature in the Bay.

Dams Area



Map 4-28 - Dams Area

A series of airports have been built to service Hydro-Quebec dams. The better known are those along the river called "La Grande Riviere": La Grande 2, La Grande 3, and La Grande 4. Other northern dams being regularly serviced are Nemiscau, Fontanges and Chute-des-Passes. Hydro Quebec has contracted out daily scheduled flights to and from these dams and the southern cities of Montreal, Quebec City, and Bagotville.

In normal years, the seasonal changes, from winter to summer conditions and vice versa, usually occur over a short two-week period. For example, the fall transition generally occurs around Halloween, October 31st. This is due to the fast freezing of rivers and lakes during very cold nights.

Throughout the year, turbulence and low level wind shears are very rare due to the general flatness of the landscape. They can, however, be encountered at some airports due to local rugged terrain. For example, southerly or southwesterly winds will produce crosswind turbulence at La Grande 4, due to the rugged terrain to the south of the airport and the east west orientation of the runway. Another case is with northerly winds at Nemiscau (elevation 800 feet), due to the presence of an 1,800-foot hill just to the north of the airport with a very steep southern face, causing strong downdrafts and moderate or stronger mechanical turbulence. Fortunately, these occurrences at Nemiscau are very rare as predominant winds are from the south or the southwest.

(a) Winter and Spring

Once the ice has set on the lakes, reservoirs, and rivers, visibility becomes bound only by the horizon, and the sky is generally cloudless. These excellent flying conditions are only interrupted when a large-scale weather system passes through the area. As a result, only 30 percent of Hydro-Quebec flights require an instrument approach. On extremely cold days (e.g. -45°C at night and -35°C during sunny days), ice fog may occur but it is rare and seldom affects flights. Similarly, engine-exhaust contrails, produced by the aircraft turboprop engines on take off, usually dissipate 200 to 300 feet behind the aircraft. These clear conditions usually last until the end of May. During the spring transition period, instrument approaches become more frequent and mud becomes an issue at some airports. Low pressure systems are moving through the area, at that time, with their clouds and precipitation. Easterly winds are then observed, announcing warm frontal weather conditions: nimbostratus and low level stratus, rain, drizzle and mist reducing ceilings and visibilities. These reductions are usually less severe than those observed in the fall.

(b) Summer

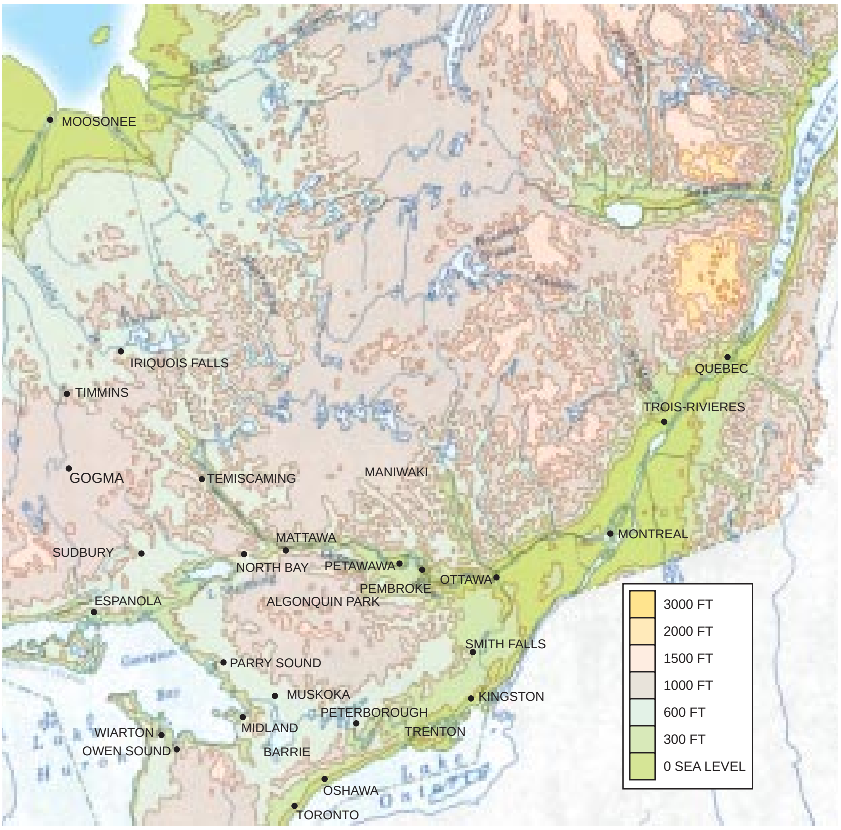
Summer flying conditions are usually not much of a challenge. Scattered or broken cumulus or stratocumulus cloud based at 3,000 feet AGL are generally encountered over the area. Lower conditions may occur when a warm front or a cold front goes through the area. Isolated thunderstorms can develop on moist and unstable days. Turbulence is rare, except for the convective turbulence associated with the cumulonimbus and towering cumulus (cumulus congestus). La Grande 3 Airport is subjected to localized turbulence close to the airfield on hot and sunny summer days. There is a sandpit 1/4 statute miles to the east end of the runway, immediately followed by a small land depression. On these days, fixed wing aircraft are subjected to a sudden loss of altitude, approximately 50 feet, as the aircraft moves over the ground depression after passing over the sandpit. This is caused by differential heating of the two ground surfaces by the sun.

(c) Fall

During the fall transition period, up to 70 percent of flights require an instrument approach. Easterly winds become more frequent as low pressure systems move through the area in an incessant ballet, bringing with them their warm frontal weather conditions. The cooling ground and shortening days contribute to the formation of mist and fog in the rain, thus reducing visibilities further. A change from rain to snow, or vice versa can also occur. Freezing precipitation can sometimes be observed as well.

Westerly winds from James Bay can carry very low stratus cloud, mist, fog and sometimes freezing drizzle in upslope circulation along the largest rivers up to 60 nautical miles inland. La Grande 3, not far away, is immune to these westerly low ceilings and visibilities. Light rime or trace icing is usually encountered in low pressure system cloud between 10,000 and 18,000 feet ASL. A quick transition through liquid-phase, low-level stratus coming from Hudson Bay (on approach or takeoff) does not seem to cause much of a problem for larger aircraft (Bombardier Dash-8 or Convair 580). However, the SLD icing and freezing drizzle generated by these low-level clouds may endanger small aircraft, which usually fly at these altitudes.

Northwestern Quebec

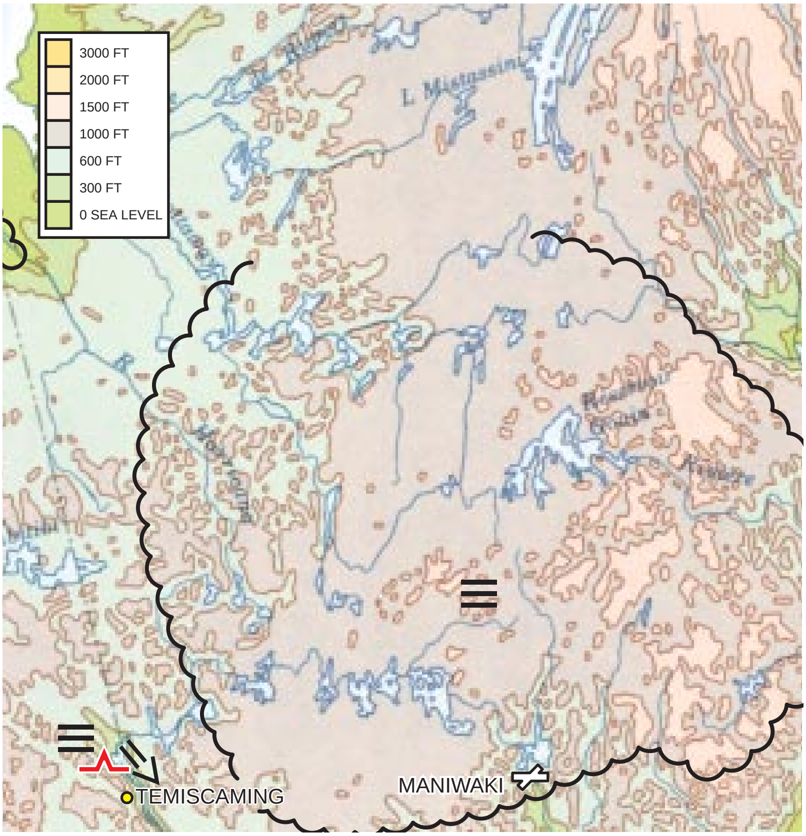


Map 4-29 - Northwestern Quebec

Northwestern Quebec, the area southeast of James Bay, essentially has two season of the year. In the dead of winter, a continental regime of cold arctic air prevails, giving excellent flying conditions along with frigid air temperatures that have their own adverse effects on ground operations and piston engines. Furthermore, jet engine exhausts being rich in moisture tend to generate ice fog.

Summer is the convective season. With the warmer temperatures thunderstorm activity is the main weather maker.

Chibougamau Mistassini Area



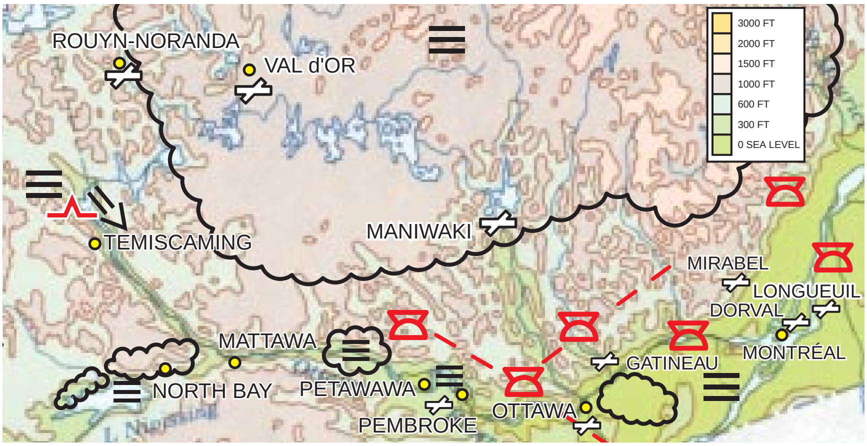
Map 4-30 - Chibougamau Mistassini Area

The terrain around Matagami is relatively flat with marshlands to the northwest and a large lake to the northeast. There is a hill to the east-northeast of the airport, which can generate significant turbulence when the wind comes from that direction. Northeasterly winds can bring fog over the airport in the fall. At any other times, flying conditions are usually good in Matagami.

Chibougamau is a different matter altogether. The land is much higher in Chibougamau than in Matagami. There are lakes in every direction from the airport with a very large one, Lake Mistassini, further to the northeast. There are also higher mountains to the north-northeast and to the east. As a result, winds coming from any of these directions can produce moderate or greater turbulence. Pilots report that clouds tend to close in faster than elsewhere while ceilings and visibilities lower very rapidly. As a result, flying conditions deteriorate much faster and much sooner in the Chibougamau area than anywhere else when a large-scale low pressure system moves in from the west or the southwest. Low stratus clouds, with bases around 400 or 500 feet AGL, are frequent and sometimes are even lower. Flights must frequently be redirected to a nearby airport where conditions are much better.

During the summer months, usually July and August, a quasi-permanent line of cumulonimbus clouds, producing thunderstorms, can be observed in a line passing to the south of Matagami and Chibougamau, and extending to the west and to the east of these two land marks. These thunderstorms usually reach their full development between 3 and 4 pm.

Abitibi Area



Map 4-31 - Abitibi Area

Most of the weather problems in this area occur during the summer or the fall. During the winter the continental regime which predominates generally results in excellent flying conditions. Strong southwesterlies can sometimes push lake-effect streamers generated over Lake Huron and Georgian Bay all the way to Val d'Or. Freezing precipitation is a very rare occurrence in this area. Local weather specialists could only recall two cases of freezing rain in early winter over a nine-year period.

The weather conditions in the western portion of the area seem to be somewhat poorer than further east. This might is likely due to the presence of Lake Abitibi to the northwest and a better alignment with James Bay with the onset of northerly winds, generating upslope flow over rising elevations.

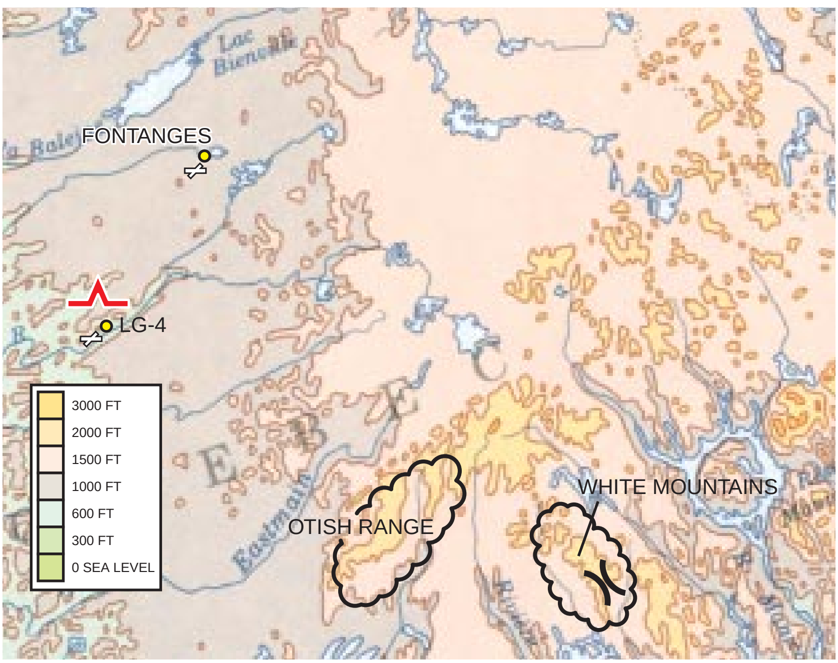
Summer convection tends to create challenging flying conditions. The nature of the terrain and the vegetation combines with favourable weather conditions to give frequent, strong and violent thunderstorms with hail, weak tornadoes (F0) and "Chablis", especially in the La Verendrye Park, situated to the southeast of Val d'Or. Some of the affected areas are well travelled due to fish being abundant in many lakes.

A "Chablis" is a localized-forested area where all or most trees have been felled in either in a line or a star or spiral pattern. The line is usually indicative of a very strong gust front. The star pattern is usually indicative of a downburst or a microburst while the spiral is usually produced by a weak tornado. At other times, high-based (often 10,000 feet) towering cumulus clouds are frequent in the summer. It is prudent to watch for telltale signs of strong descending winds, causing downbursts or microbursts and severe turbulence. These signs can be a swirl of dust at the surface underneath the cloud or the presence of virga. The complete evaporation of the rain aloft results in adiabatic cooling which generally results in a significant acceleration of downward winds and an increase of the associated turbulence.

Cold fronts tend to be very strong and to accelerate as they move across the Abitibi area in August, fall and winter. Large and rapid temperature drops are often noticed with the passage of the front. Behind the front the northwesterlies often generate 1,000-foot thick stratocumulus clouds based around 3,000 feet AGL until the lakes freeze over in the fall.

Throughout the Abitibi area there seems to be some delay in clearing lower clouds after the onset of a northwesterly circulation in the fall and in the spring with regard to other times of the year.

Otish Range and White Mountains Areas



Map 4-32 - Otish Range and White Mountains Areas

The Otish Range is oriented along a southwest-northeast axis with peaks up to 3,725 feet ASL. Low-level clouds tend to hang on along the Otish Range with very low ceilings and very poor visibilities and no holes in the clouds to pass through. Ceilings and visibilities improve somewhat when there are very strong winds. However, aircraft have to handle moderate to severe lee wave turbulence.

The White Mountains, with peaks up to 3,400 feet ASL, are surrounded by the Riviere-des-Montagnes-Blanches to the west, the Manouanis River to the south, the Outardes River to the East, Pletipi Lake to the northeast, and the Lac-aux-Deux Decharges to the north. The area is rugged with very narrow river valleys. When weather conditions go bad, pilots have nowhere to go.

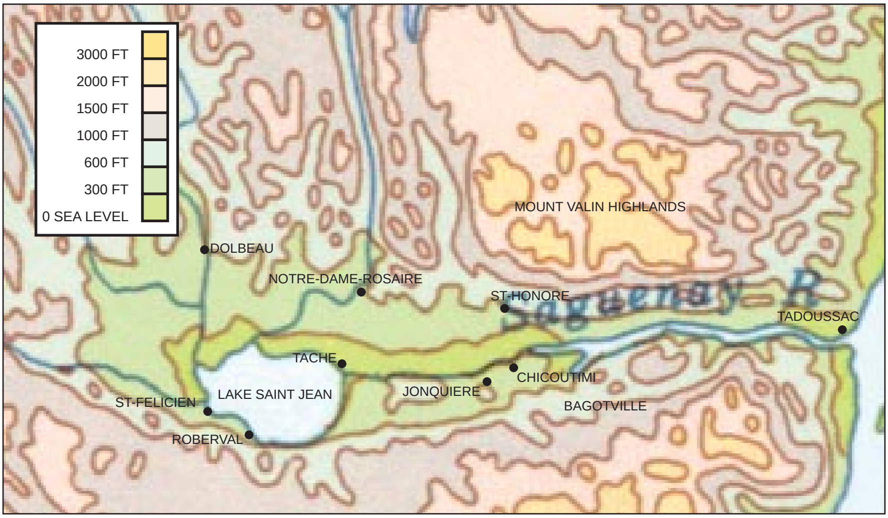
Saguenay, Lake Saint-Jean, and surrounding mountainous terrain

The weather conditions in the Saguenay River Valley and surrounding area are strongly influenced by Lake Saint-Jean itself and the mountains surrounding the valley. As a moisture source, Lake Saint-Jean usually freezes in early December and its ice melts in early May.

When the trajectory of large-scale, low-pressure systems is to the north of the Saguenay River Valley, this induces a southwesterly flow over the area (except in the valley itself). Most of the precipitation falls over the Laurentides Wildlife Reserve and little falls in the valley. On the other hand, if the trajectory is south of the valley, predominant winds are from the east and most of the region can expect generous precipitation and low ceilings and visibility. The general circulation is from the northeast, the Mount Valin Highlands act as a barrier, offering good protection and resulting in minimal precipitation amounts.

Local effects

Saguenay River Valley



Map 4-33 - Saguenay River Valley

Throughout the year, predominant winds tend to be aligned with the valley. Easterly winds are generally associated with deteriorating weather conditions while westerlies are a precursor of fair weather or clearing. Poor weather conditions associated with an approaching large scale low pressure system usually reach the airport of St-Honore three to four hours after reaching Roberval.

Winds aloft, however, are frequently from the southwest. Low-level wind shear near the ground is a rare occurrence in the upper Saguenay River Valley. When present, the wind shear is usually encountered between 1,500 and 3,000 feet ASL in the St-Honore area. The altitude and strength of the wind shear usually depends on the intensity and height of the temperature inversion.

Pilots usually avoid flights in the lower Saguenay River Valley (also know locally as the Saguenay Fjord) due to its narrowness, its deep canyon-like topography and the presence of high power electric transmission lines crossing the river. As a result, little information is available for the Fjord. Experienced pilots, who have occasionally used that route, have indicated the occasional onset of moderate to severe mechanical turbulence from L'Anse-St-Jean to Tadoussac, then along the north shore of the St. Lawrence toward Charlevoix.

Low-level moderate mechanical turbulence is often encountered over an area extending from the western half of Lake Kenogami, up to and including the northern bank of the Saguenay River.

Due to the shape of the valley, there is a sharp funnelling of northwesterly winds, resulting in frequent westerly winds of 40 knots, or above, over the river. Wind speeds of 70 knots have been reported on occasion by Coast Guard ships in the Fjord.

(a) Spring

Flying conditions are usually fair in the valley. When clouds are observed, pilots in the area report cloud bases are typically between 3,000 and 4,000 feet ASL. North of the Saguenay River, just to the east of Lake Saint-Jean, when the wind is from the south or the southwest, fog is sometimes observed in April and May. This fog often lasts all day. Light rime icing in cloud is encountered at altitudes of 5,000 to 10,000 feet ASL, in early spring.

(b) Summer

Flying conditions are generally favourable in the valley. Thunderstorm activity tends to remain over mountainous terrain during the day, drifting toward the valley in late afternoon. Most thunderstorms tend to follow one of two tracks situated on either side of the valley. The southern track starts south of Lake Saint-Jean and continues eastward, passing to the south of Canadian Forces Base (CFB) Bagotville. The northern track begins at Dolbeau and follows the southern edge of the Mount Valin Highlands.Some of the strongest thunderstorms, producing hail, are often found along this northern track, between Lake Labrecque and Lake Sebastien. The visibility easily lowers to 5 statute miles in the rain and sometimes as low as 3 miles. Pilots report that convective clouds usually tend to develop from Alma to Bagotville with a base between 3,000 and 4,000 feet ASL. On these days, light to moderate convective turbulence can be expected over most of the valley flat lands. This is common in June, July and August.

(c) Fall

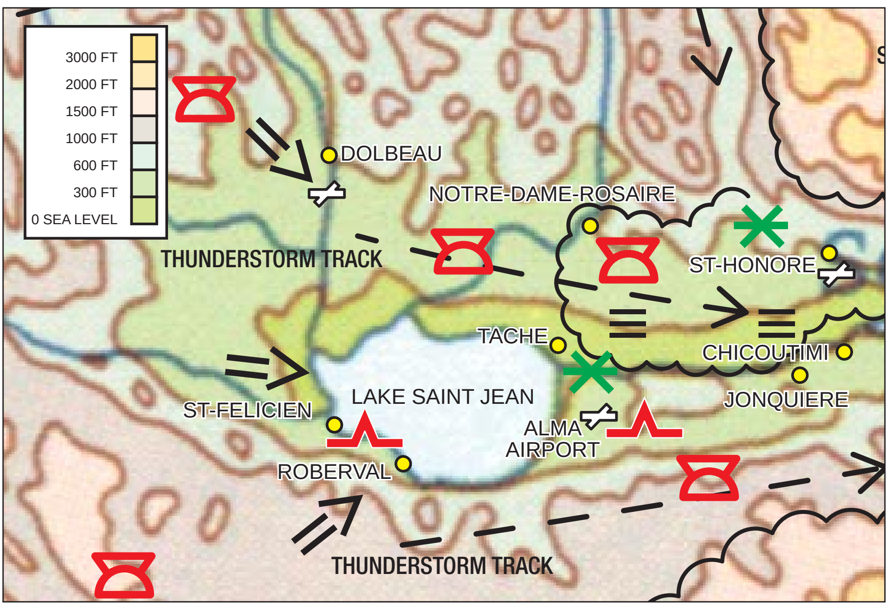
In October, fog is often observed just to the north of Lake Kenogami. In the same month, fog often forms over the Saguenay River just after sunrise, extending to just south of the St-Honore Airport with light southwesterly winds, lasting all morning and dissipating around noon. When the wind increases, the fog bank can extend to the southern half of this airport. From mid-November to late-December, low stratus clouds (with ceilings around 1,500 feet above ground), virga and snow (with visibilities as low as 1-1/2 statute miles) are frequently encountered in an area extending northward from the Saguenay River to the hills, and bound by Tache, Notre-Dame-du-Rosaire, St-David-de-Falardeau and St-Honore. Further to the east up to the foothills, cloud ceilings lower to 1,000 feet above sea level. From late-October to mid-December, clouds are ever present with a cloud base varying between 1,500 and 2,000 feet. Snowfalls come in waves, usually caused by arctic air moving over the still-warm waters of Lake Saint-Jean, amassing moisture and energy, and producing strong convection. Vsibilities can lower to 1/8 statute mile in these heavy snowshowers.

Freezing precipitation is a rare occurrence in the valley. On these occasions, this is freezing drizzle which is generally being reported. It happens when the air temperature in the valley remains around zero to -2°C, although the warm air and the associated rain may reach the terrain north of the valley. The wind in the valley is then predominantly from the east.

(d) Winter

Flying conditions are usually excellent in the valley once Lake Saint-Jean freezes over, save for the occasional snowfalls usually due to large-scale low pressure systems. The weather regime becomes continental with very cold temperatures. Flying then becomes mostly limited by these frigid temperatures, although the sky is usually clear and the visibility unrestricted. When the wind blows from the west-northwest in late fall and winter, there is an area between Larouche and Jonquiere where snowshowers tend to last longer than elsewhere. A visibility of 3 statute miles is common in snowy precipitation. On very cold days, mist or ice fog is often observed in the Chicoutimi area due to the presence of open waters in the Saguenay River, up to the Shipshaw hydroelectric dam and moisture laden smoke coming from the various aluminium- and paper-making plants.

Lake St. Jean Area



Map 4-34 - Lake St. Jean Area

Throughout the year, weather conditions are generally favourable to low-level flights. The predominant winds are usually from the southwest to the northwest. Most of the thunderstorms form over the hills surrounding the lake in the summer and remain there. Others that are north and south of the lake move east toward the Saguenay River Valley.

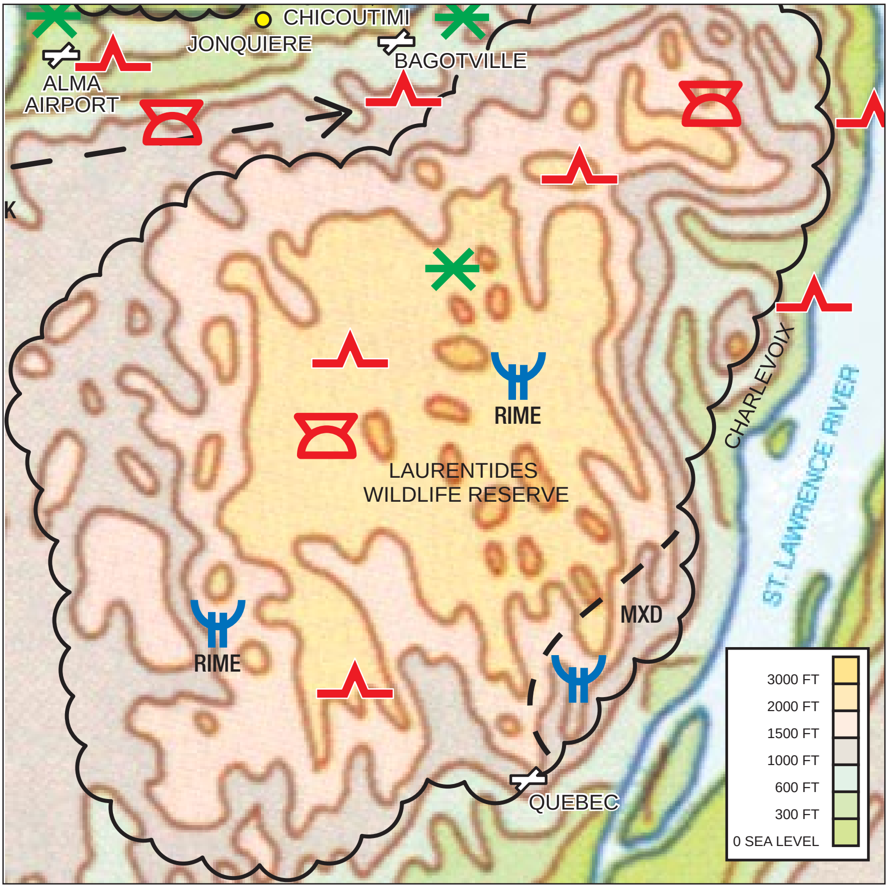
Fog tends to form over the lake in May with the arrival of warmer airmasses and their passage over the near-freezing waters and remaining ice floes. The fog is then transported inland by the generally associated southwesterly flow.

There are three airports around the lake (Alma to the east, Roberval to the southwest, and Dolbeau to the northwest) and three hydrobases (St-Felicien to the west, Roberval so the southwest and Alma to the east). These airports and hydrobases are well situated since predominant winds are coming from the land instead of the lake. This is especiallt true for Alma, where the airfield is sufficiently to the south to be out of the main track followed by the fall lake-effect snow. The runway in Dolbeau is well aligned with the predominant winds, thus reducing the occurrence of mechanical turbulence. In Alma, crosswinds are frequent but the forest nearby acts as a screen and the wind dies down on the runway. There can be some mechanical turbulence on approach, however. There may also be some convective turbulence over the lake in the fall but pilots seldom fly over the lake, usually electing to follow the shoreline.

Pilots are reporting that cloud ceilings are generally above 3,000 feet ASL and visibility above 6 statute miles around the lake. They also report the presence of a very localized high-pressure system around the lake in the summer, likely due to the cold water.

Mechanical turbulence and wind shear are rare occurrences around the lake. There is, however, a small section of the shore to the southwest of the lake where mountainous terrain approaches the shoreline. This closeness generates low-level moderate mechanical turbulence over a distance of approximately 10 nautical miles, with occasional low-level wind shear. This turbulence is more prominent in the summer than in winter.

Laurentides Wildlife Reserve



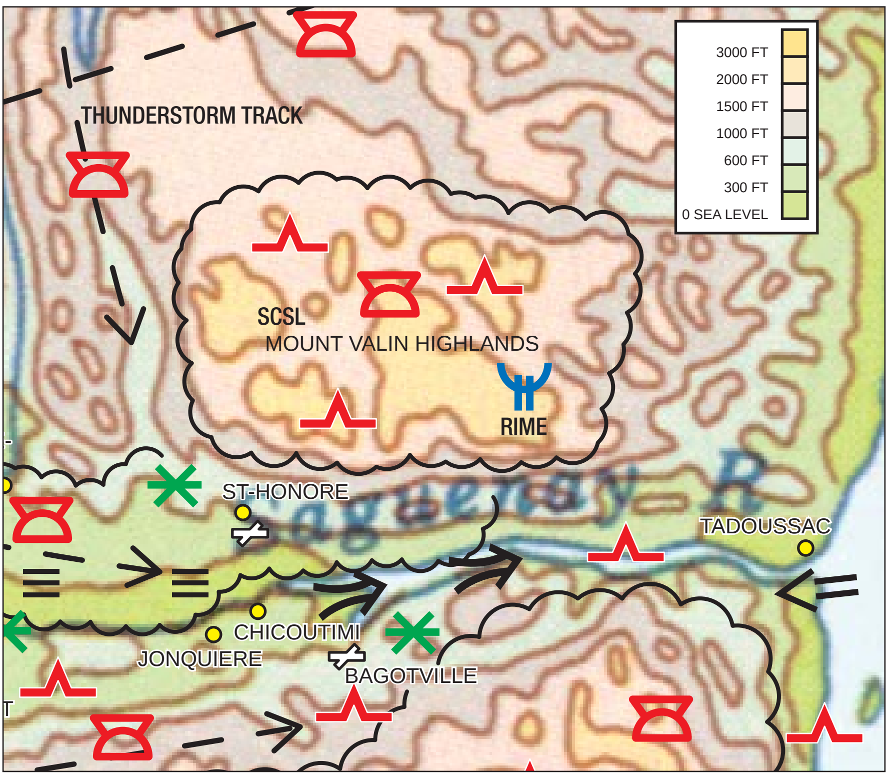
Map 4-35 - Laurentides Wildlife Reserve

Low-level clouds are predominant over the Laurentides Wildlife Reserve, formerly known as the Laurentides Park. This is a vast area of rolling highlands, part of the Canadian Shield, which culminates at 3,825 feet ASL. There is an upslope circulation from every wind direction. Additionally, the nature of the terrain favours the convective activity. As a result, the Laurentides Wildlife Reserve is cloudy most of the year. Pilots report that clear skies may be encountered in this area only 6 or 7 days per year. Cloud bases are usually above 1,000 feet, which means that these clouds frequently obscure the mountaintops. The base can be less than 1,000 feet if the airmass is very unstable. Beneath the clouds, low visibility is frequent in mist or in precipitation. The lowest ceilings and visibility are generally in the fall and in winter. Local pilots have noted that the top of the clouds over the wildlife reserve is usually found between 6,000 and 8,000 feet ASL. The first snowfall in the Laurentides Wildlife Reserve usually occurs in mid-September.

Pilots also report the presence of a permanent area of moderate mechanical turbulence and wind shear below 6,000 feet ASL along the foothills, extending east-south-eastward from the eastern tip of Lake Kenogami for at least 20 nautical miles. This is usually observed when the wind is from the south or the southwest. Pilots of smaller planes flying at 3,000 feet ASL, on approach to the Bagotville Airport, sometimes report moderate to severe mechanical turbulence when crossing this narrow area. A seasoned flight instructor has reported that a safety belt left inadvertently unbuckled has resulted in his head hitting the cabin roof. Even when buckled in, pilots and passengers can feel themselves lifting off their seats for a few seconds. This occurs only when there is no snow on the ground. Elsewhere in the wildlife reserve, light to moderate mechanical or convective turbulence is common with the type of turbulence depending on the weather situation.

Light to moderate rime icing can be expected near the cloud tops, usually around 7,000 feet above sea level. Pilots report a change to moderate mixed icing near the cloud top when they reach the mountains at the southern edge of the Laurentides Wildlife Reserve.

Mount Valin Highlands



Map 4-36 - Mount Valin Highlands

Weather conditions over the Mount Valin Highlands are very similar to those found over the Laurentides Wildlife Reserve. If anything, some situations can produce even more dangerous flight conditions. For example, moderate to severe lee wave turbulence, producing stratocumulus standing lenticularis (SCSL) are a frequent occurrence over the Mount Valin Highlands and can extend further east or southeast depending on the winds aloft. These clouds and the lee wave turbulence are commonly found at altitudes up to 6,000 feet ASL, but may sometimes reach higher altitudes. These wave-like bands of lenticular clouds can often be observed on visual pictures taken from weather satellites, when there are no other cloud layers above.

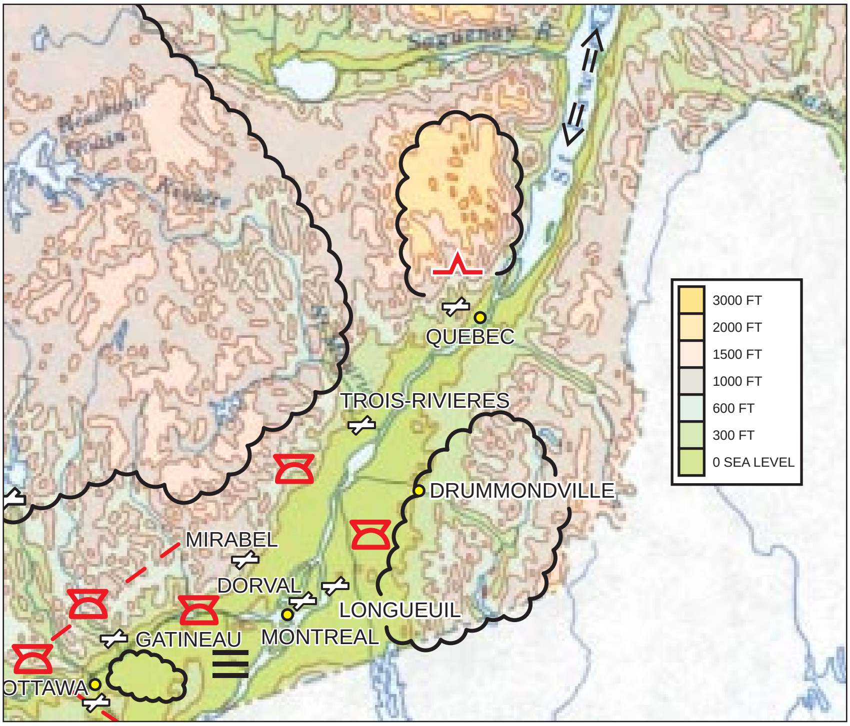
(a) Summer

Thunderstorms are frequently observed over the area in the summer. Isolated cumulonimbus clouds sometimes form over the Highlands moving southward along the Shipshaw River, in late morning or in the afternoon.

(b) Fall and winter

Light to moderate rime icing is often encountered over the Mount Valin Highlands between 5,000 and 6,000 feet ASL, in the fall or in winter. Pilots also report the frequent occurrence of 500-foot obscured ceilings and visibility of 1/2 statute miles in fog or precipitation over the area.

Saint Lawrence river valley and surrounding terrain



Map 4-37 - Saint Lawrence river valley and surrounding terrain

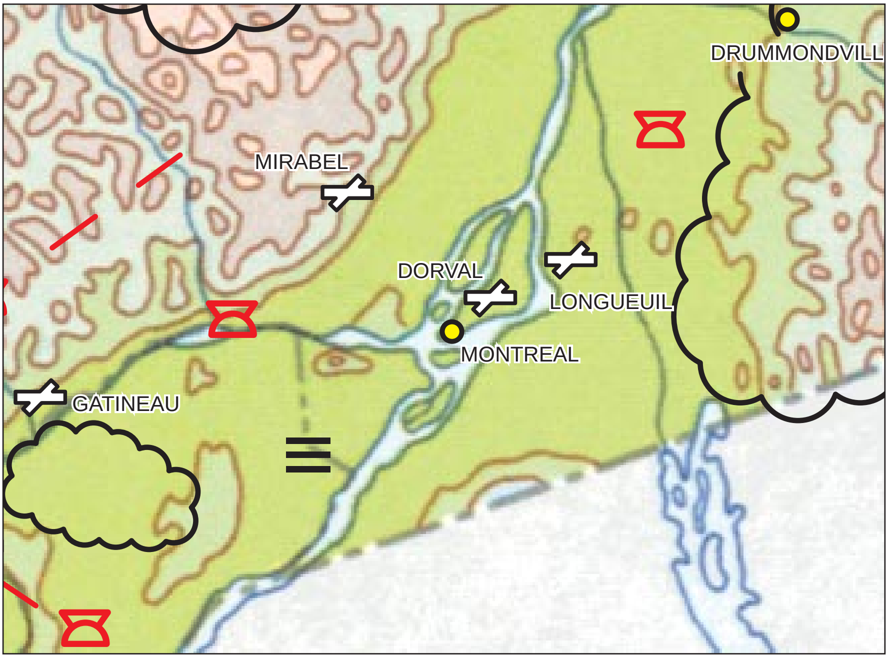
The southwest to northeast orientation of the Saint Lawrence River has an important influence on the weather. At the same time, the difference in latitude throughout the valley results in climatological variations such as seasonal regimes and the onset of thaw and freeze-up.

Most of the time the large-scale weather systems originate from the west (Alberta Clippers or Great Lakes Lows) or the southwest (Colorado Lows). In some instances, however, as is the case with Hatteras Bombs or cold lows, clouds and precipitation may arrive from the south, east or the north.

One of the great forecast challenges in this area is associated with system re-developments on the eastern side of the Appalachian Range. A Great Lake Low which moves straight east often weakens as it hits the western edge of the Appalachians. A new low develops on the eastern side and moves off to the north, or northeast, shifting the precipitation pattern with it. In situations like these, the western section of the valley is hit by precipitation from the west that tapers off as the initial low dissipates. As the redeveloped low forms, and if its trajectory is sufficiently northerly, the precipitation will then spread into the remainder of the valley and could even wrap around the low, hitting the western section once again but from a different direction.

Local effects

Greater Montreal and Monteregie



Map 4-38 - Greater Montreal and Monteregie

Throughout the year, the land south of Montreal, commonly known as Monteregie, is mostly devoted to agriculture. The terrain is flat with a few hills scattered throughout the area. These hills are not that large but still pilots report the occasional occurrence of lee turbulence near Mount Rougemont, Mount Yamaska, Mount St-Hilaire, and Mount Shefford.

When bad weather occurs, the lowest ceilings tend to occur north of Montreal, rather than south. It usually takes approximately two hours for poor weather to move from Montreal-Mirabel International Airport to the Montreal / St-Hubert Airport on the south shore. Low stratus clouds are rather rare over the Montreal / St-Hubert Airport, unless there is nimbostratus producing continuous precipitation. In this case the combination of the precipitation and mist or smog tends to lower the visibility to near 3 miles.

In the presence of generally southerly circulation, either at the surface or aloft, precipitation associated with large-scale low pressure systems approaching from the west often reaches the Montreal-Mirabel International Airport, but dissipates before reaching Montreal-Dorval International Airport.

Depending on the direction, the winds often vary between Montreal-Dorval International Airport and Montreal-Mirabel International Airport. Southwesterly winds tend to be stronger at Montreal-Dorval than at Montreal-Mirabel. Montreal-Dorval typically will report winds 15 gusting to 25 knots while Montreal-Mirabel will be reporting only 5 knots. In a light southerly circulation ahead of a large-scale low pressure system, Montreal-Dorval International Airport often registers a south-easterly wind of 5 to 10 knots while Montreal-Mirabel International Airport will report a northeasterly wind of 5 to 10 knots. Northwesterlies tend to be slightly weaker at Montreal-Mirabel International Airport than at Montreal-Dorval International Airport.

Fog is another phenomenon which occurs throughout the year. Fog, with visibilities of 5/8 statute miles or less, is much more frequent over and in the vicinity of the Montreal-Mirabel International Airport, than in Montreal-Dorval International Airport. It is also more frequent at the Montreal/St-Hubert Airport than at the Montreal-Dorval International Airport. In the first case, this is likely due to cold air draining from the mountains to the north of the Montreal-Mirabel International Airport. For the same reason, the fog tends to persist longer, not dissipating until the late morning. In the Montreal / St-Hubert Airport, the fog tends to be localized over the northeast section of the runway complex. The fog layer tends to be shallow, typically 15 to 30 feet thick. It tends to form in the evening and lasts most of the night. On occasion, a quick reformation of the fog can be observed early in the morning but it does not persist for long. The most likely cause of this fog is a light drainage wind from the surrounding built-up area stirring the air laden with moisture from the city and local soils. Montreal-Dorval is sheltered from this development, however, the ceiling and visibility tends to lower with an easterly wind due to the moisture and drainage coming from downttown Montreal Downtown and oil refineries further east.

The lowland area north of the Saint Lawrence River, between Mascouche and Lake St-Pierre, is drier with widespread low ceilings and visibilities being rare occurrences. Elsewhere, the geographical environment often combines with winds to generate low level wind shear and/or turbulence. Pilots landing at the Sorel airfield often encounter moderate turbulence on final approach when the wind exceeds 15 knots. This wind and turbulence will cease abruptly as the plane lands, likely due to the forest that surrounds the runway. In St-Mathieu-de-Beloeil, moderate turbulence is common on take off and landing when westerly winds of 15 knots or greater are present, likely due to eddy effects from several buildings built along the runway.

(a) Spring

Low level stratus ceilings, around 1,200 feet, tend to be common in the Monteregie with northwesterlies. Over the Montreal archipelago and north, up to Montreal-Mirabel International Airport, clouds tend to scatter out with cloud bases around 2,000 feet. Further to the north, cloud bases tend to be lower.

(b) Summer

Thunderstorm activity is the main problem in the summer. Depending on the degree of instability of the atmosphere, scattered thunderstorms (cumulonimbus) and shower-producing towering cumulus (TCU) can develop rapidly. Typically, showers develop in the early afternoon with the thunderstorms holding off until the late afternoon, around 4 p.m. These thunderstorms can also form into an organized line. These thunderstorms are stronger in intensity and generally follow one of three tracks, depending on wind direction aloft. One of the tracks, the northern track, follows the Lower Laurentian foothills, passing over Montreal-Mirabel International Airport in a northeasterly direction. Another extends from Alexandria in Eastern Ontario, passes near Valleyfield, and then moves toward Lake Champlain. The third track lies mostly over the South Shore, just south of the Montreal Island toward Victoriaville and then continuing northeastward.

Pilots report that thunderstorms tend to be the most severe along the northern track, especially in the St-Jerome and Joliette areas. There is a high occurrence of localized cumulonimbus, based around 1,500 feet, producing funnel clouds over the St. Lawrence River, especially near Valleyfield, when the air is humid and unstable. Thunderstorms tend to dissipate over Montreal Island and redevelop over the south shore.

There is little occurrence of fog at Montreal-Dorval International Airport during the summer. There is, however, an area south of the Saint Lawrence River, bordered by Montreal / St-Hubert Airport, Iberville, Farnham, Bromont, Gramby, and St-Mathias, where mist (visibilities greater than 5/8 statute miles but less than 6 statute miles) tends to linger on.

Haze can be a problem in the greater Montreal area, more so than elsewhere in southwestern Quebec. Haze is caused by high levels of pollutants and humidity in the lower strata of the atmosphere. Although not an immediate hazard, the haze tends to reduce the visibility, blur details, and make navigation more challenging when facing into a setting or rising sun.

Moderate wind shear and turbulence are sometimes encountered by pilots south of Montreal, during flights at night. These usually occur at 2,000 to 3,000 feet above ground, in the presence of a warm front and a low-level jet stream. This may cause a 45° drift during a flight.

(c) Fall

Over the Monteregie, northwesterlies often result in a low level cloud deck, with ceilings of 1,100 to 1,200 feet above ground. North of the Saint Lawrence River, however, these winds generally result in much better conditions, such as in Mascouche or Joliette.

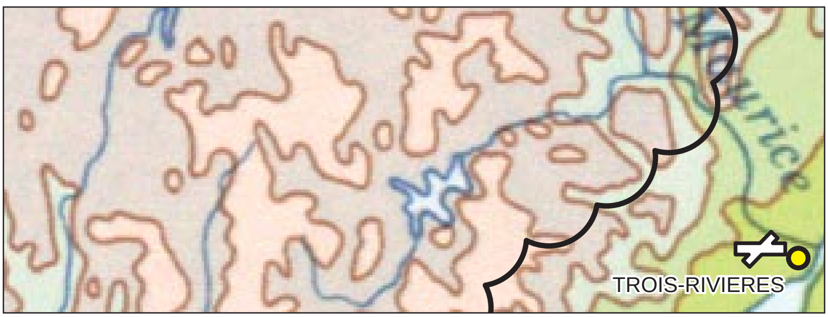
One of the great forecasting challenges in the fall is that of precipitation type. It is common to observe rain in the valley and snow in the mountains. Sometimes, Montreal-Dorval International Airport will report light rain while ice pellet or freezing rain is falling at Montreal-Mirabel International Airport. On occasion, Montreal / St-Hubert Airport will stay in the warm sector, south of the warm front (eg. +10°C), while the air temperature at Montreal-Dorval International Airport remains below freezing. Similarly, when the air temperature rises above freezing at Montreal-Dorval International Airport, it tends to remain below freezing for a longer period of time at Montreal-Mirabel International Airport.

(d) Winter

As in the fall, warm fronts tend to linger on between Montreal-Dorval International Airport and Montreal / St-Hubert Airport, along the Saint Lawrence River. Ice fog is also a common winter occurrence at Montreal / St-Hubert Airport, while it tends to be rarer at Montreal / Dorval Airport.

Southerly winds tend to become a problem in winter at Montreal / St-Hubert Airport, since runway 28 is not maintained in winter, thus creating crosswinds on the remaining runways.

Lower Laurentians

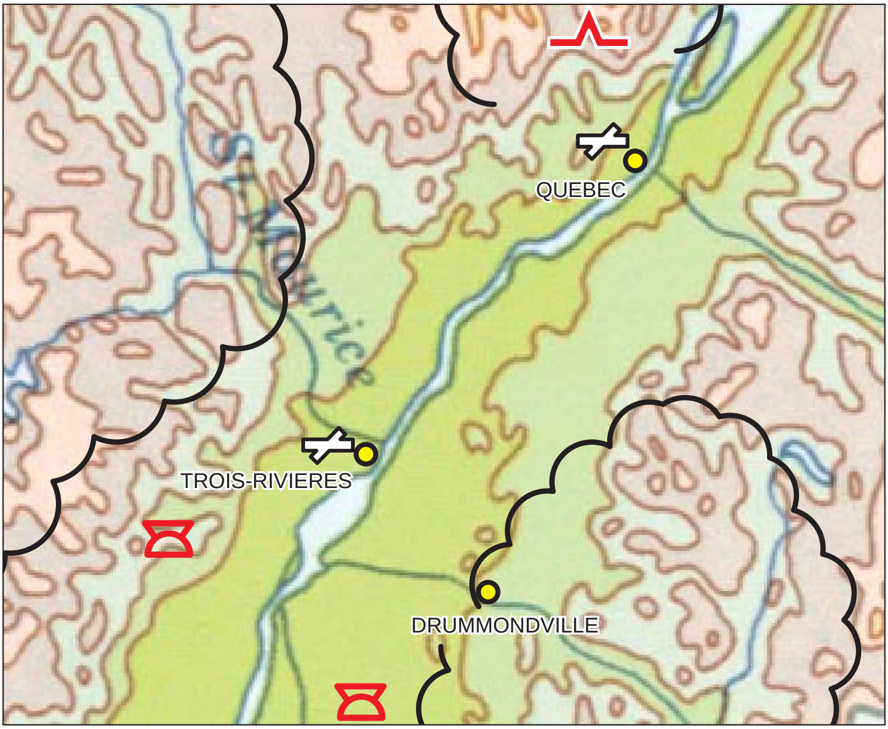


Map 4-39 - Lower Laurentians

Over the mountainous terrain of the Lower Laurentians, stratus clouds with a base around 3,000 feet above sea level are often observed by pilots, resulting in some mountain tops being hidden by clouds. Fog and mist are frequently associated with this cloud. The cloud tends to become patchy in the afternoon and sometimes will dissipate entirely in late afternoon. Further to the north, cloud bases tend to be lower, especially when the wind blows from the northwest. Clouds and fog tend to be particularly extensive during the summer months.

Thunderstorm activity is a common summer occurrence over the Lower Laurentians, especially south of a line extending from Fort Coulonge on the Quebec Ontario border, to St-Jovite to St-Gabriel, near Lake St-Pierre.

Quebec City - Trois-Rivieres - Drummondville Area



Map 4-40 - Quebec City - Trois-Rivieres - Drummondville Area

Greater Quebec City Area

South of the Saint Lawrence River, but north of the Appalachian foothills, offers the best conditions for flying. The area situated to the east of the Chaudiere River usually has good visibility and, when clouds are present, their base tends to vary between 4,000 and 5,000 feet ASL. West of the Chaudiere River, the base of the cloud tends to be slightly lower, usually around 3,000 feet ASL.

During the summer months, convective clouds are common and cumulus clouds are often based around 2,000 feet along the south shore of the Saint Lawrence River. On hot and humid days, when the air temperature reaches or exceeds 28°C, haze becomes widespread, lowering the visibility as low as 5 statute miles. When there is rain, the visibility tends to be 5 statute miles or greater, while cloud bases vary between 1,500 and 2,000 feet above sea level. If mist forms in the rain, then the cloud base lowers further, to below 1,000 feet above sea level.

Clouds tend to be predominant in the area between the Saint Lawrence River and the Laurentians foothills, especially north of Quebec City. It is in this area that Canadian Forces Base Valcartier is situated, with its heliport at an elevation of 550 feet.

During the summer months, thunderstorms form over the Laurentians Foothills and Mount Belair, moving in a southeasterly direction toward the town late in the day. During the rest of the year, from the time the snow melts in the spring until lakes and rivers freeze up in the fall, fog is a concern.

Drummondville

Pilots report an interesting microclimate effect around Drummondville. It seems to delineate poor weather. When lower ceilings and visibility is reported, such as in snow, to the east of Drummondville, conditions tend to be much better west of Drummondville. When the lower ceilings and visibilities are reported west of Drummondville, conditions are much better east of the city.

Drummondville frequently tends to have better weather than both Montreal and Quebec City. For example, clouds could be based at 3,000 feet above sea level within a radius of 20 nautical miles of Drummondville, while much lower ceilings and visibilities prevent flights for fixed wing aircraft in both Quebec City and Greater Montreal areas.

Trois-Rivieres

When a large-scale low pressure system approaches Montreal, the Trois-Rivieres Airport tends to be much slower to see lower ceilings and visibility than both Montreal and Quebec City.

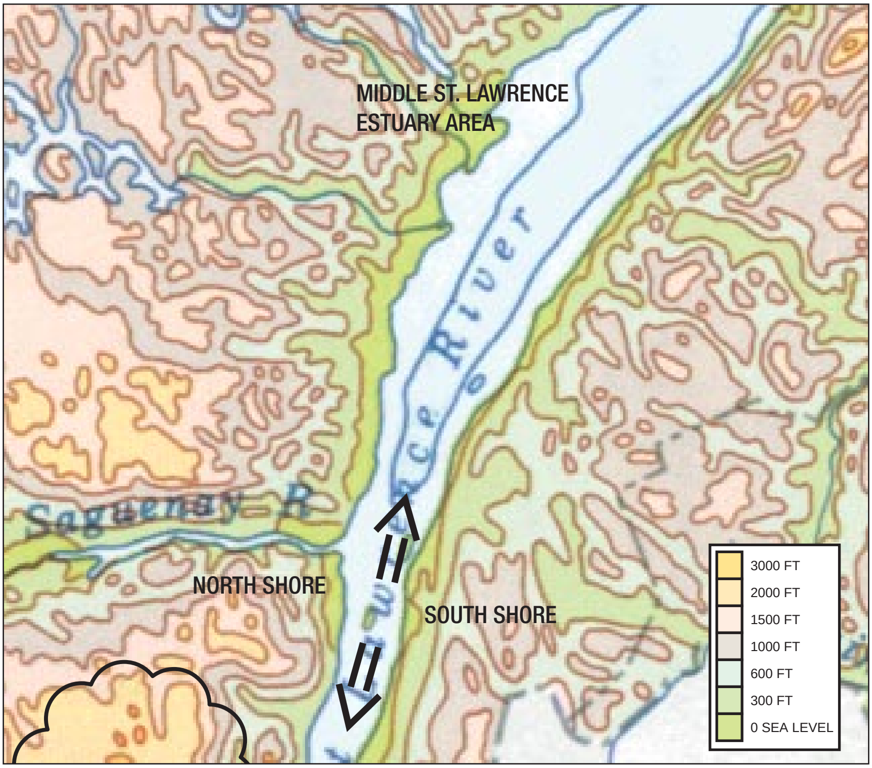
The Trois-Rivieres Airport is seldom affected by lake breezes coming from Lake St-Pierre. On the other hand, crosswinds and the associated low level turbulence are common when the wind blows from the southeast or the northwest. Wind shear, however, is a rare occurrence in Trois-Rivieres.

In the fall, the general cloud base is around 5,000 to 6,000 feet above ground over the Trois-Rivieres area, with a lower broken cloud layer based at 400 or 500 feet above ground over the actual airport. The lower cloud layer tends to dissipate around 11 am. East of the airport, toward Quebec City, a cloud layer based at 1,500 feet above ground is often observed.

The behaviour of fog at the Trois-Rivieres Airport is similar to Montreal / St-Hubert Airport, especially in summer and fall. The fog tends to be localized and shallow, often forming in the evening and persisting through much of the night. At times, fog may form in the early morning but soon dissipates.

Middle Saint Lawrence Estuary Area

South Shore Area



Map 4-41 - South Shore Area

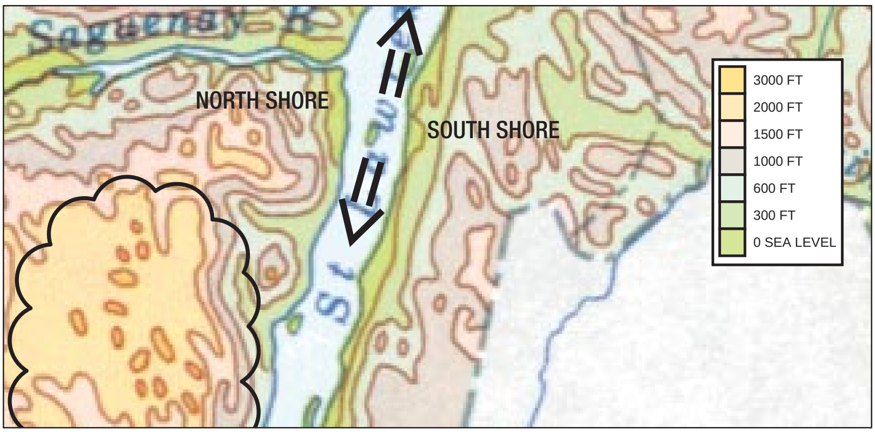
The poorest weather is usually associated with northeasterly winds, especially ahead of approaching low pressure systems. Due to the funnelling effect of the valley between the mouth of the Saguenay River and Orleans Island, the northeast winds tend to be very strong, with gusts sometimes exceeding 50 knots. The cold waters of the St. Lawrence River keep the air cool and favour the formation of fog. In late fall and early winter, the northeasterlies, combined with open waters, produce very low visibilities and ceilings in moderate to heavy snowfalls. Pilots frequently report moderate icing in cloud below 6,000 feet, over the river and along the south shore, often extending to the hill range. Throughout the winter, the area surrendering Montmagny generally gets twice the snowfall amounts that Quebec City gets.

Further inland, over the mountains and toward the border with Maine, cloud bases are usually between 3,000 and 5,000 feet above sea level.

West to southwest winds usually bring better flying conditions, with scattered to broken clouds. There is one exception, however. The onset of very cold arctic air after the passage of a particularly intense cold front can generate intense frontal snow squalls, with visibilities of 1/4 statute miles or less, and obscured ceilings near or below 200 feet. This phenomenon is usually short lived, typically one to two hours, over a specific location but it stays with the front as it swipes across the province. An abrupt reduction in ceiling and visibility, very strong and gusty northwest winds, moderate or greater turbulence, and a rapid drop in air temperature usually accompany these frontal squalls. The improvement behind the front can be equally as abrupt.

The best weather comes with south to southwest winds that generally result in warming air temperature and mostly sunny days.

North Shore Area



Map 4-42 - North Shore Area

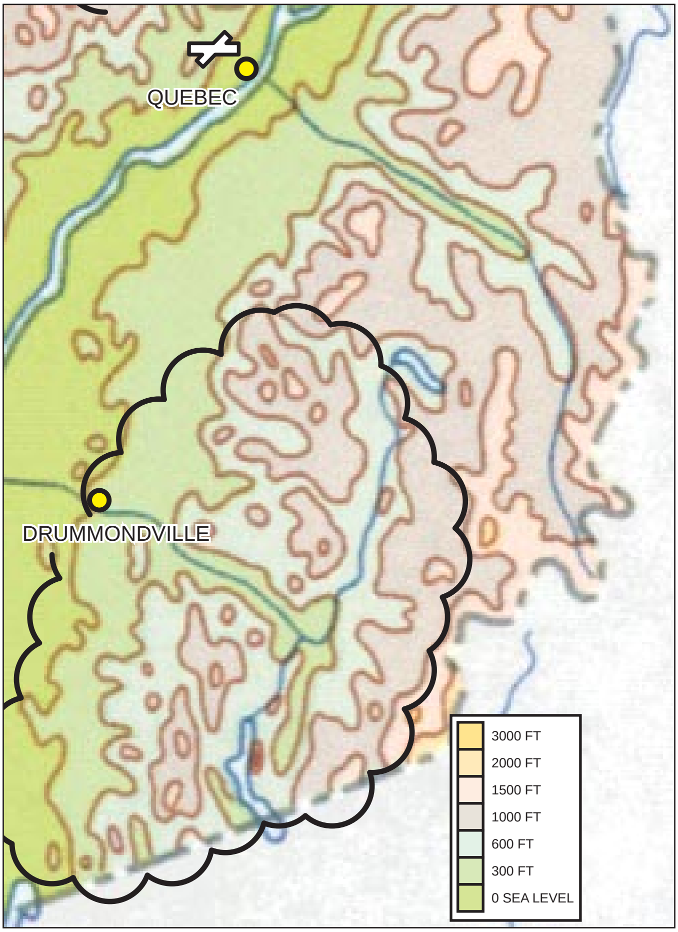
Along the north shore, northeasterlies and southwesterlies are the prevalent winds. The northeasterlies usually announce the arrival of poor flying conditions, with very low cloud bases, thick cloud layers and low visibilities in precipitation. This is especially true when there are strong south to southwest winds aloft pushing warmer and moist air over the area, while the surface air remains much cooler due to the influence of cool St. Lawrence river waters.

Northerlies and northwesterlies usually result in excellent ceilings and visibilities as the air subsides along the southern mountain slopes. These strong katabatic winds do, however, generally result in moderate to severe turbulence, especially in the area between Baie-St-Paul and the mouth of the Saguenay River.

Eastern Townships and Beauce

The mountainous nature of the terrain creates its own set of meteorological challenges to flying operations. The poorest conditions are often associated with a northerly to northwesterly circulation as the air is forced upslope, due to the rising terrain. Low conditions can also be found with an approaching and intense low pressure system. At any other time, cloud base is usually between 3,000 and 5,000 feet above sea level with visibilities excellent to the north of the foothills.

Eastern Townships Area



Map 4-43 - Eastern Townships Area

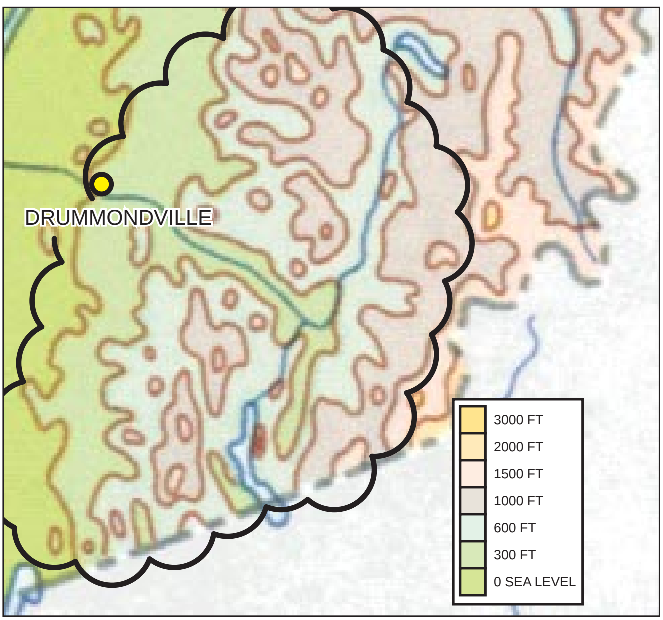
Low clouds and poorer visibilities, along with obscured mountaintops, can be expected at any time of the year. Also, because of the higher elevations, snow shows up earlier and stays longer than anywhere else in the area. Narrow valleys and deeply set lakes also affect clouds and precipitation types. Fall, early winter, and spring are times of the year when precipitation types can change rapidly from snow to freezing rain to rain or vice versa over short distances or with slight changes in elevation.

Mountainous terrain is conducive to the pooling of cooler air in narrow river valleys and deeply set lakes, during the night, with the onset of the nightly katabatic circulation. Fog often forms in these areas either in the evening or early morning. This fog may slowly lift in a thin stratus cloud hugging the valley summits.

Wind shear is common as the surface winds tend to follow river valleys and long lakes, while the upper winds remain better aligned with the general atmospheric circulation. As a result, the winds reported at some Eastern Townships airports may be weaker than actually occurring winds in the surrounding area.

The greatest concern expressed by several pilots travelling southward from St-Hubert into the New England states in the U.S., at low altitude, is the frequent occurrence of moderate or greater turbulence over Eastern Townships Mountains. Stratocumulus Standing Lenticularis (SCSL) clouds are frequent whenever there is a strong circulation from the northwest, as well as the occasional rotor cloud. The intensity of the turbulence tends to increase toward the American border and further south. Satellite pictures can be a great help in identifying these areas.

Beauce Area



Map 4-44 - Beauce Area

Similar to the Eastern Townships, the mountains in this area also exert a strong influence on the local weather. Upslope flow produces low cloud especially over the Beauce Highlands, during the winter months.

Pilots have also identified an area over the foothills, limited to the east by the

Chaudiere River and to the west by Coleraine and Inverness, where lower cloud bases tend to be more common. On the other hand, the area closer to the American border, from St-Georges on east, tends to have cloud bases around 6,000 feet ASL and excellent visibilities.

There is a higher hill range, which peaks at 3,040 feet ASL, that lies to the south of St-Philemon and Buckland. Lower clouds are a common occurrence over this range.

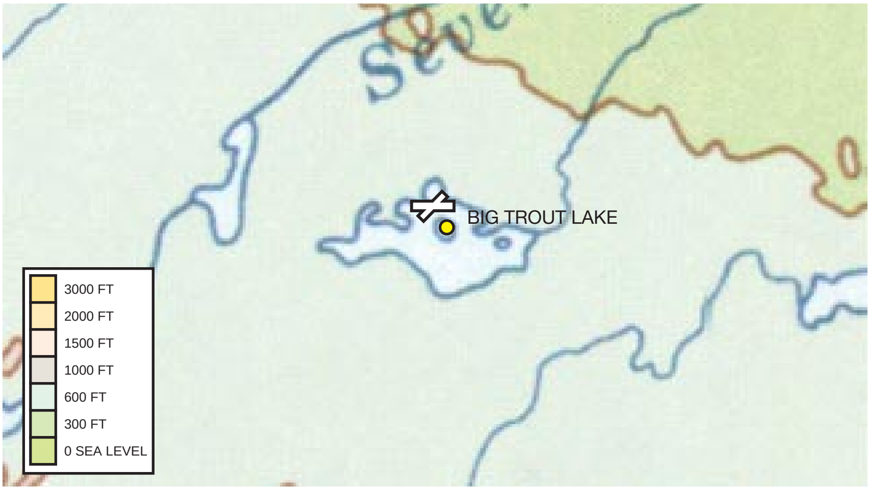
Notes:

Chapter 5

Airport Climatology

Ontario and Quebec

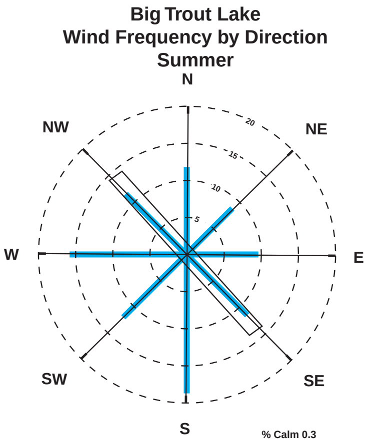
(a) Big Trout Lake

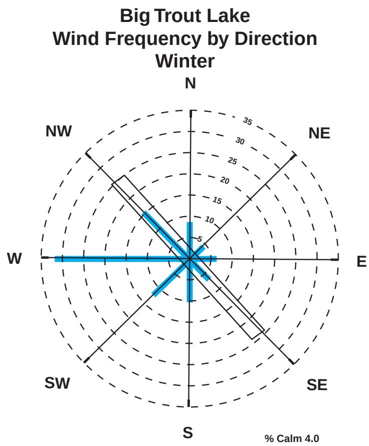


Big Trout Lake, one of the larger lakes in northwestern Ontario, is itself surrounded by numerous smaller lakes, marshes and rivers. The Severn River crosses the region 30 miles to the northwest, draining much of the region as it meanders northeastward to Hudson Bay. The community and airport at Big Trout Lake are situated on Post Island, near the northeastern lakeshore. The island is connected to the shoreline by a road built atop a narrow bridge of land. The landscape of Post Island and the area surrounding Big Trout Lake is mostly flat, forest covered and dotted with marshes. On a broader scale, the terrain to the north and northeast slopes gently down toward Hudson Bay, while the terrain of the Canadian Shield rises equally gently to the south and southwest.

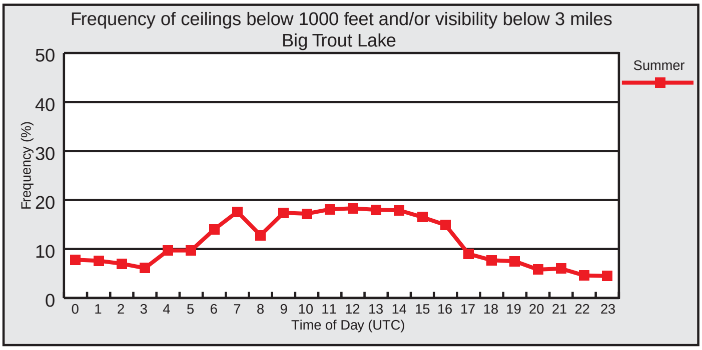
During the winter months, west winds prevail both in direction and strength, while winds from the east and northeast occur infrequently and tend to be much lighter.

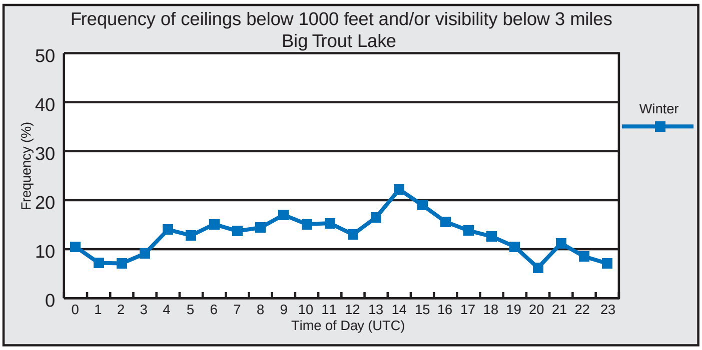
Summer wind patterns are more diverse. Winds from the northwest to south occur around 15 percent of the time and are stronger, while southeast to northeast winds only occur about 10 percent of the time and are lighter.





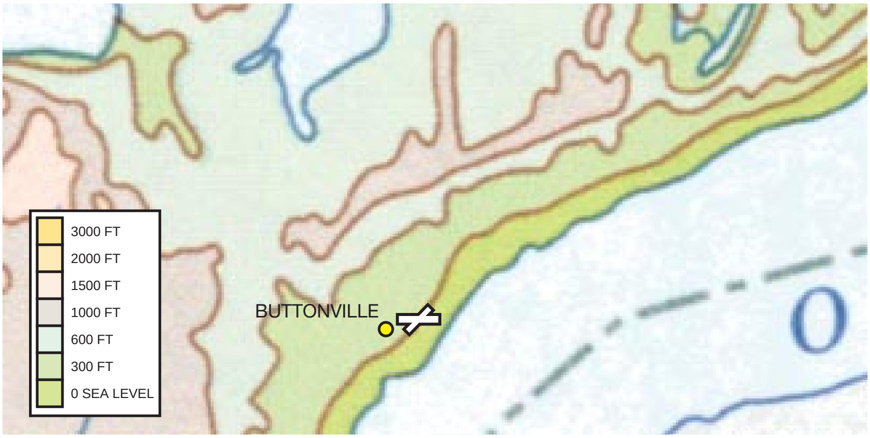
Summer provides a good deal of fair weather flying over northwestern Ontario and, in general, the frequency of IFR weather diminishes. This holds true for Big Trout Lake; however, IFR conditions occur from time to time, particularly in the early and latter part of the season. Fog tends to be one of the chief causes, forming in the early morning hours and reducing visibility, then dissipating during the early part of the day. A second contributing factor in the development of IFR conditions is upslope flow. Winds from the north and northwest are upslope across this section of the Canadian Shield and tend to result in the formation of areas of low cloud. Finally, convective clouds and showers also make their contribution to IFR weather in the summer months, usually developing in the afternoon and dissipating in the evening.





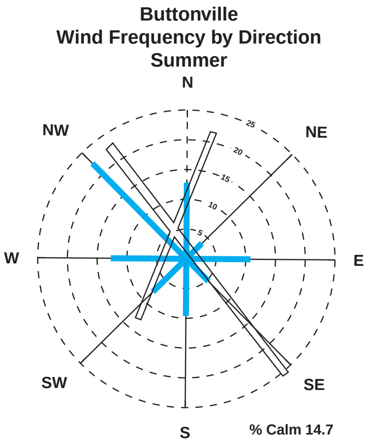
The causes of winter IFR weather have similar roots to those found in the summer. Fog is again a primary culprit, tending to occur more frequently in the early and latter part of the season when moisture is still available from open water sources. As in summer, it tends to form in the early morning hours but will often be slower to dissipate. As temperatures begin to plunge below zero, ice fog starts to develop and can be persistent, especially under calm or low wind conditions. Ice fog can form quickly at times, often triggered by aircraft exhaust or smoke from the chimneys of the nearby community. Another frequent cause of winter IFR conditions is snow or blowing snow. When low ceilings and/or visibility is associated with a rapidly moving weather system, ceilings and visibility tend to be reduced as it passes, followed by a fairly rapid clearing in its wake. Stalled lows; however, can cause periods of low ceiling and visibility to persist for more extended periods of time.

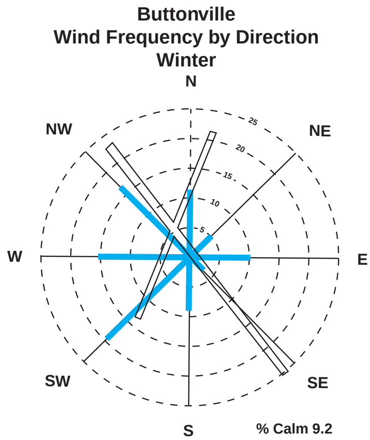
(b) Buttonville



Buttonville Airport is situated in an area of urban development amongst slightly rolling terrain, 16 miles north-northwest of downtown Toronto. The airport has an elevation of 650 feet ASL. The lands to the south of the airport slope gently down to the shores of Lake Ontario. To the north, the land rises along the slopes of the Oak Ridges Moraine, reaching elevations of 1,330 feet ASL.

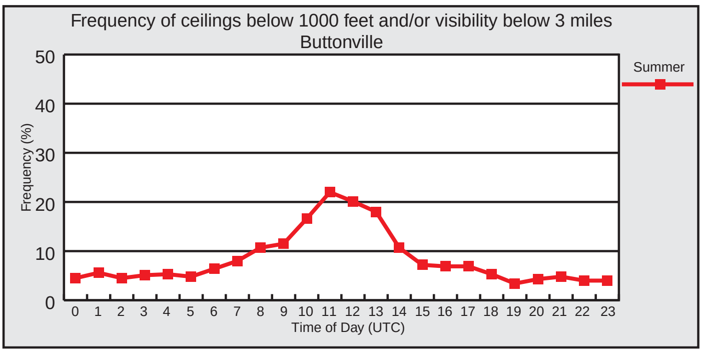
The predominant wind directions at Buttonville are from the southwest and northwest. Northwest winds become subsident as they flow down the south facing slopes of the Oak Ridges Moraine, toward the Buttonville airport. Southwest winds, flowing across Lake Erie and western Lake Ontario, tend to parallel the terrain along the northwest shore. Winds from the east and southeast are upslope and, though they occur with less frequency, they bring some of Buttonville's lowest ceilings and visibilities.

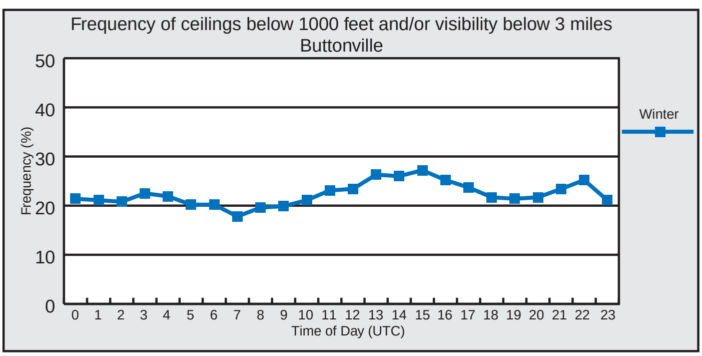




Good flying weather can be expected throughout the bulk of the summer. The sloping terrain surrounding the airport offers fairly good air drainage and, on average, fog only develops 2 to 3 times, mainly during late summer and early winter. Radiation fog, forming in the early morning hours, usually dissipates by mid morning and rarely lasts in to the afternoon. Haze is another common restriction to visibility in summer. It often develops in the more stagnant air mass beneath a ridge of high pressure and is made worse by conditions of high humidity. Haze will occasionally reduce visibility to near 5 miles, but rarely to less than 3 miles.

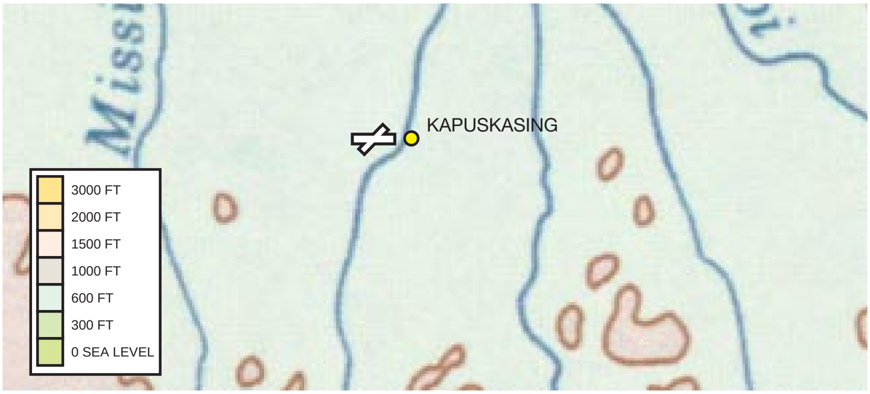
Lake breezes off Lake Ontario will frequently trigger convective cloud development along the surrounding upslope terrain during summer afternoons and, if the air mass is sufficiently unstable, will result in thunderstorms. Most thunderstorm activity tends to occur along the higher terrain to the north of the airport. Thunderstorms occur an average of 25 times per season.





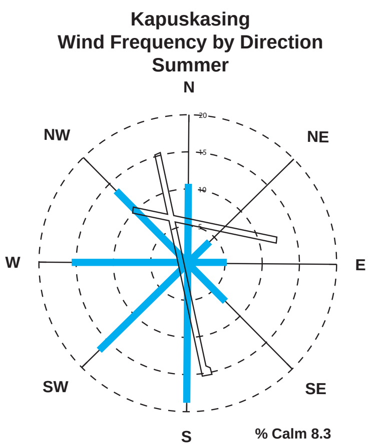
During the winter months, the prevailing winds are southwesterly. Migratory low pressure systems begin to track across the Great Lakes in greater numbers and the primary causes of winter IFR conditions tend to be low ceilings and poor visibility in snow. With the passage of a low pressure system, the rising upslope terrain and ridges to the north often see lower ceilings and poorer visibility in snow than that experienced at the airport. Under a strong northwest flow, lake effect cloud can generate significant snowfalls and IFR conditions along the upslope areas to the north of these ridges, while conditions at Buttonville Airport, on the downslope side of this terrain, will be significantly better.

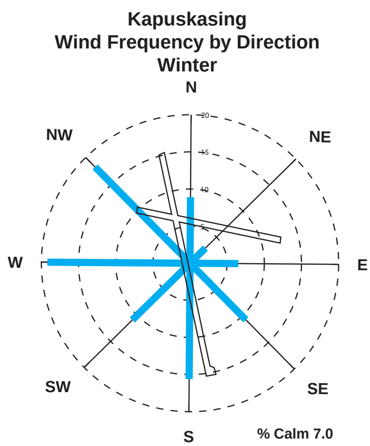
(c) Kapuskasing



Kapuskasing Airport in northeastern Ontario lies one mile west of the town centre and half a mile south of the Trans-Canada Highway. There are several smaller communities within the surrounding area including Kitigan, about 7 nautical miles to east-southeast; Lepage, 6 miles to the west-northwest; Harty, 11 miles to the west-northwest; and Val Rita, 4 miles to the northwest.

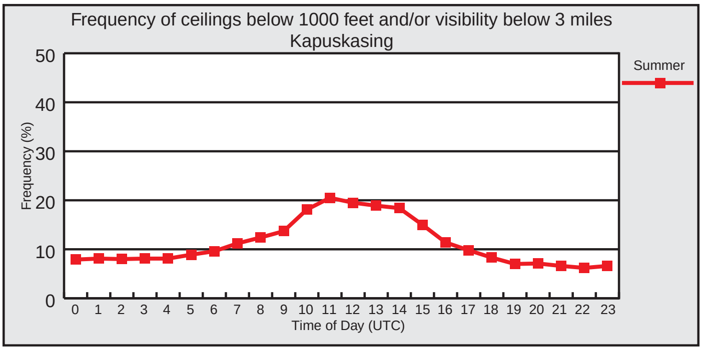
The surrounding terrain consists of low rolling forested hills. The highest of these has an elevation of 735 feet ASL and lies about 12 miles to the southwest. The Kapuskasing River passes within a little over a mile to northeast of the airport. It takes a winding path across the region, flowing northward down the gently sloping terrain toward the Hudson Bay lowlands.

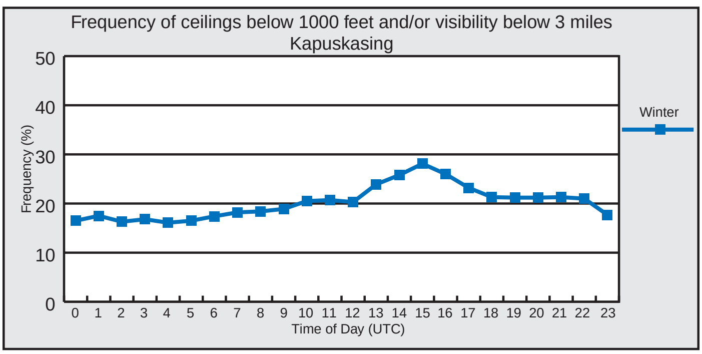




Winter brings prevailing winds out of the west or northwest at Kapuskasing. South and southwest winds are less frequent in both direction and strength throughout the winter and winds from the northeast rarely occur.

During summer, the dominant wind direction is from the south or southwest. Northwest winds diminish in strength and occur about half as often, while winds from the eastern quadrants are rare.





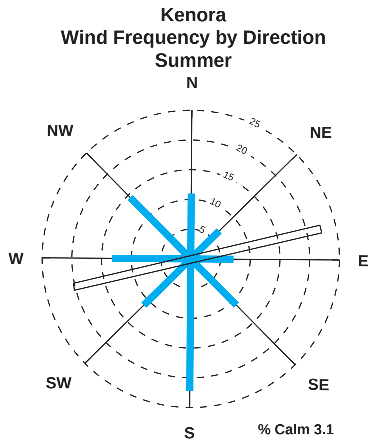
IFR weather occurs about 15 to 25 percent of the time in winter and is often associated with poor visibility in fog or snow. Fog occurs more frequently in the early and latter part of the season, before the local surface moisture sources freeze over. The fog tends to form in the early morning hours, is at its worst just after sunrise, and is slow to dissipate. Later in the season, as temperatures begin to plunge below freezing, ice fog begins to develop and can be persistent, especially under calm or low wind conditions. Ice fog can form quickly at times, often triggered by aircraft exhaust or smoke from a nearby community.

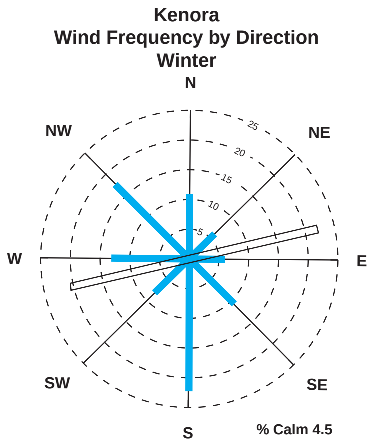
Other common causes of winter IFR conditions are system cloud, snow and blowing snow. This type of weather generally begins and ends for reasons unrelated to the time of day; therefore, there is little diurnal variation in the frequency of IFR weather in winter. Northwest winds, which are upslope for Kapuskasing, bring some of the worst flying weather. IFR conditions are more than twice as likely to occur under a northwest flow than with winds from any other direction.

Kapuskasing generally sees good flying weather throughout the summer; however, IFR conditions do occur at times, particularly in the early and latter part of the season. Fog is again the most common cause, forming in the early morning hours and reducing visibility, then dissipating during the early part of the day. Low ceilings occur less frequently, most often is association with an upslope northwesterly flow. Convective clouds and showers also make a contribution to IFR weather in the summer months, usually developing in the afternoon and dissipating in the evening. Thunderstorms occur infrequently, reaching a peak in July with an average of six per month.

(d) Kenora

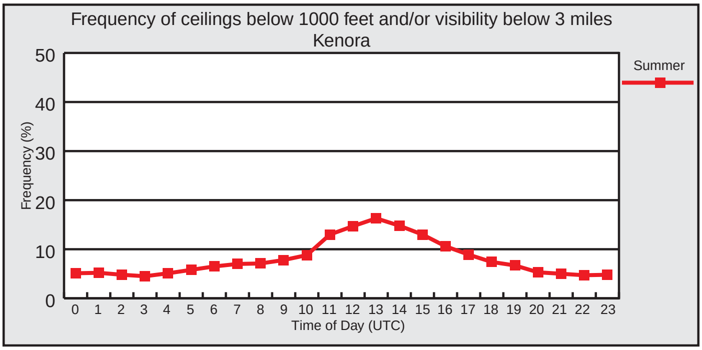
Kenora lies in northwestern Ontario, along the northern shore of Lake of the Woods. The airport is located 5 miles east-northeast of the city. Numerous smaller lakes dot the region's rocky, forest covered and rolling landscape. In general, the terrain rises to the east and falls in elevation to the west.

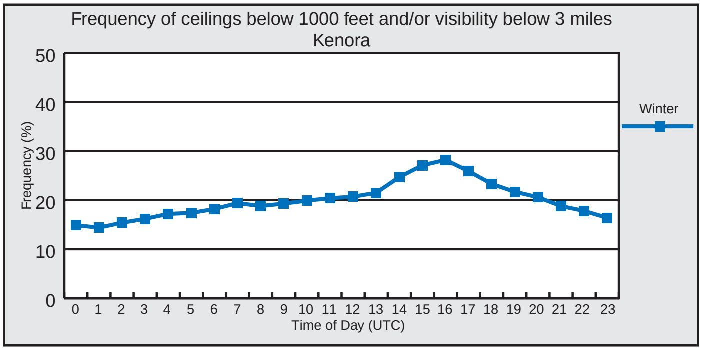




During summer, the dominant wind direction is from the south and occurs about 22 percent of the time. Northwest to southwest winds occur less often and easterly winds are more rare.

The winter wind pattern at Kenora airport is dominated by winds out of the northwest and south. Westerly winds, and those out of the southeast, occur about half as frequently and tend to be lighter. Winds out of the east or northeast occur much less often.



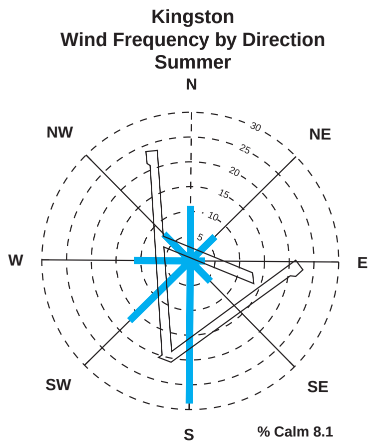


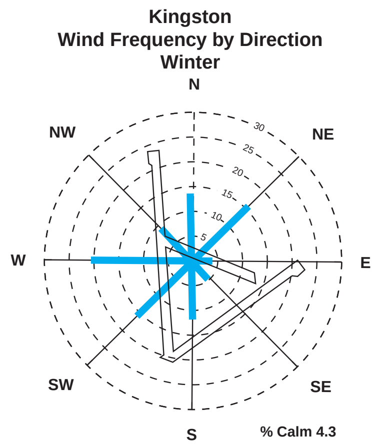
Summer generally brings fair weather flying to the Kenora area. IFR conditions develop infrequently, but occur more often in the early and latter part of the season. Fog typically forms two or three times a month, usually developing during the early morning hours, from moisture that is readily available from the many surrounding lakes. The fog usually dissipates during the early part of the day, seldom lasting beyond noon. Low ceilings are not often a problem, but tend to develop more frequently under a southerly flow off Lake of the Woods. Convective clouds and showers make a small contribution to IFR weather in the summer months, usually developing in the afternoon and dissipating in the evening. Thunderstorms tend to develop several times a month throughout the summer, peaking in July with an occurrence rate of seven per month.

Winter brings on a rise in the frequency of IFR weather as the number of migratory low pressure systems tracking across the region increases. Fog is generally not a problem to operations, but forms more often in the morning during the early and latter part of the season, before freeze up and during the spring melt. Low cloud and snow begin to develop more frequently in December and January. Low ceiling and visibility, when they do occur, are rarely persistent as most migratory systems pass within 24 hours and are often followed by fairly rapid clearing.

(e) Kingston

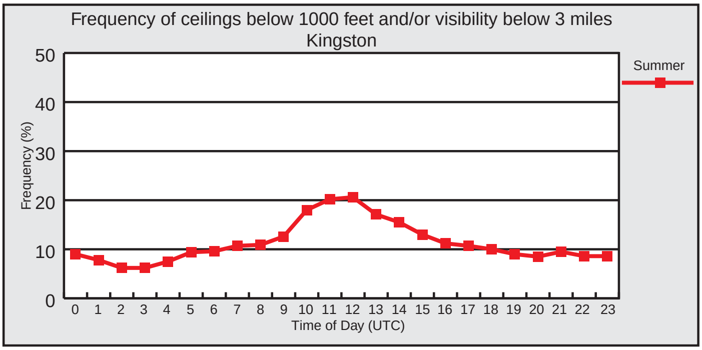
The Kingston Airport is located near the eastern end of Lake Ontario, on the northern shore, 4 nautical miles west of the city of Kingston. A fairly level landscape surrounds the airport, which has an elevation 60 feet above that of the lake. Sparsely treed, rolling farmland rises gently to the northwest through northeast and is dotted with numerous small lakes and rivers. To the southwest, lie the open waters of Lake Ontario, and to the east the headwaters of the St. Lawrence River and the Thousand Islands region.

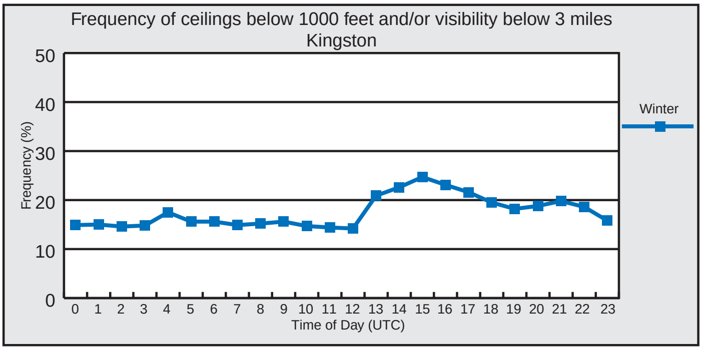




Throughout the summer, south and southwest winds off Lake Ontario dominate the wind pattern at Kingston. Winds from the northern quadrants occur with less than half the frequency, and those out of the southeast and especially the east are quite rare.

In winter, westerly winds are slightly more dominant over those out of the southwest and northeast. As in summer, east and southeast winds are fairly uncommon.



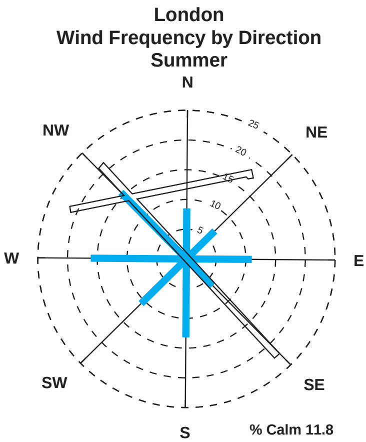


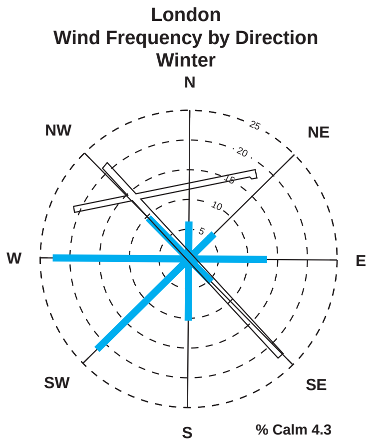
Kingston Airport sees little IFR weather during the summer. Radiation fog will sometimes develop in the early morning hours, under calm or light wind conditions, but usually dissipates within a few hours of sunrise. Low ceilings and visibility are more often seen in association with migratory low pressure systems and southerly winds which are upslope and carrying moisture off Lake Ontario. Summer convective cloud tends to develop along the warm slopes and rising terrain to the north of the airport, at times resulting in lines of thunderstorms. The cool waters of Lake Ontario serve to dampen summer convection; therefore, few thunderstorms develop or pass within the immediate vicinity of the airport

In winter, migratory low pressure systems begin to track across the Great Lakes in greater numbers and the occurrence of IFR conditions begins to rise. System cloud and reduced visibility in snow, rain and fog account for much of the increased IFR weather at Kingston. In the absence of synoptic scale weather systems, a south or southwest flow over the open waters of Lake Ontario can subject the airport to lake effect low cloud and reduced visibility in snowfall. Kingston is also prone to an average of 2 to 3 occurrences of freezing rain per month, throughout the winter, as warm frontal air masses approaching from the west or southwest encounter and override cold arctic air spilling out from the Ottawa River Valley and along the St. Lawrence.

(f) London

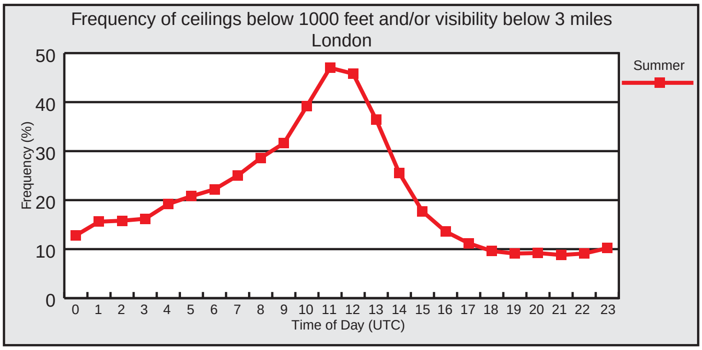
London Airport lies on a plain of gently undulating terrain that falls slowly toward the shores of Lake Erie, 23 nautical miles to the south, and Lake Huron, 32 miles to the northwest. To the northeast, the land rises across a distance of 7 miles, reaching an elevation of 1,200 feet ASL. A northern branch of the Thames River wanders across the region and passes within 1-1/2 miles of the airport, where a dam has been constructed to create Fanshawe Lake. The southern branch of the Thames River passes within 4 miles to the south of the airport and joins the northern branch at a point 6 miles to the southwest.

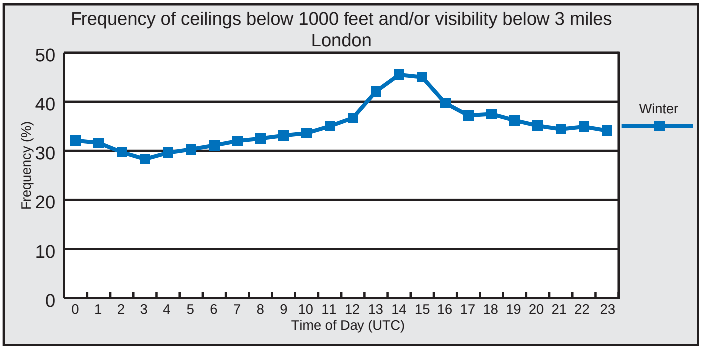




Airport climatology here is influenced to some extent by local topography but is dominated by the presence of the Great Lakes, which for the most part surround southwestern Ontario. By frequency of occurrence, west and southwest winds tend to prevail throughout the winter months, with a secondary peak from the east. Winds show more diversity in direction throughout the summer, with wind from the west and northwest being slightly more dominant over those winds out of the south.

London generally sees fairly good flying weather during the summer but that is not to say that IFR conditions do not occur. On average, fog develops 3 times per month during the early summer and six times per month in August and September. Usually resulting from radiation cooling under clear skies, the fog tends to form in the still morning air a few hours before sunrise, then gradually dissipates and seldom lasts beyond mid morning. Haze, on the other hand, is another common restriction to visibility in summer, arising from the accumulation of aerosols and particulates in the atmosphere. It often develops in the more stagnant air mass beneath a ridge of high pressure and is made worse by conditions of high humidity. Haze can be more persistent and has been known to reduce visibility at London airport to less than 3 miles. Low ceilings and poor visibility also tend to accompany migratory low pressure systems, especially in conjunction with an upslope southerly or northwesterly flow. London lies in a region of strong convective development driven by daytime heating and convergence of lake breezes off Lake Erie, to the south, and Lake Huron, to the north, resulting in an average of seven thunderstorms per month during the summer. Waterspouts are a common occurrence over nearby Lake Erie and severe convection occasionally results in tornadoes over the land.





Fog occurs an average of 3 or 4 times per month in winter and usually dissipates late in the day. However, during the winter, it is the migratory low pressure systems, with their cloud and snow, that are the primary causes of IFR conditions. In the absence of synoptic scale systems, a strong northwest to north flow over the open waters of Lake Huron can bring lake effect cloud and snowfall to London. Since the southern end of Lake Huron is fairly shallow and tends to freeze over, lake effect clouds and snowfall usually diminish in January and February.

(g) Moosonee

Moosonee Airport is located on the north bank of the Moose River, 10 nautical miles from where the river empties into James Bay. The airport has an elevation of 30 feet ASL and is surrounded by a near flat landscape of poorly drained muskeg areas, interspersed with low sandy rises covered in spruce, poplar, willow and alder trees. The town of Moosonee itself lies less than one mile to the southwest of the airport. The waters of the Moose River are fresh in this area, with strong currents throughout the summer months and tides of nearly 6 feet. Across the river, 1-1/2 miles to the southeast, lies the town of Moose Factory situated on Factory Island, one of a cluster of several islands in the Moose River, where it broadens to a width nearly 3 miles before emptying into James Bay. The river freezes over during the winter months providing a seasonal ice bridge, however, during periods of freeze-up and break-up helicopters provide transportation between these two communities.

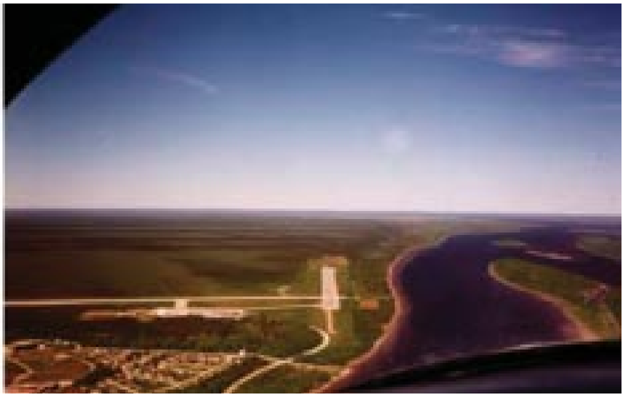
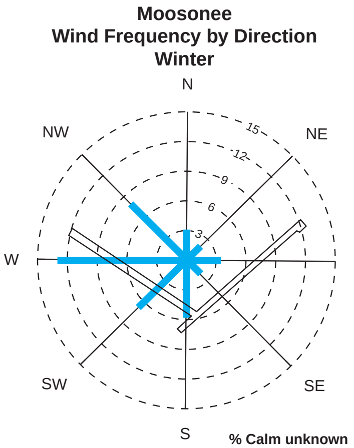
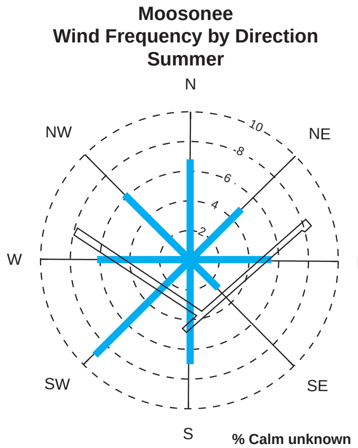
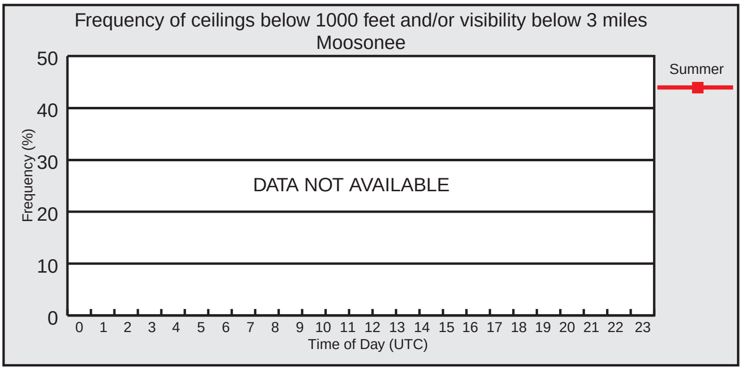


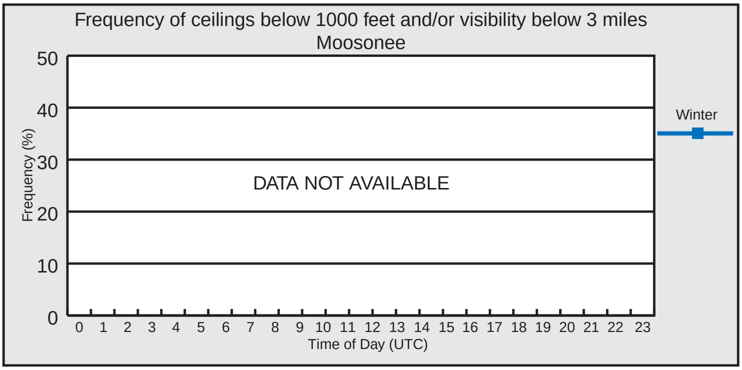
Photo 5-1 - Moosonee Airport credit: Source unknown





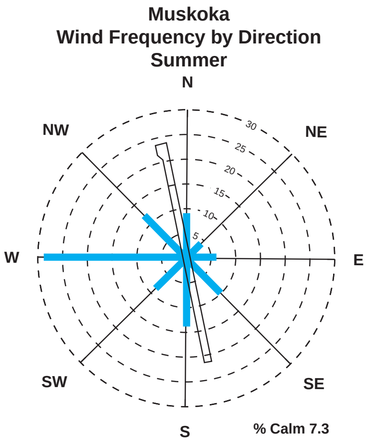
Southwest winds predominate throughout the summer months at Moosonee Airport, while westerly winds prevail during the winter months. Other wind directions are much less frequent and are usually associated with passage of low pressure systems across the region. Both the mean wind speeds and maximum gust speeds show only slight seasonal variation.

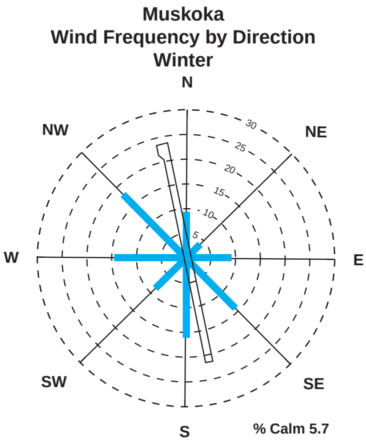




(h) Muskoka

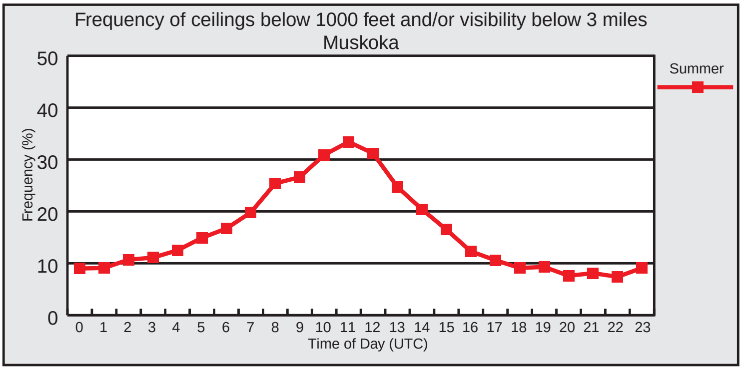
Muskoka Airport is located in central Ontario, 3 nautical miles to the east of Lake Muskoka and midway between the towns of Gravenhurst, 5 miles to the southwest and Bracebridge to the north. The smaller community of Muskoka Falls lies 2 miles to the north. This is a cottage and resort region dotted with numerous lakes, of which Lake Muskoka is the largest. The lands surrounding the airport are varied, consisting of fairly flat areas intermixed with low rolling hills covered in forest and shrubs and dotted with rocky outcroppings. The Canadian Shield gradually rises to the northeast, while the waters of Georgian Bay open up 30 miles to the west.

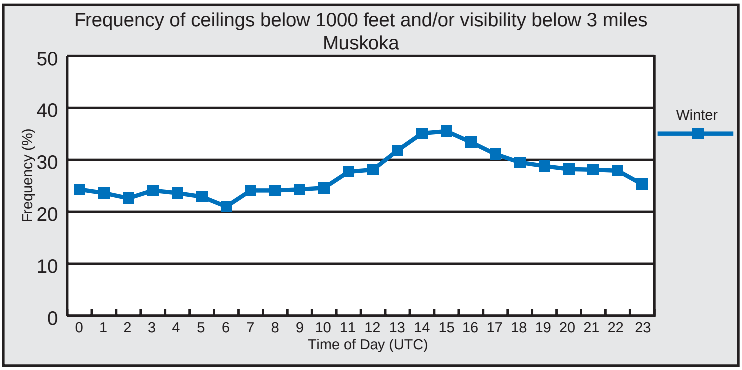




Westerly winds dominate the summer months at Muskoka, however, southerly winds frequently prevail for periods of time depending upon the pressure pattern. During the winter, as the storm track shifts northward and the frequency of low pressure systems increases, a more pronounced split develops, with winds from the northwest maintaining only a slight dominance over those from the south and southeast.

Low ceilings and/or visibility develop infrequently at Muskoka throughout the summer, usually in the early and latter months of the season. When IFR conditions do occur, it is often the result of mist, fog or low stratus which forms during the early morning hours, from moisture off the numerous surrounding lakes and rivers, and dissipates before midday.





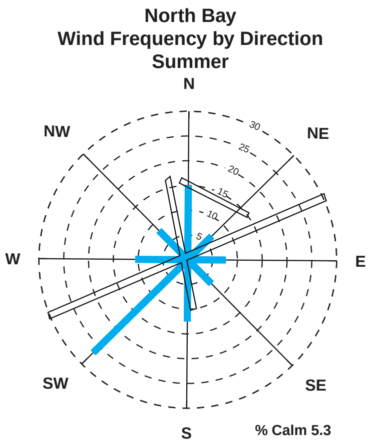
During the winter, IFR conditions are usually associated with snowstorms. Snowstorms can be “lake effect” in origin, developing under a northwest flow that carries moisture inland from Georgian Bay, or they may be linked to migratory low pressure systems, which tend to wrap moisture across the region from the south or southwest. Both can give periods of low ceiling and poor visibility in cloud and precipitation.

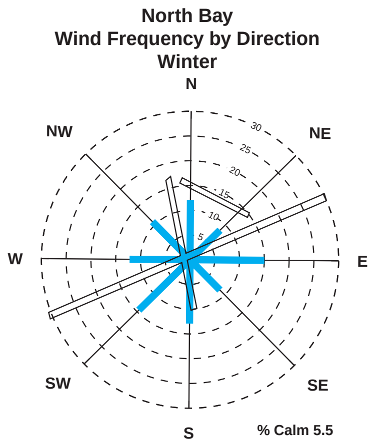
While flying weather is generally at its worst over Muskoka in the winter and best in the summer, it should be noted that the frequency of occurrence of IFR conditions peak during the early morning hours of the spring and fall.

(i) North Bay Airport

North Bay Airport lies just over 4 nautical miles northeast and approximately 500 feet above the shores of Lake Nipissing, atop a plateau of Canadian Shield granite. To the northeast of the airport, the terrain continues to rise gently in rows of low hills forested in a mix of birch, poplar and maple. To the south, the plateau falls away steeply in elevation to a lower table of land on which the city of North Bay spreads out to the lakeshore.

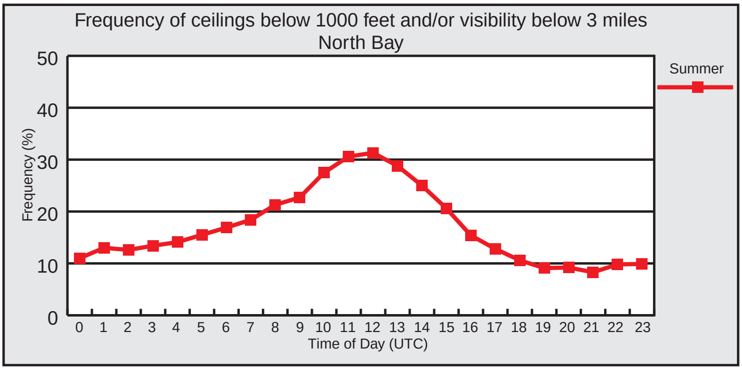
Photo 5-2 - North Bay Airport credit: Source unknown

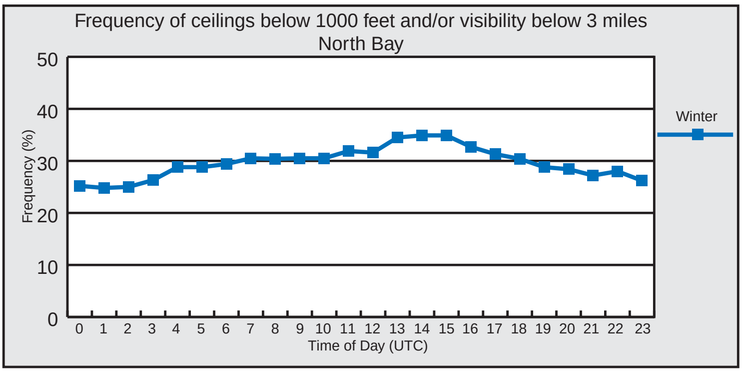




The dominant wind direction at North Bay during the summer months is southwesterly, off of Lake Nipissing. Northerly winds occur with less than half the frequency and tend to be lighter than of those out of the southwest. Winds from the remaining compass points are often weaker and even less frequent.

The winter wind regime becomes much more diverse, reflecting shifts in wind direction associated with the passage of an increasing number of low pressure systems along the winter storm tracks. Southwest winds are still dominant but their frequency of occurrence is nearly matched by winds out of the north and east.





The frequency of IFR weather conditions drops to a minimum in the summer, usually occurring in the early and latter part of the season and most often in association with southwest winds. Winds from the southwest through southeast are upslope for North Bay and tend bring the worst flying weather. It is southwest winds that dominate throughout the summer months, carrying moisture off Lake Nipissing and, more distant, Georgian Bay and contributing in combination with daytime heating, to cloud and shower development along the rising slopes of the Canadian Shield. This pattern is evident in the accompanying summer chart which shows IFR conditions peaking as cloud develops from late morning to early afternoon. IFR frequency then diminishes in the late afternoon and evening as cloud begins to dissipate. North Bay Airport is not particularly susceptible to summer radiation fog.

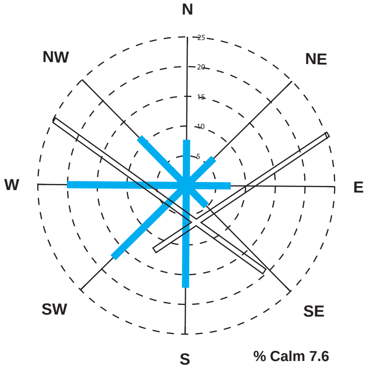
During the winter months IFR conditions develop more often and are much more evenly distributed throughout the day and night hours. This can be attributed to the fact that IFR conditions in winter tend to arise from a combination of snow, blowing snow, fog and low cloud associated with winter's increased numbers of migratory low pressure systems. It should be noted that throughout the winter, IFR weather occurs much more frequently with winds from the southwest and southeast quadrants, indicating a strong contribution from upslope flow.

(j) Ottawa

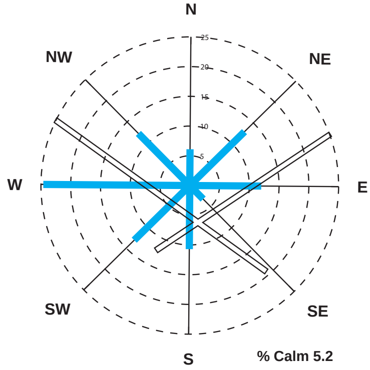
Ottawa Airport is located about 90 nautical miles northeast of Lake Ontario, near the junction of Ottawa and St. Lawrence River Valleys. It is sited on a plain of rolling farmland about 6 miles south of the city. The Rideau River, a little over a mile to the west, flows northward past the airport and through the city to join the Ottawa River about 6 miles to the north. The airport has an elevation of 375 feet ASL, about 240 feet above the level of the Ottawa River. The surrounding terrain rises to the north along a section of the Canadian Shield known as the Gatineau Hills, which reach elevations near 1,300 feet some 15 miles from the airport.

Ottawa's winds tend to be channelled by the surrounding river valleys. During the summer, south through west winds prevail both in strength and direction. Northwest winds occur less frequently and winds seldom flow out of the eastern quadrants.

Ottawa
Wind Frequency by Direction
Summer

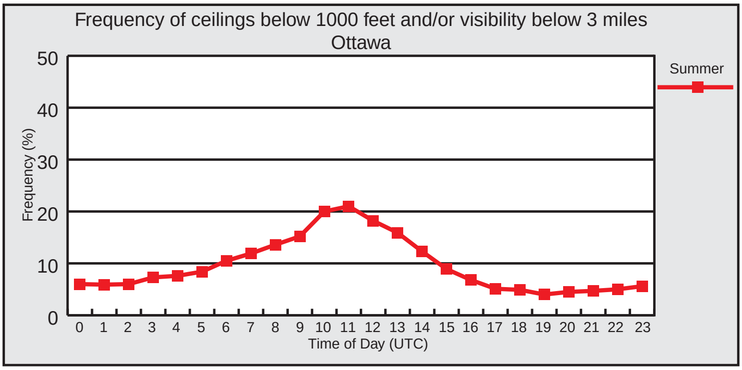


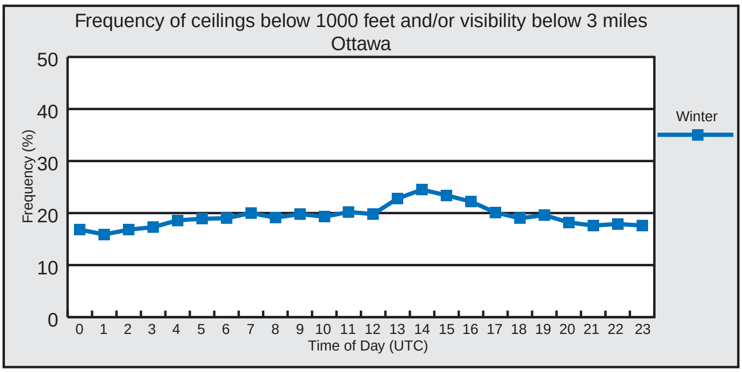
Ottawa
Wind Frequency by Direction
Winter



During the winter, west winds flowing out of the Ottawa Valley are dominant in both direction and speed and, to a somewhat lesser extent, winds out of the east-northeast and southwest, which are channelled along the St. Lawrence Valley. Winds seldom arise from the north or southeast as they are blocked by the Gatineau Hills and the Appalachian Mountains, located to the south of the St. Lawrence Valley.

Summer generally brings good flying conditions at Ottawa and little in the way of low ceilings or poor visibility. Radiation fog is one of the most common causes of IFR conditions, developing in the early morning hours under calm or light winds. Radiation fog usually dissipates within a few hours of sunrise and rarely last into the afternoon. On average, fog restricts visibility to less than half a mile, 2 to 4 times per month, reaching its highest frequency during the late summer and early winter. Low ceilings and visibility also tend to occur in association with the passage of migratory low pressure systems but, again, poor conditions are seldom persistent. Ottawa has an average of 24 thunderstorms per season, peaking in number during July and August and rarely developing outside of the period April through October.





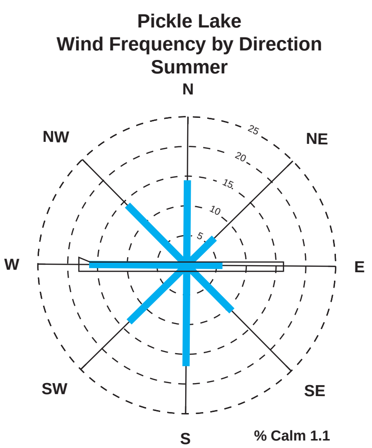
Migratory low pressure systems begin to track across southern Ontario in greater numbers in winter and the occurrence of IFR conditions arising from low ceilings and poor visibility in snow begins to rise.

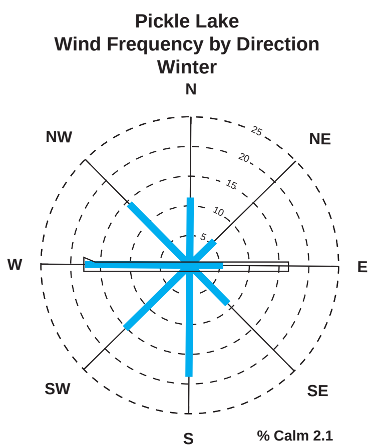
Probably the greatest risk to aviation in the Ottawa area is freezing rain. Ottawa averages 3 to 5 occurrences of freezing rain per month between November and April. Freezing rain commonly lasts an hour or less, however, freezing rain can persist for several hours at a time. One of the most prolonged periods of freezing rain ever recorded in Canada occurred January 5-10, 1998, during which time nearly 85mm of freezing rain fell in the Ottawa area.

(k) Pickle Lake

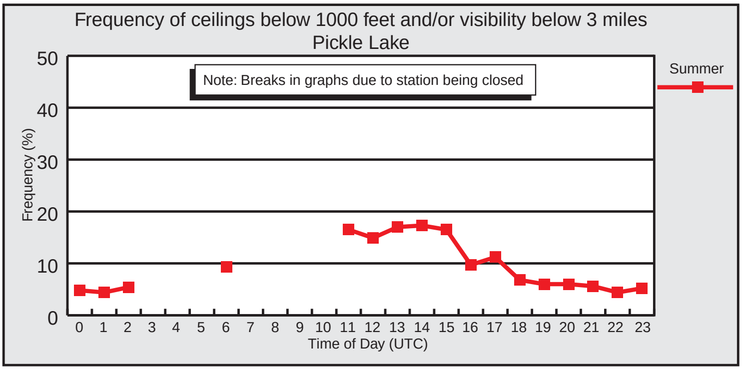
Pickle Lake Airport is located in northwestern Ontario, near the southern shore of Pickle Lake. The local community, which also bears the lake's name, is sited about 2 nautical miles to the northeast. The airport is fairly exposed and the surrounding terrain is made up of gently rolling, forested hills with rocky outcroppings interspersed with numerous small lakes.

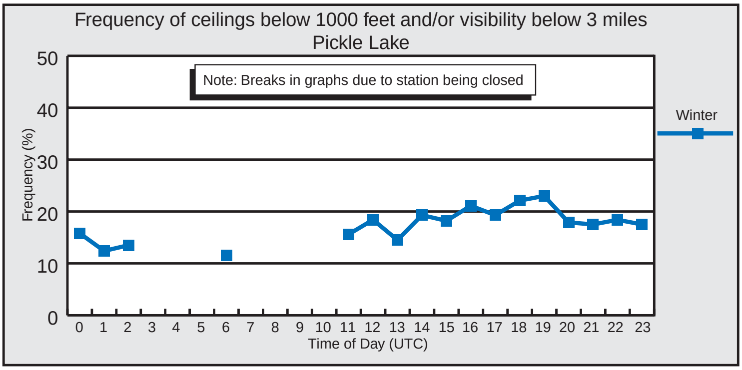
During the winter months westerly winds prevail in both strength and direction; however, winds out of the northwest, southwest and south occur almost as frequently. In summer, the prevailing wind direction becomes south or west, although winds out of the northwest occur only slightly less frequently. The least favored wind directions throughout both winter and summer are those out of the east or northeast.





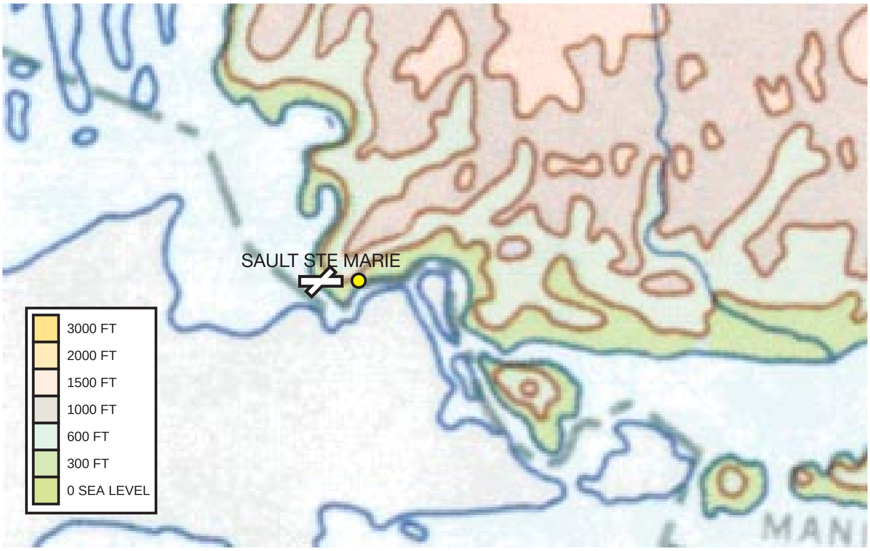
Summer usually brings good flying weather to Pickle Lake and northwestern Ontario in general, however IFR conditions sometimes occur. One of the most common causes is radiation fog, which occurs more often later in the season. Shallow fog will typically form overnight and dissipate within a few hours of sunrise. To a lesser extent, summer convection and thunderstorms can also lead to low ceilings and visibility developing in showers. This is often the case with the passage of a cold front but, on occasion, will occur in stronger storms that arise with daytime heating.





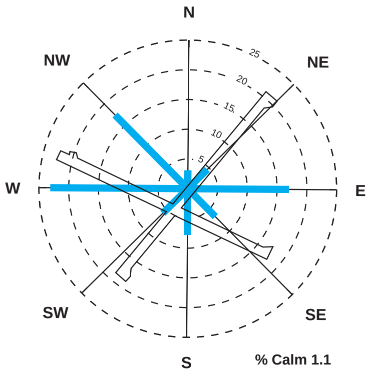
Low ceilings and visibility occur more frequently in winter. This is particularly true of the early part of the season, when open water is still present. At this time of year, fog is more prevalent, especially in the morning and it tends to linger into the day. Convection also remains somewhat of a problem until freeze up, as warm water in surrounding lakes gives rise to lake effect snowfall, which can reduce visibility at times to between half and a quarter of a mile and persist for several hours. Once local lakes freeze over, flying conditions usually improve, however, winter brings an increase in both the number and intensity of low pressure systems. These disturbances often bring low ceilings and periods of poor visibility in snow or blowing snow. Most low pressure centers or frontal systems move across the region in less than 24 hours, followed by fairly rapid clearing in their wake. Stalled lows can cause periods of low ceiling and poor visibility to persist for more extended periods of time.

(l) Sault Ste. Marie

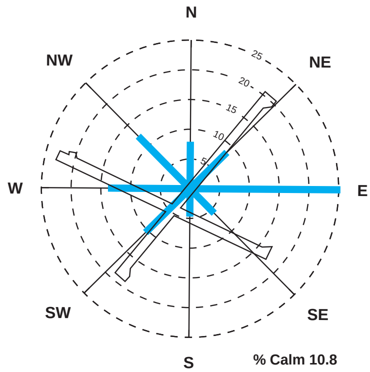


Sault Ste. Marie Airport is located on a broad, relatively flat peninsula at the south-eastern end of Lake Superior. Reaching an elevation of 672 feet ASL, only slightly higher than that of the adjacent waters of Whitefish Bay to the west and the St. Marys River to the east, the peninsula abuts the Canadian Shield approximately 3 nautical miles north of the airport. Here the terrain rises abruptly to an elevation of 899 feet. The Shield then continues to rise slowly to the north in a series of sharp, thinly forested ridges and deep, more densely forested valleys. The city of Sault Ste. Marie is situated 8 miles east-northeast of the airport on the banks of the St. Marys River. Across the river, the near flat landscape of Michigan state extends 40 miles south to the shores of Lake Huron, and southwest 42 miles to the to those of Lake Michigan.

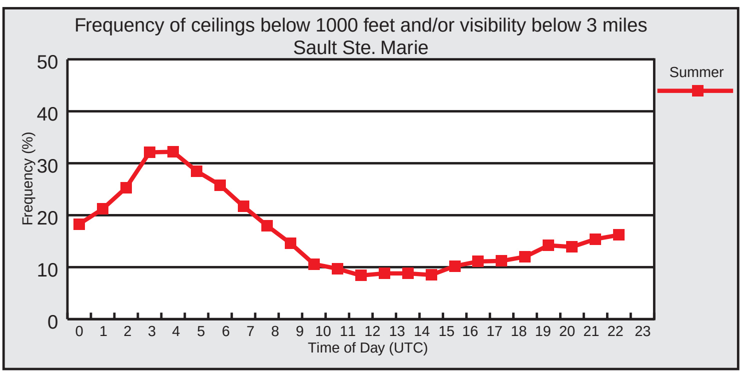
Sault Ste. Marie
Wind Frequency by Direction
Summer

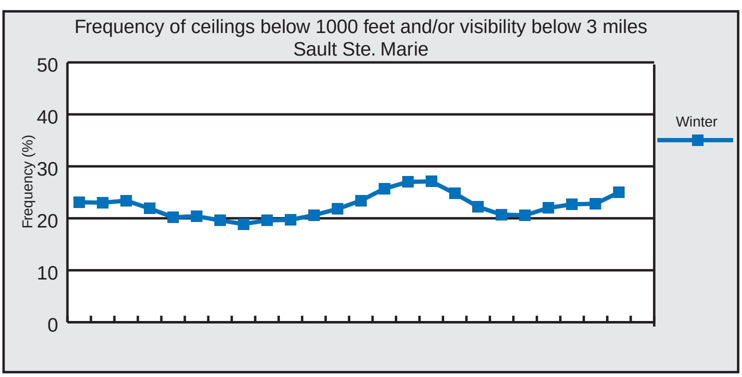


Sault Ste. Marie
Wind Frequency by Direction
Winter



On a year round basis the prevailing wind directions at Sault Ste. Marie are from the northwest, west and east. Winds rarely occur from the south and southeast. In large part, this is due to topography. The airport is exposed to winds off Lake Superior and Whitefish Bay, as well as winds channelled by the St. Marys River, but is sheltered by the rising slopes of the Canadian Shield to north of Lake Huron.



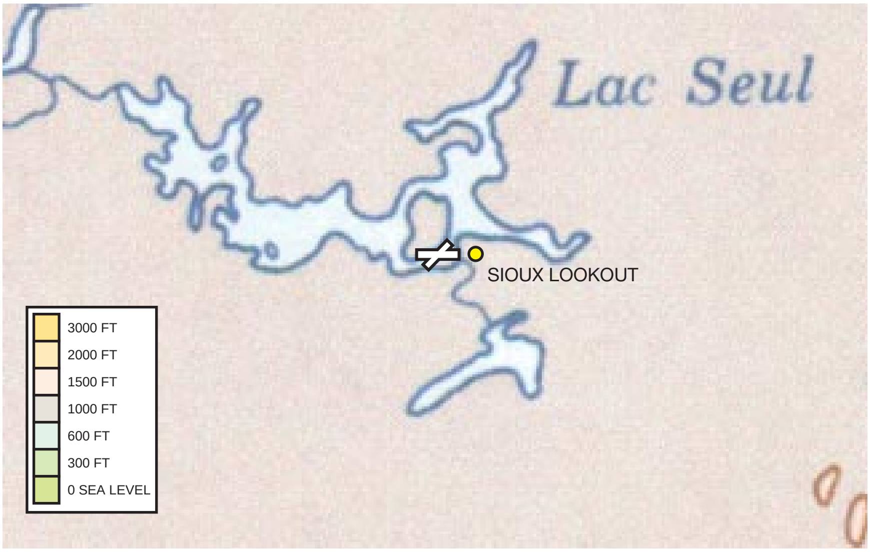


During the winter months, winds tend to flow out of the east. This direction is upslope for Sault Ste. Marie and IFR conditions are generally at their worst, occurring between 20 and 25 percent of the time. Snowstorms associated with migratory low pressure systems cause much of the IFR weather but most can be attributed to lake effect streamers. These can arise out of a southeast flow off Lake Huron but are more often associated with a strong northwest flow off of Lake Superior. Lake effect snowfalls are usually much heavier in the steeper upslope areas of the Canadian Shield, to the north and east of Sault Ste. Marie. Since the beginning and ending of this type of weather is to a large extent independent of the time of day, there is little diurnal variation in the frequency of IFR weather in winter.

During the summer months, west to northwest winds prevail in both strength and direction, enhanced by daytime heating and lake breeze effects. East winds occur less frequently and are usually lighter, tending to develop overnight.

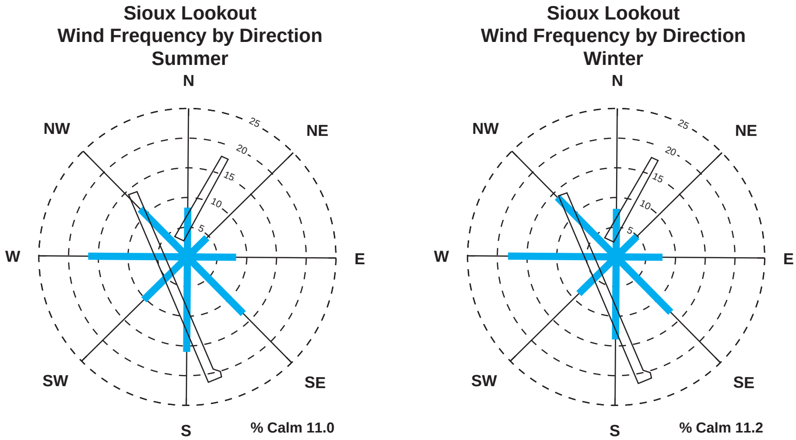
Summer brings some of the best flying weather. Fog and low stratus does occasionally form during the early morning hours but generally burns off with in a few hours of sunrise and, by mid morning, IFR weather occurs less than ten percent of the time. Thunderstorms are not uncommon, but usually develop over the upper Michigan Peninsula and track to the northeast and southeast Sault Ste. Marie Airport.

(m) Sioux Lookout



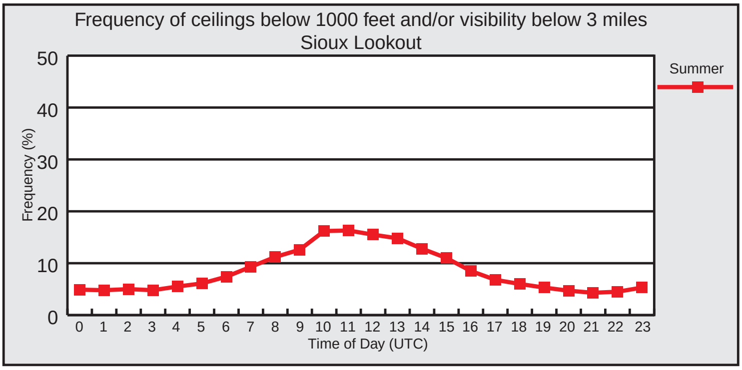
Sioux Lookout is located on the shore of Pelican Lake in northwestern Ontario. The airport is situated just to the northeast of the town centre. This is a region dotted with numerous lakes. The largest of these, Lac Seul, has a surface area of almost

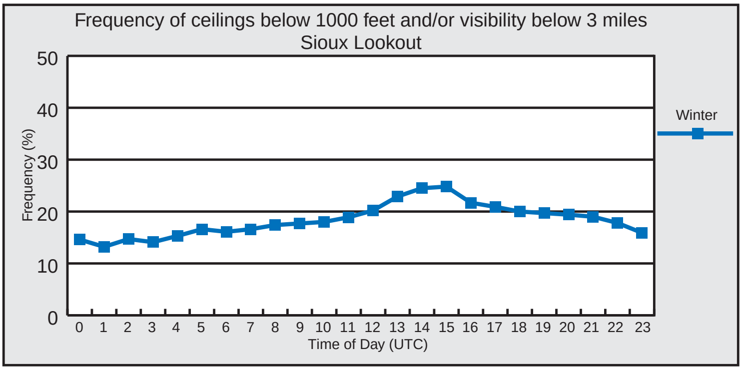
640 square miles. Its shoreline lies 15 nautical miles to the northwest of the airport. The surrounding terrain is typical of the northern Canadian Shield, consisting mostly of low, rolling, forested hills and rocky outcroppings, interspersed with areas of flat land and marshes.



The winds at Sioux Lookout show very little variation between summer and winter. While the winds do show a preference for south or west, all other directions except north, northeast and east occur with reasonable frequency. Winds from these directions are infrequent and light.

Summer months usually offer fair weather flying over northwestern Ontario. Sioux Lookout is no exception, having little persistent fog, heavy precipitation or significant low cloud. That being said, IFR conditions do occur from time to time, particularly in the early and latter part of the season. The most common cause is radiation fog, which tends to form during the early morning hours and dissipate within a few hours of sunrise. To a lesser extent, summer IFR conditions can be attributed to convective cloud and showers, forming in the afternoon with daytime heating and dissipating near sunset. This pattern is reflected in the accompanying graph, which shows peak IFR frequency in the morning, falling to minimum values later in the day.

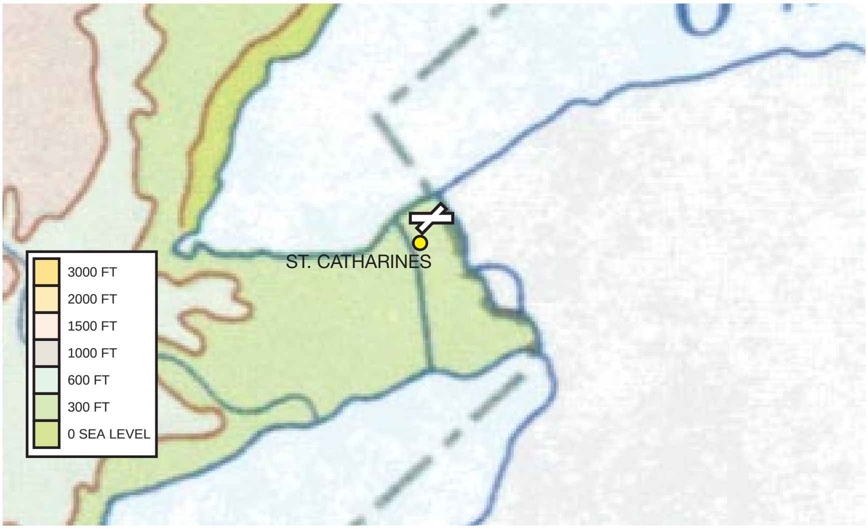




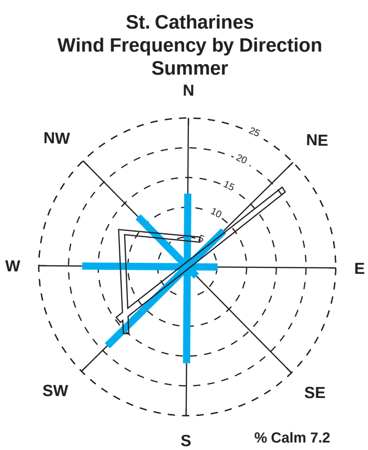
IFR weather occurs with much higher frequently during the winter months at Sioux Lookout. There are several reasons for this. Prior to freeze up in late November or early December, and during break up in March and April, open water provides moisture to fuel the formation of fog. Until the surrounding lakes freeze, fog tends to form and linger into the day. After freeze up, the air mass becomes drier and the occurrence of fog diminishes. Winter also brings an increase in both the number and intensity of low pressure systems tracking across the region. These disturbances often bring low ceilings and periods of poor visibility in snow or blowing snow. Most low pressure centres or frontal systems move across the region in less than 24 hours, followed by fairly rapid clearing in their wake. Stalled lows, however, can cause periods of low ceiling and poor visibility to persist for more extended periods of time.

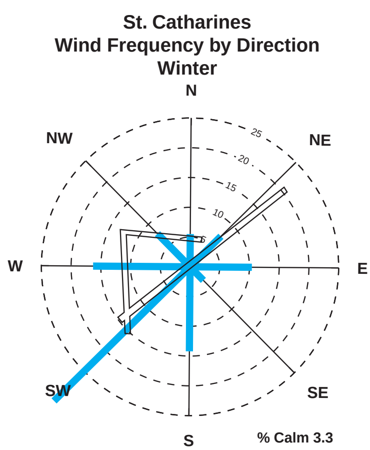
In the absence of fog and migratory low pressure systems, Sioux Lookout can at times fall subject to IFR conditions due to lake effect clouds and showers from nearby Lac Seul. This tends to occur infrequently in the fall and lasts only until the lake freezes over, since it requires a strong northwest flow of cool air across the long fetch of open water between Earl Falls and Sioux Lookout.

(n) St. Catharines

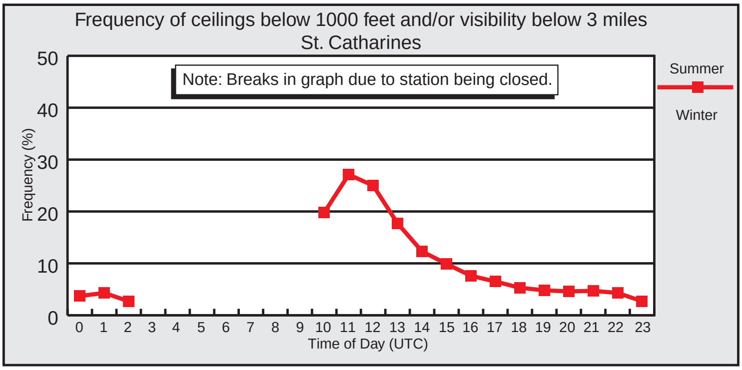


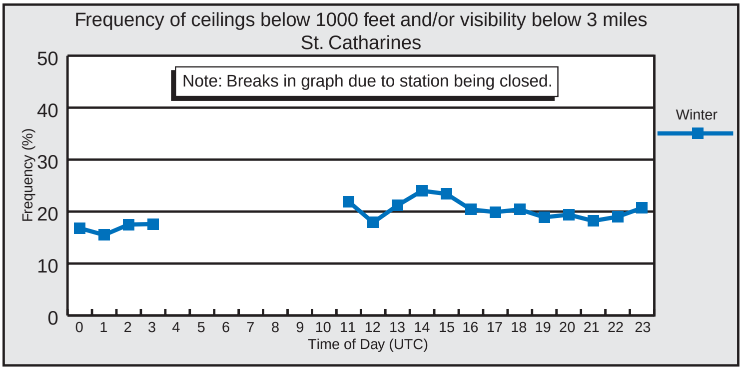
The St. Catharines Airport is located near the western end of Lake Ontario, approximately 4 nautical miles inland from the southern lakeshore. It sits on the rolling plains just below the Niagara Escarpment, which parallels the Lake Ontario shoreline from east to west. The surrounding terrain rises suddenly to the south and falls gently to the north. The Niagara River lies about 6 miles to the east and the Welland Canal, which separates the airfield from the city of St. Catharines, is about 2 miles to the west.





Winds flowing over lake Erie and across the Niagara Peninsula from the west through south tend to prevail throughout the year at St. Catharines. Winds from other directions are generally weaker, occur with less frequency and, due to rising terrain, rarely develop from the southeast.





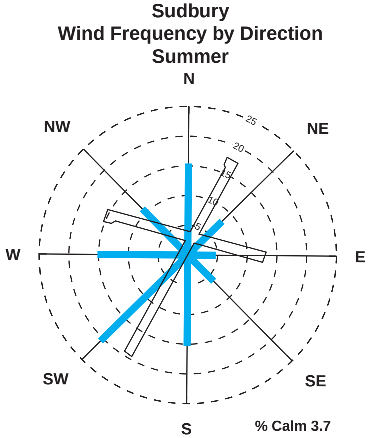
St. Catharines sees little IFR weather throughout the summer months. When it does occur, it is usually as a result of radiation fog or low stratus. Both conditions occur more frequently in the early and latter part of the season. Radiation fog tends to develop under light wind conditions, with a moist airmass and cool early morning temperatures associated with clear nigh time skies. Fog often dissipates at St. Catharines within a few hours of sunrise and seldom persists beyond mid morning. Low ceilings tend to accompany migratory low pressure systems and southwest winds which carry moisture off Lake Erie. Low stratus ceilings will also develop with northeast winds, which carry moisture off Lake Ontario and are upslope across the Niagara escarpment.

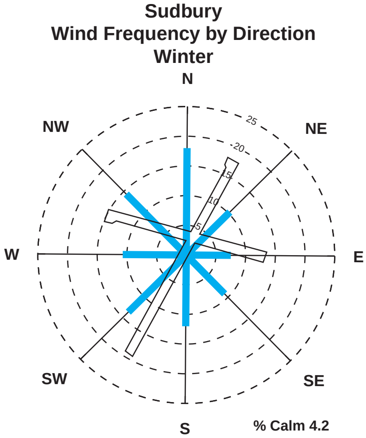
St. Catharines is not known for severe summer thunderstorms however waterspouts are common, often forming over Lake Erie and, within view of the airport, over Lake Ontario.

During the winter months, migratory low pressure systems begin to track across the Great Lakes in greater numbers and the occurrence of IFR conditions begins to rise. System cloud and reduced visibility in snow account for much of this increase. Since the beginning and ending of this type of weather is, to a large extent, independent of the time of day, there is remarkably little diurnal variation in the frequency of IFR weather in winter. Even in the absence of synoptic scale weather systems, a strong southwest flow over the open waters of Lake Erie, or northeast flow over Lake Ontario, can subject St. Catharines to lake effect cloud and snowfall.

(o) Sudbury

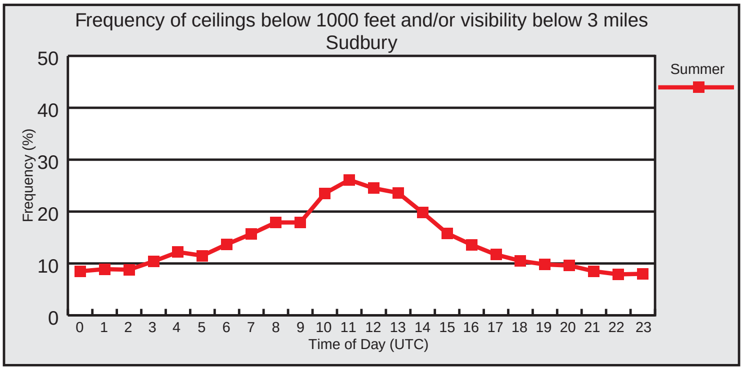
Sudbury Airport is located in northern Ontario atop a small plateau, about 11 nautical miles northeast of the city. The landscape surrounding the airport consists of low and rocky, sparsely treed hills, generally falling in elevation to the south. Sixteen miles to the north, the terrain reaches elevations of near 1,600 feet ASL. Three large smokestacks, ranging in height from 1,280 to 1,550 feet, are sited about 3 miles south of the airport. Wanapitei Lake lies about 9 miles to the north and drains southward through the Wanapitei and French Rivers into Georgian Bay, 50 miles to the south.

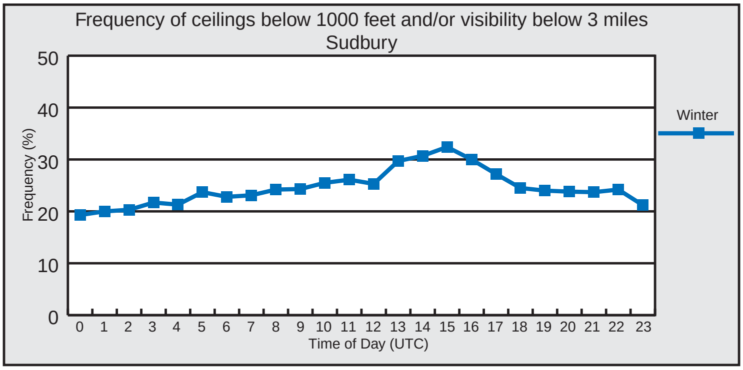




The prevailing wind direction at Sudbury during the summer months is southwesterly; however, winds from the northwest, west and south are all about equal in occurrence and happen only a few percentage points less than the southwest wind. Winds from the northeast, east and southeast are often weaker and occur much less frequently.

The winter wind pattern is much more diverse and reflects the shift in wind direction associated with the passage of the increasing number of low pressure systems along the winter storm track. Southwest winds are still dominant but their frequency of occurrence is nearly matched by winds out of the northwest and northeast.



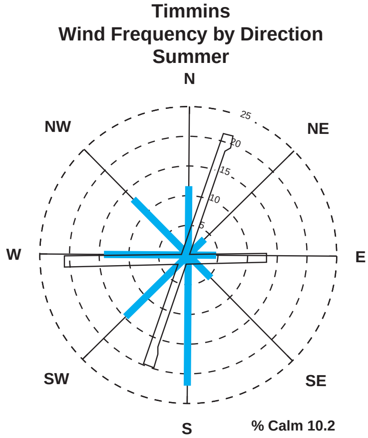


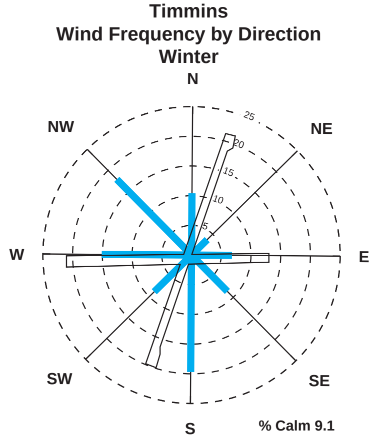
Sudbury generally enjoys good flying weather during the summer, however, several factors can contribute to the development of poor visibility and low ceilings. Fog occurs on an average of 5 or 6 times a month through mid summer and 7 or 8 times a month during the later part of the season. Radiation fog that forms overnight, then dissipates within a few hours of sunrise, rarely affects operations beyond mid morning. Low ceilings and poor visibility in precipitation on the other hand, are commonly associated with the passage of migratory low pressure systems and are often more persistent. These conditions tend to be at their worst under an upslope southwest flow. IFR conditions also arise from convective clouds and showers. On average, Sudbury has 4 or 5 thunderstorms per month throughout the summer.

During the winter months, IFR conditions develop more often and the probability of occurence is evenly distributed throughout the day and night hours. This can be attributed to the fact that IFR conditions in winter tend to arise from a combination of snow, blowing snow, fog and low cloud associated with winter's increased numbers of migratory low pressure systems. It should be noted that, throughout the winter, IFR weather occurs much more frequently with winds from the southwest and south-east quadrants, indicating a strong contribution from upslope flow.

(p) Timmins

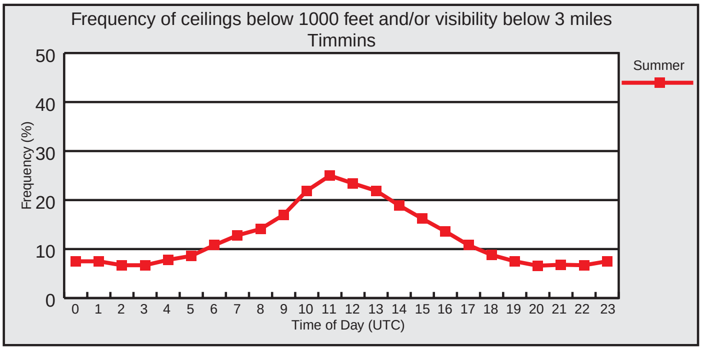
The Timmins Airport is located approximately 6 nautical miles north-northwest of the city. The landscape surrounding the airport rises gently to the south and consists of fairly flat terrain covered in forest and dotted with open marshes. The Mattagami River wanders across the region, skirting the western edge of the city, turning and coursing westward at a point 3 miles south of the airport, then turning again and flowing northward to meet with the Moose River, 55 miles southwest of Moosonee.

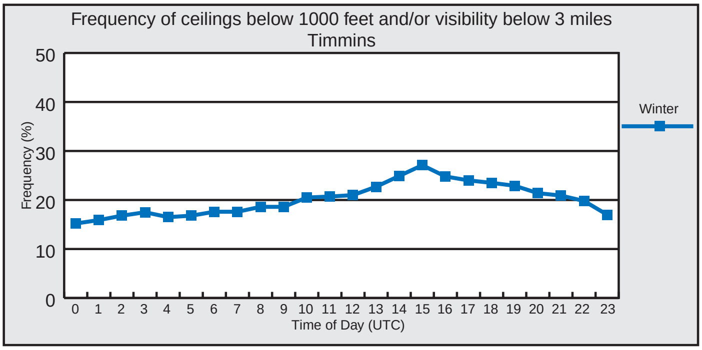




During the winter, winds out of the northwest, west and south are almost equally dominant in both direction and strength. Northeast winds are a rare occurrence at Timmins, and southeast winds develop infrequently and tend to be much lighter.

During summer, the dominant wind directions are from the south with wind from the southwest, west and northwest being a close second. Easterly winds are rare.





IFR weather occurs 15 to 20 percent of the time in winter and is often associated with poor visibility due to fog or snow. Fog occurs more frequently in the early and latter part of the season when moisture is still available from open water. As in summer, fog tends to form in the early morning hours, but in winter it will often linger until later in the day. As temperatures begin to plunge below zero, ice fog begins to develop and can be persistent, especially under calm or low wind conditions. Ice fog can form quickly at times, often triggered by aircraft exhaust or smoke from a nearby community.

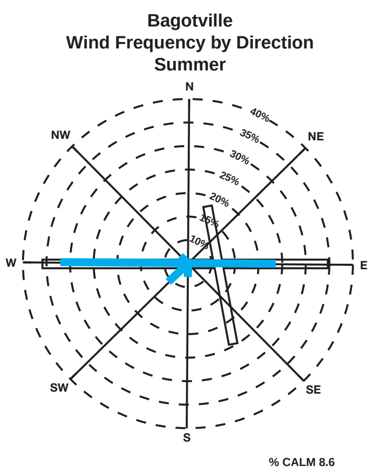
Other common causes of winter IFR conditions are system cloud, snow and blowing snow. This type of weather begins and ends independent from the time of day; therefore, there is remarkably little diurnal variation in the frequency of IFR weather in winter.

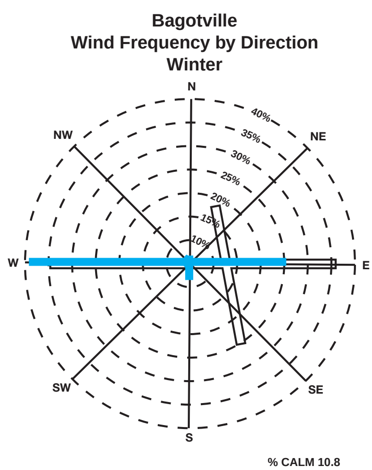
Summer generally brings fair weather flying at Timmins; however, IFR conditions do occur at times, particularly in the early and latter part of the season. Fog is most often the cause, forming in the early morning hours and reducing visibility, then dissipating during the early part of the day. Low ceilings occur less frequently but tend to develop in a north or northwest flow, which is upslope across this section of the Canadian Shield. Finally, convective clouds and showers make their contribution to IFR weather in the summer months, usually developing in the afternoon and dissipating in the evening.

Airport Climatology - Quebec

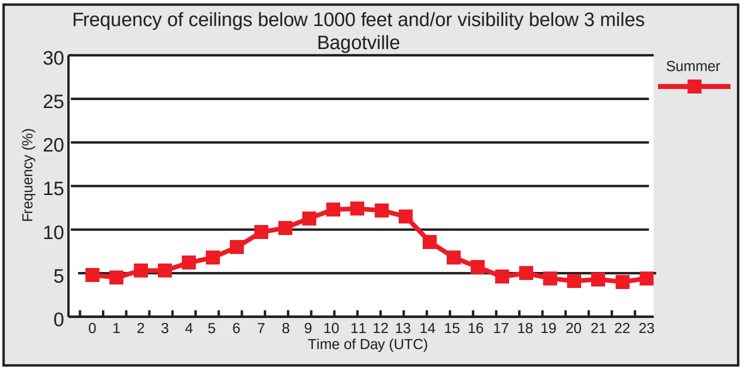
(a) Bagotville

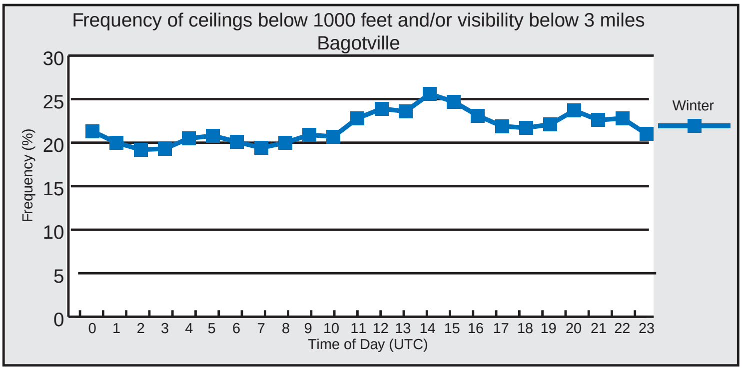
Bagotville Airport is located near the Saguenay River, some 6 miles from the town of Bagotville. The runway elevation is 522 feet ASL. Most buildings are located to the northeast of the junction of runways 11-29 and 18-36.





The Saguenay River Valley, which runs east to west in the area, has a major impact on the local winds. During the summer months the winds tend to be either westerly (32 percent of the time) or easterly (24 percent of the time). Other directions occur infrequently (less than 10 percent of the time) with the wind being calm 6 percent of the time. Wintertime shows little change in this pattern. The westerly wind is observed 39 percent of the time while the easterly wind takes place nearly 26 percent of the time. The other wind directions remain insignificant in occurrence, and the occurrence of calm winds rise to almost 11 percent.



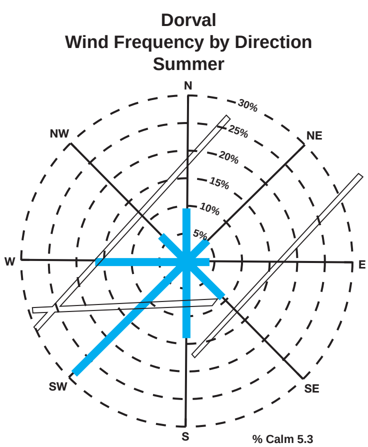


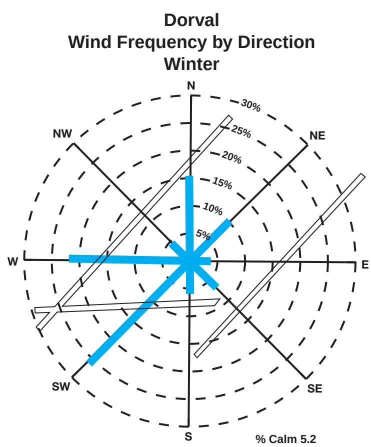
Flying conditions during the summer months tend to be good. Thunderstorms do move along the valley giving brief periods of reduced ceilings and visibility. At the same time the presence of the nearby river and small lakes do lead to periods of low cloud or fog. This tends to occur mostly overnight, reaching a peak near 11 UTC then dissipating rapidly between 15 and 17 UTC.

Winter is a different story. The valley is subject to the trapping of cold air with low level moisture. As such, low cloud and visibility do occur between 20 to 25 percent of the time at almost any hour of the day. At the same time, periods of snow or freezing precipitation can make aviation operations hazardous throughout the area.

(b) Dorval International Airport

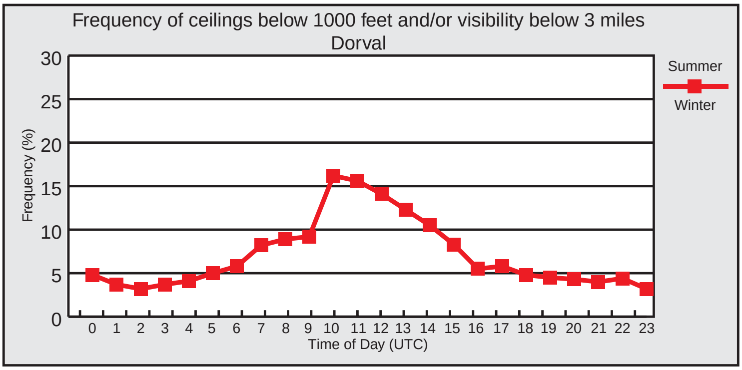
The Dorval International Airport is situated on the western half of the island of Montreal, in the midst of the city. The runway elevation is 117 feet ASL. The area surrounding the airport comprises an industrial park, bungalows, and very few high-rise buildings.

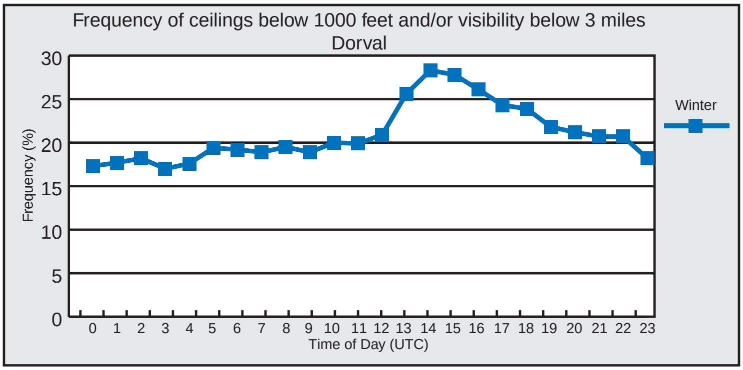




Southwest winds are predominant by far throughout the year. During the winter, the second most frequent wind direction is west with north following in third place. In the summer, west winds are slightly more frequent than northeast winds. During this same period west and south winds are half as frequent as southwest winds. As for the other directions, each occurs less than 10 percent of the time whether it is winter or summer.

Strong winds, wind shear and moderate turbulence are often observed on approach to the east-west runway, e.g. wind gusts of 30 knots behind cold front when runway 28 is in use.





The lowest ceilings and visibilities usually occur with east or northeast winds. On the other hand, ceilings and visibility are usually much better with westerly winds except in the case rain or snow showers, which are usually of short duration. The Dorval International Airport is better protected from fog than nearby aerodromes when the wind is a light southwesterly or light northwesterly. The visibility tends to go down; however, with light easterly winds. Usually, visibilities below 3 statute miles and ceilings below 1,000 feet AGL are usually observed just after sunrise, most often due to the formation of fog, and conditions tend to improve rapidly thereafter. The occurrence is usually low in the summer, around 15 per cent or less.

In late fall and winter, warm fronts tend to linger over the Saint Lawrence River, between the Dorval International Airport and the St. Hubert Airport on the South Shore, with large temperature differences between the two airports. As a result, freezing rain can be expected when there is significant warm air aloft but cold air drainage from the northeast is holding the air temperature just below the freezing mark. Ice fog is seldom observed at Dorval International Airport. In winter, ceilings below 1,000 feet and visibility below 3 statute miles are more frequent in the morning than at any other time.

Precipitation approaching from the west or generated over Lake Ontario often dissipate before reaching Dorval International Airport, when the surface wind is from the south, regardless of the time of year.

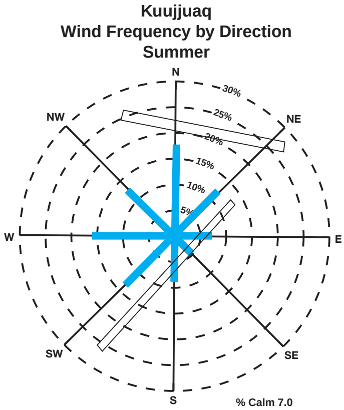
(c) Kuujjuaq

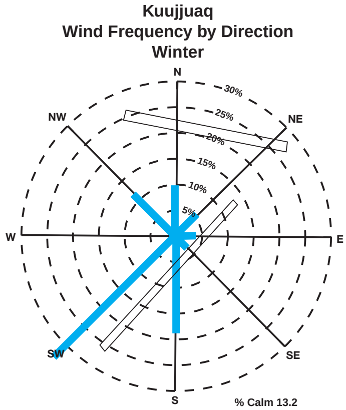
Kuujjuaq Airport is situated on the western bank of the Koksoak River, approximately 52 nautical miles from the river mouth. The runway elevation is 196 feet ASL, while the land rises gently toward the west.

Photo 5-3 - Kuujjuaq and the Koksoak River looking toward the southwest. credit; Gilles Simard, MSC

Southwesterly winds are predominant in Kuujjuaq in the ice-free season. It is the northeast winds, however, that are the most troublesome as they advect low weather conditions in from Ungava Bay. Such conditions never last long, however. Ceilings and visibilities seldom go below 200 feet and 1/2 mile visibility (10 days per year on average). In turn, northwesterly winds usually clear the poor weather when it occurs.

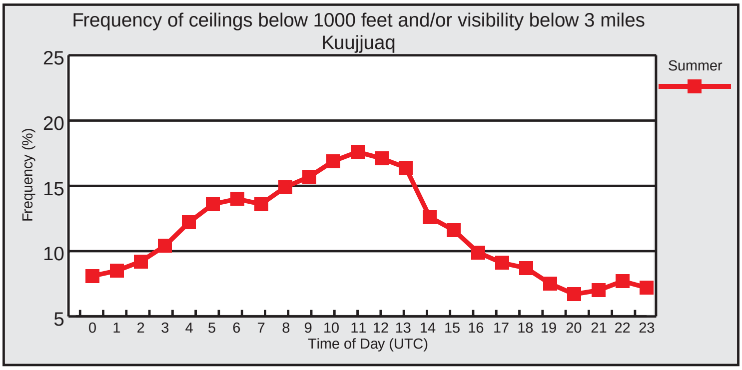
Thick fog is never far away. In late spring, it usually remains to the north over the bay during the day and it will move toward the aerodrome in early evening, pushed by the sea breeze (typically between 5 and 6 pm in early May and around 7 pm by early June). The fog tends to move out once the sea breeze dies down during the evening. During the summer months, it takes the best part of the day for the sea breeze to establish itself. In July, for example, the wind tends to shift from light westerly to strong northeasterly around 3 pm. Fog is also observed briefly in early morning but it dissipates rapidly. Winds from the south to southwest usually result in nice and warm weather. Southerly winds tend to be strong, in the 20 to 30 knot range.

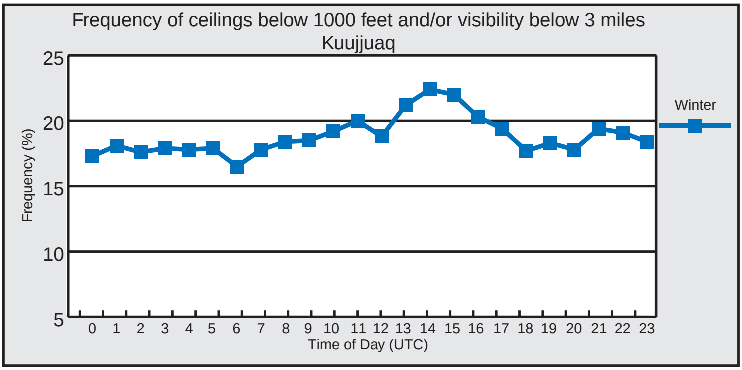




The fall is usually the worst season, especially when warm air moves over cold ground, such as in the warm sector of a synoptic low pressure system, often resulting in rain or freezing rain or wet snow. The onset of easterly winds tends to be a good precursor of precipitation. Northeasterly winds usually result in low stratus cloud and freezing drizzle, later changing to snow. North to northwest winds usually vary between 10 and 20 knots. Wind shear may occur in late summer, or fall, when strong westerly winds are occurring.

In winter, once Ungava Bay freezes over, the sky and the horizon are generally clear with ice fog often observed over the river. Whiteout conditions are common with falling snow and, on very cold days, blowing snow and ice crystals may combine to produce whiteout.

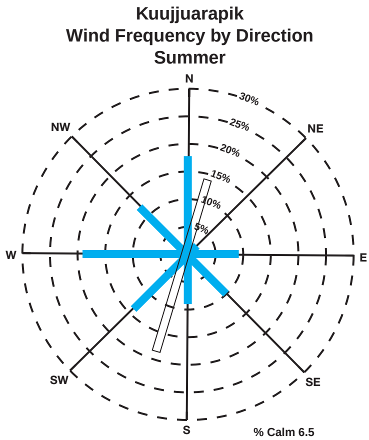


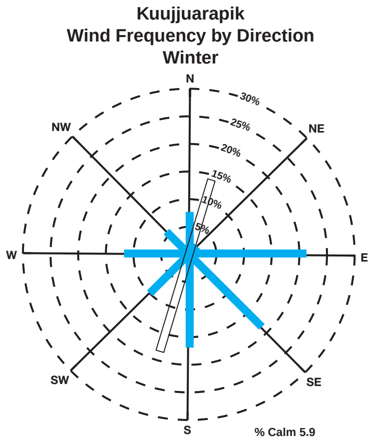


The spring weather usually offers excellent flying conditions. On occasion, there may be some foggy mornings with humidity rising from melting snow or lakes. Low level clouds are usually a rare occurrence, unless associated with falling precipitation from a well-organized weather system.

(d) Kuujjuarapik

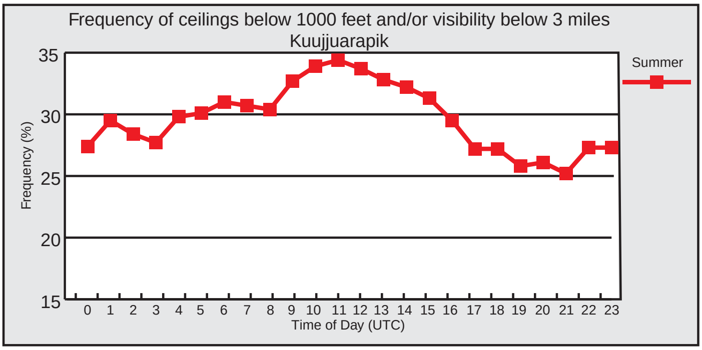
Kuujjuarapik airport is situated on Sable Point, between the shore of Hudson Bay and the mouth of "Grande Riviere de la Baleine" (loosely translated as Great Whale River). The land is generally flat with a single 1,231-foot hill situated approximately 3 nautical miles to the northeast of the aerodrome.

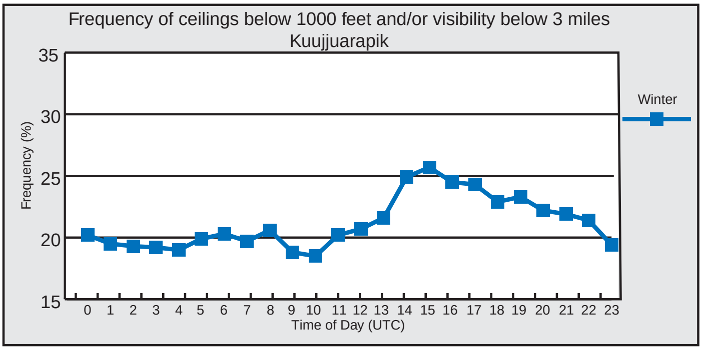




During the ice-free season, fog and very low stratus move onshore whenever the wind direction is between the southwest to north quadrants, with the worst visibilities and ceilings when the wind usually comes from the west or the northwest. July and August are usually the worst months for ceilings below 500 feet and visibilities below 1 mile. These conditions usually persist until there is a change in wind direction. Thick fog has been observed even with strong northwest winds, sometimes reaching 40 knots. There was once a 22-day period when their planes could not land in Kuujjuarapik, due to insufficient ceilings and visibilities in fog. This occurred in July, with west to northwest winds of 6 knots or less.

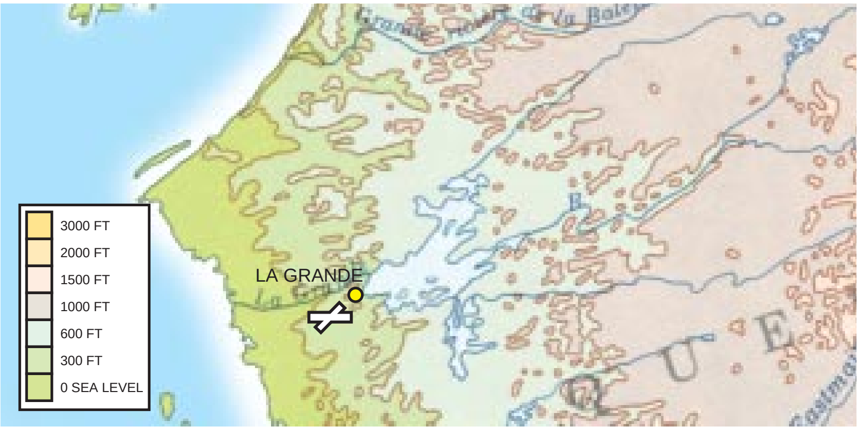
In the fall, west to northwest winds usually bring freezing drizzle and very low stratus. On the other hand, the arrival of cold arctic air usually results in zero, or near zero, ceilings and visibilities in snow squalls.



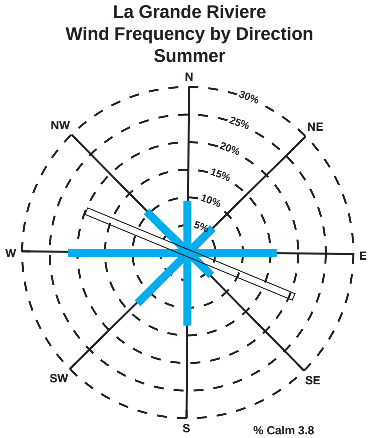


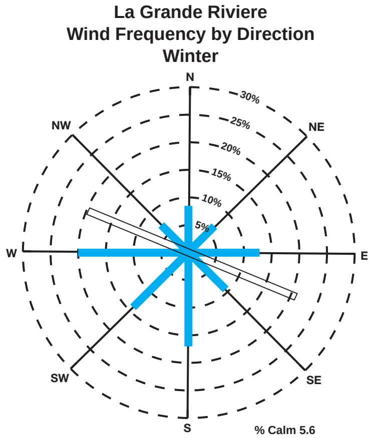
In winter, once the ice pack is well established, flying conditions are generally more favourable. Ice fog may occur when the ice pack shifts under the force of strong easterlies, exposing open water. Throughout the year, east to northeast winds are usually associated with favourable flying conditions. Strong northwesterlies are generally not aligned with the runway, and may generate difficult landing conditions.

(e) La Grande Riviere

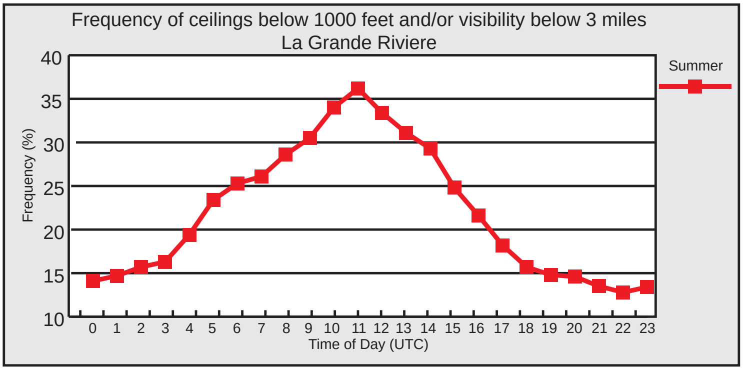


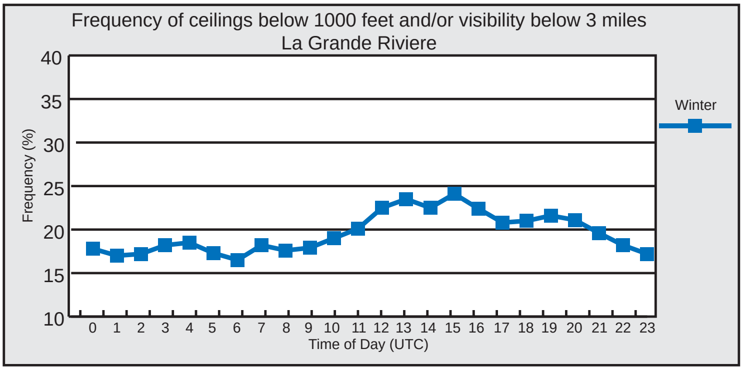
La Grande Riviere is one of a series of airports built by Hydro-Quebec to service their dams. The airport at La Grande Riviere sits in the middle of a series of power lines taking power south. The runway, oriented west-northwest to east-southeast, has an elevation of 639 feet ASL. Near the southeast end of the runway is a butte, otherwise the terrain is made up of a multitude of small hills and lakes. The soil is largely gravel with small trees and lichen. To the east of the airport is an extensive area of flooded terrain that formed behind the dams. To the west, some 90 n. miles distant, is James Bay.





The winds in the summer months can be quite variable but show a preference for the westerly quadrants. The most common wind is the westerly winds at 22 percent; however south and southwest winds occur around 13 percent of the time while northwest and north winds occur nearly 10 percent of the time. Other than the east wind, at 16 percent of the time, all other directions are infrequent. Calm winds are also infrequent occurring only 4 percent of the time. During the winter, the winds show a preference for the southwest quadrant (west -19 percent; southwest - 14 percent; south - 17 percent) and an east wind (13 percent). All other directions are infrequent. Calm winds occur 6 percent of the time. It is worth noting that throughout the year turbulence and low level wind shears are very rare due to the general flatness of the landscape.

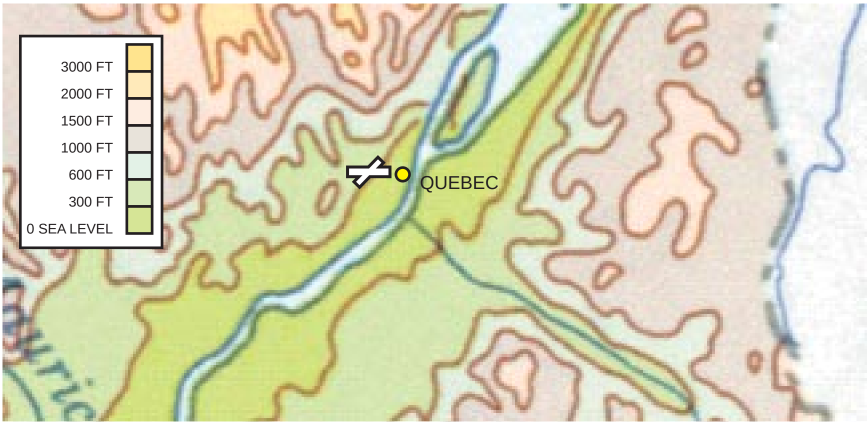




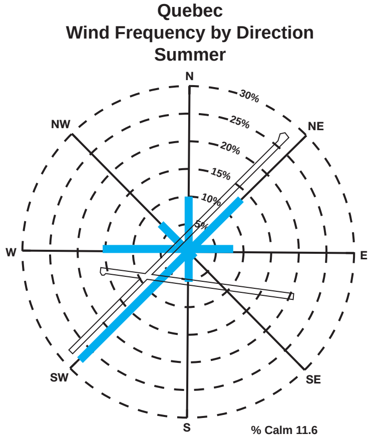
Summer flying conditions are usually benign. Clouds tend to be scattered or broken cumulus or stratocumulus over the area. Low conditions may occur when a warm front or a cold front goes through the area. Isolated thunderstorms can develop on moist and unstable days. This being said, the presence of so much water in the area causes a problem with low cloud and fog, especially during the fall. These conditions tend to form overnight, reaching a peak around 11 to 12 UTC then gradually dissipating between 12 and 18 UTC as the day warms.

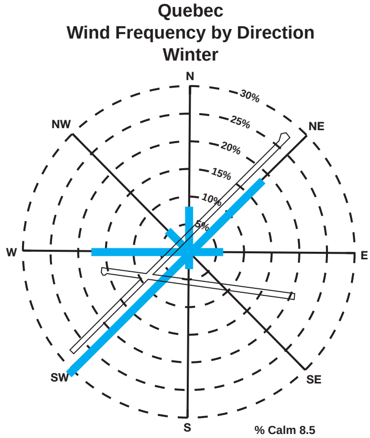
The transition from summer to winter tends to be abrupt, usually taking a short two-week period. This is due to the fast freezing of rivers and lakes during very cold nights. Once the ice has set on the lakes, reservoirs, and rivers, visibility becomes bound only by the horizon and the sky is generally cloudless. These excellent flying conditions are only interrupted when a large-scale weather system passes through the area or the occurrence of fog prior to freeze-up and during spring melt. Westerly winds from James Bay can carry very low stratus cloud, mist, fog and sometimes freezing drizzle in upslope circulation along the largest rivers up to 60 nautical miles inland. Low ceilings and visibility typically occur around 18 percent of the time, but do show a slight peak of 25 percent near dawn.

(f) Quebec



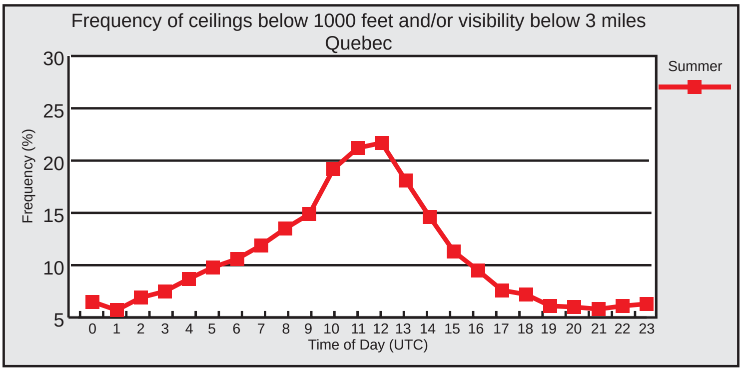
The Jean-Lesage International Airport is situated on a small plateau just to the northwest of the city. The runway elevation is 244 feet ASL. Most airport buildings are found to the south of the main runway, which is oriented in a northeast to southwest direction, and to the east of the secondary and shorter runway, which is oriented in a southeast to northwest direction. There are also some forested areas parallel to the two runways and built-up areas surrounding the airport land. There is a rapid drop in elevation close to the south of the airport, before the ground rises again to form the Ste-Foy Plateau. To the north, the land continues toward the Laurentian foothills. There is a hill to the northwest of the airport called Mont Belair.

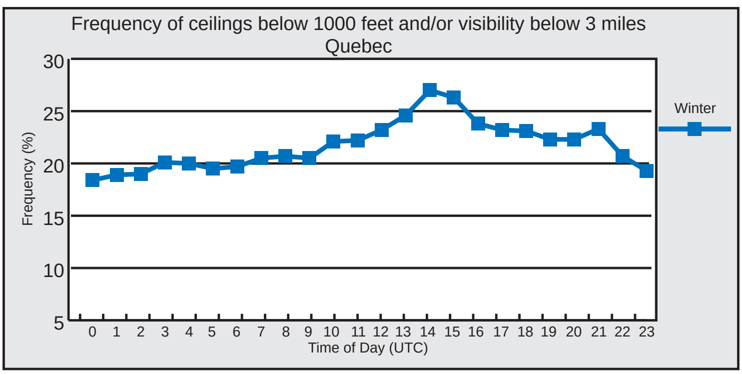




Southwest winds are predominant by far throughout the year. The second most frequent wind direction is northeast in winter, with west wind a close third. In the summer, west winds are slightly more frequent than northeast winds. As for the other directions, each occurs less than 10 percent of the time whether it is summer or winter. Southeast winds are too infrequent to even appear on the wind rose.

An experienced flight instructor reported the occasional mechanical turbulence on landing, when the wind is from 110 to 120°. The wind speed can vary greatly between the runway 24 threshold, the one for runway 30, and the official meteorological wind tower. On one occasion in October, the wind speed was 11010G15KT, 11015G20KT and 11020G30KT depending on the location in the runway complex. The presence of significant wind shear is often observed between the surface and 500 feet above the ground on final approach to runway 06, and moderate mechanical turbulence near runway 30, when a large low pressure weather system is in the area. In such instances, the general wind direction can be 120° while there might be a 30° difference at the surface.



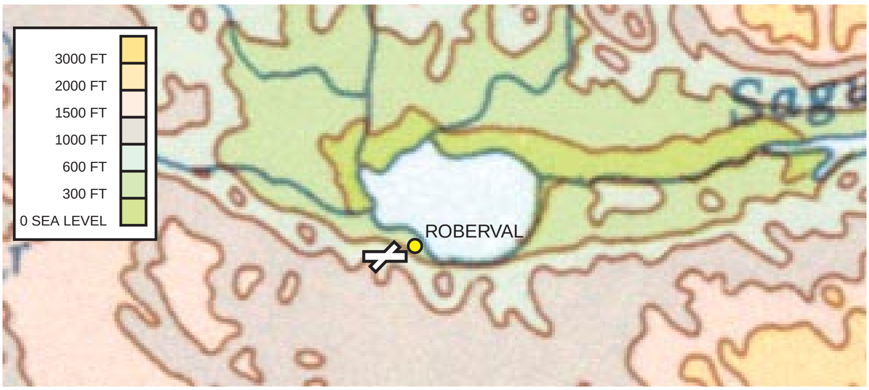


Flight conditions are generally good in the summer, except in the early morning hours when fog often reduces the visibility below 3 statute miles and the cloud base below 1,000 feet. Experienced pilots report that the fog tends to form rapidly just after sunrise, as the moisture-laden air starts to stir, reducing visibilities to 1/4 statute miles, then it tends to dissipate between 10 am and 11 am. In spring and fall, though, the fog tends to last until noon. The top of this fog layer usually lies at 200 or 300 feet above ground. It is frequent to observe the fog bank sitting over the runway complex and clear skies elsewhere. This localized fog layer appears with the thaw in the spring and is most present in the summer. It becomes less frequent in the fall.

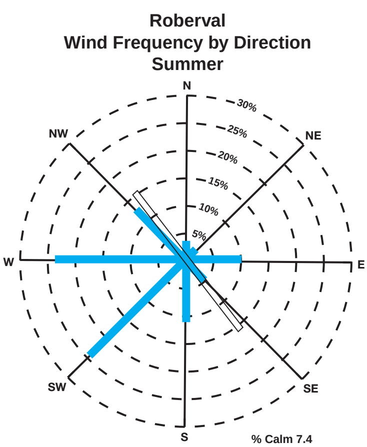
Haze, reducing the visibility to 6 statute miles in the morning, is common on hot days in July and August, when the air temperature reaches or exceeds 28° Celsius. The haze often forces pilots to fly the approach on instruments, especially when landing facing the sun. When it rains, the visibility may lower to 5 statute miles while the ceiling may lower to 1,500 to 2,000 feet ASL in the absence of mist, or even below 1,000 feet if mist forms in the rain.

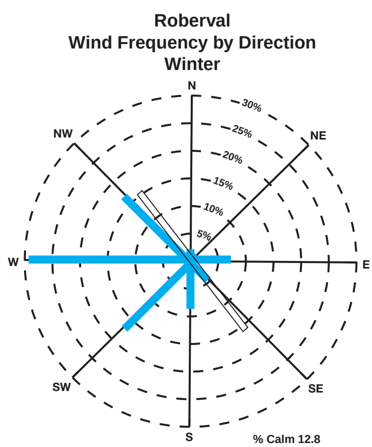
Summer thunderstorms usually move in over the airport from Mount Belair to the northwest, in late afternoon.

(g) Roberval

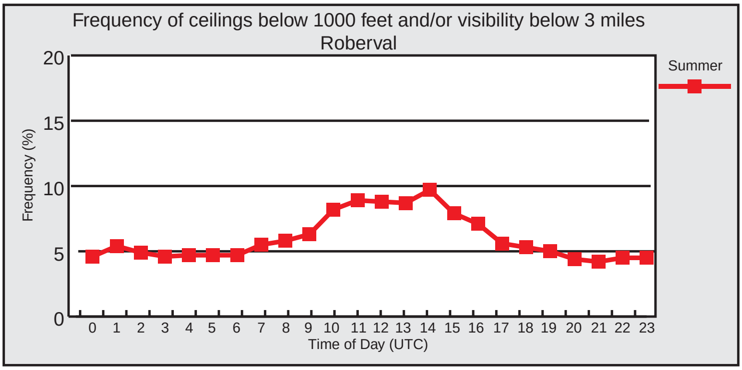


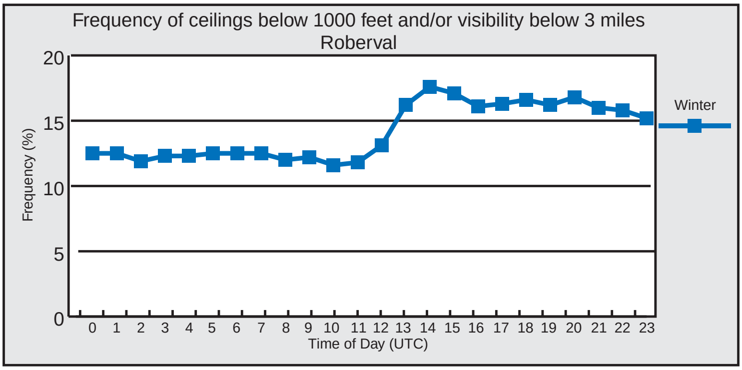
Roberval Airport is situated on a small plateau, one of many, squeezed between mountainous terrain immediately to the west and Lake St-Jean to the east. The terrain surrounding the airport is relatively flat with marshy areas. The runway elevation is 586 feet ASL and is oriented in a north-northwest to south-southeast direction, parallel to the chain of hills to the west.





Southwesterly and westerly winds are predominant in the summer while westerly are predominant in the winter with northwesterlies and southwesterlies a close second. These predominant southwest or west winds are perpendicular to the runway. As a result, wind shear and moderate mechanical turbulence are common along the runway axis as planes make their final approach. The wind shear and the turbulence are more common from late spring to late fall. The winds are usually stronger in the fall, when wind speeds of 25 to 30 knots are sometimes observed. Any winds coming off the lake often bring low clouds and low visibilities but these winds are infrequent.



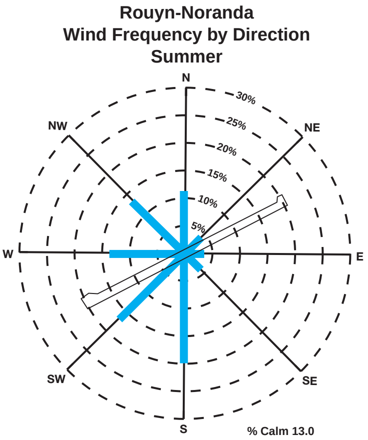


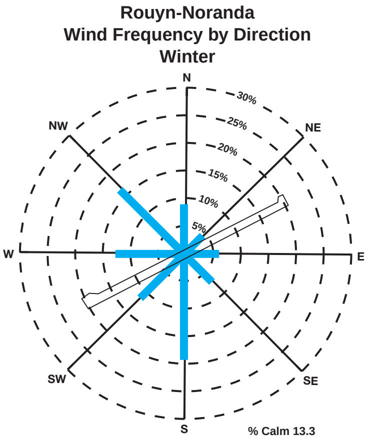
Flying conditions are usually good through out the year, although the winter morning hours tend to have the poorest weather. In winter, conditions are usually excellent except when a snowstorm affects the area. In summer, ceilings are rarely below 1,500 feet AGL. Thunderstorm activity is frequent over the land surrounding the airport in July.

(h) Rouyn-Noranda

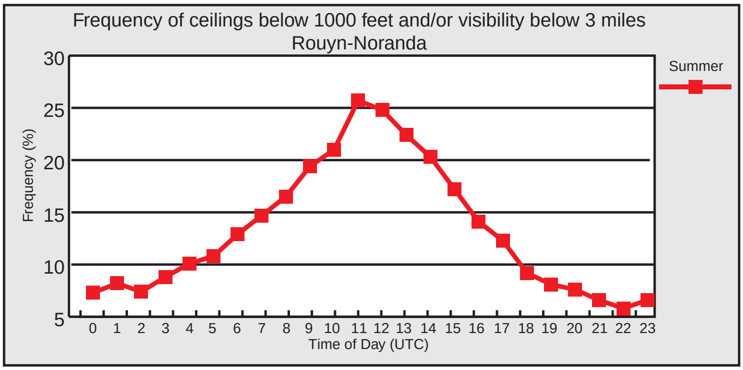
The Rouyn-Noranda Airport is situated in a forested area with the east west runway lying at an elevation of 988 feet ASL. There are some changes in elevation in the vicinity of the airport.

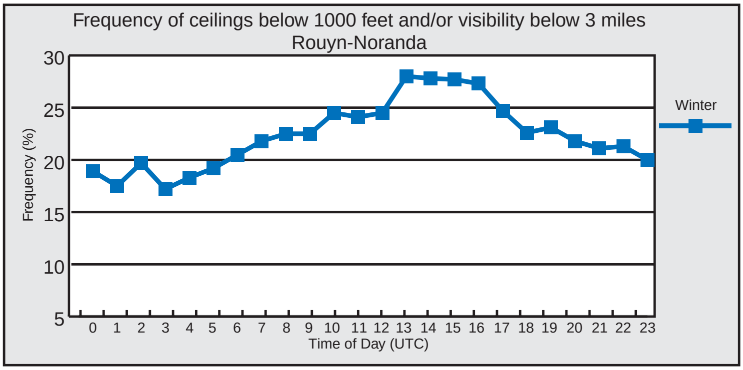
Prevalent winds are generally from the south throughout the year. Like in Val d'Or, the second most prevalent winds are either from the southwest, the northwest or the west, with the relative frequency between southwesterlies and northwesterlies changing from summer to winter.





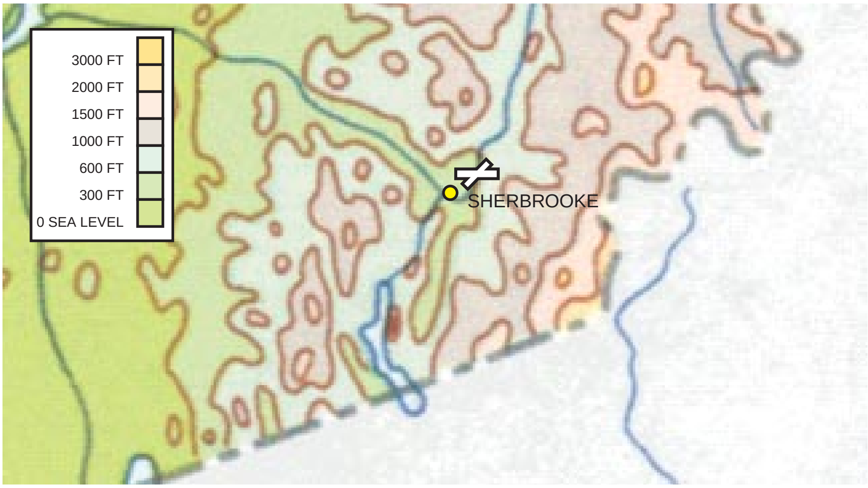
Reports from different sources indicate the existence of low-level, moderate mechanical turbulence over, and in the immediate vicinity of, the runway with northerly and northwesterly winds. Additionally, low level wind shear is reported on runway 08, with northeasterly winds, due to terrain irregularities.



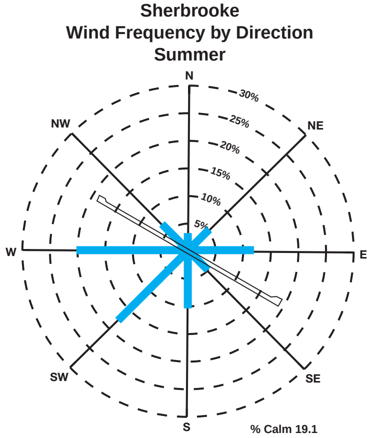


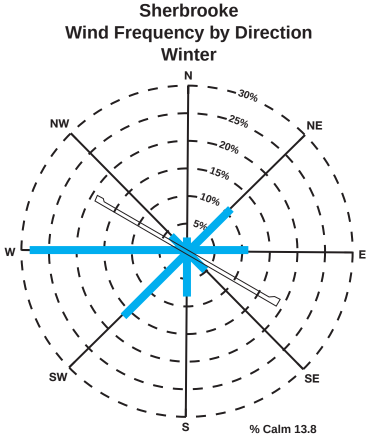
The general frequency of poor weather conditions is very similar to that at Val d'Or. Pilots, however, report that mist, fog, and low visibilities tend to occur more often in Rouyn-Noranda than in Val d'Or, in summer. They also report precipitation tends to last longer in Rouyn-Noranda than in Val d'Or.

(i) Sherbrooke

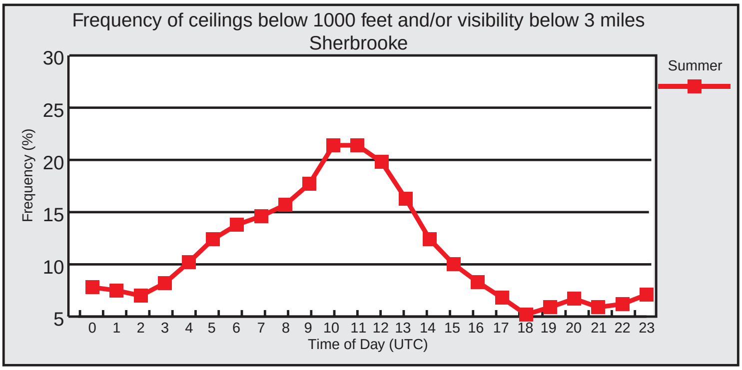


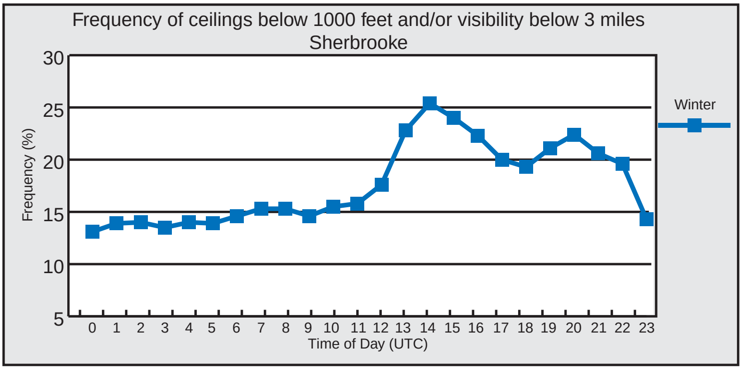
Sherbrooke Airport lies to the east of the city of Sherbrooke, across the Riviere St-Francois in a valley that runs northeast to southwest. The runway is oriented nearly northwest to southeast and has an elevation of 792 feel ASL. To the north of the airport, across the Riviere St-Francois, a series of mountains / hills rise to 1,500 to 2,200 feet ASL. To the east and south of the airport the ground is mountainous and tree-covered, rising quickly to 2,000 feet ASL and to better than 3,000 feet further southeast.





During the summer months, winds are predominantly from the west or southwest 37 percent of the time. The only two other directions of significance are a south wind 10 percent of the time and an east wind 12 percent of the time. Calm winds are observed 19 percent of the time. During the winter, this pattern does not really change except that the west and southwest wind become even more dominant, at 44 percent of the time. At the same time, the occurrence of calm winds drops to 14 percent.



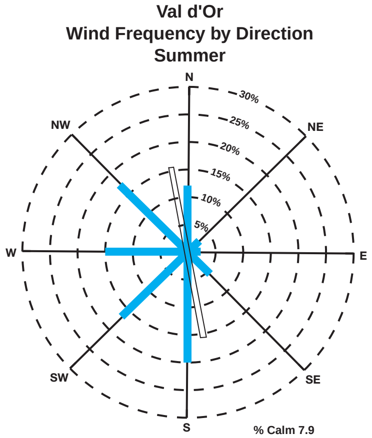


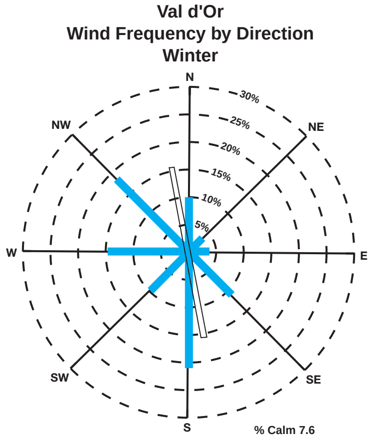
Low clouds and poorer visibilities, along with obscured higher terrain, can be expected at any time of the year. Also, mountainous terrain is conducive to the pooling of cooler air in river valleys during the night. With moisture present, fog often forms in these areas either in the evening or early morning. This fog may slowly lift into a thin stratus cloud hugging the valley summits. This pattern can be seen in the summer graph which shows a rising probability of low ceilings or visibility after 02 UTC that reaches a peak of just over 20 percent probability at 11 UTC. The probability then drops after this, during the morning hours, until it dissipates near 18 UTC.

Winter is by far the worst time of the year with poor ceilings and visibility varying between 15 and 25 percent throughout the day. The reason for this is fairly simple - all the parameters that created low cloud or fog during the summer are still in place while at the same time the sun rises later and is weaker, reducing any diurnal effect. Fall, early winter, and spring are times of the year when precipitation types can change rapidly from snow to freezing rain to rain or vice versa over short distances or with slight changes in elevation.

(j) Val d'Or

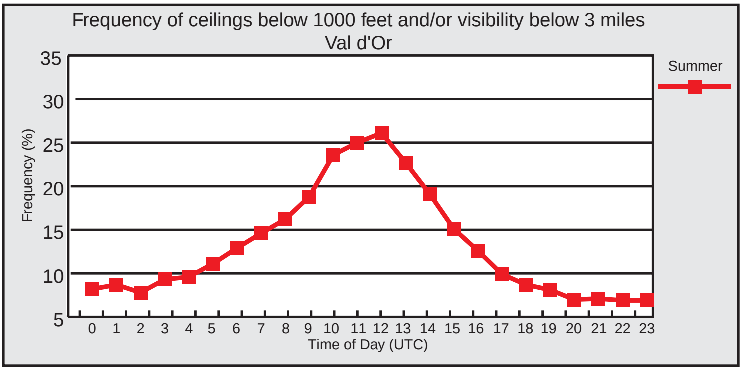
The Val d'Or Airport is situated on a small plateau just to the northwest of the city. The runway elevation is 1,107 feet ASL. Most airport buildings are found near the north end of the north south runway. The surrounding area is relatively flat and marshland can be found around the airport.

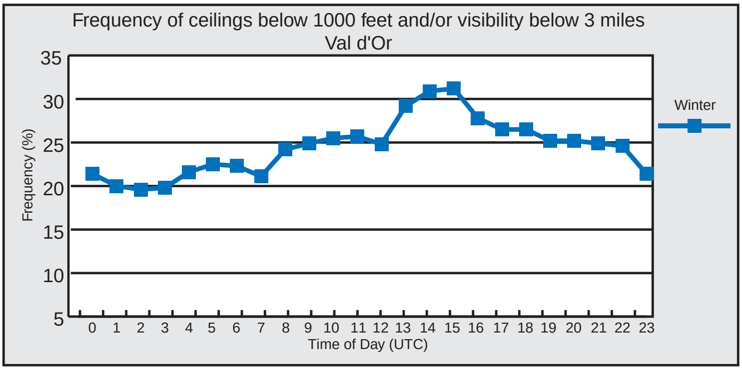




South winds are predominant, by far, throughout the year. In summer, the second rank is shared by the northwest and southwest with west winds close behind. In the winter, northwest and west winds remain as frequent as in summer, while southwest winds are half as frequent and southeast winds become more frequent. Strong wind speeds tend to be a rare occurrence in Val d'Or. Wind shear and turbulence are seldom reported in the immediate vicinity of the Val d'Or airport, except on hot convective days.

In July, thunderstorm activity is frequent over the land surrounding the airport.





Flying conditions are usually good throughout the year, although the winter morning hours tend to have the poorest weather. There is also the usual bout of fog or mist in the wee morning hours but it starts to dissipate as early as 8:30 am, during the summer and early fall. In many instances, the fog moves in over the southern half of the runway from a nearby lake. Once winter sets in and lakes freeze up, continental conditions (cold and dry arctic air) usually predominate, except for the occasional low pressure systems bringing some snow accumulations. Freezing rain is very rarely observed in Val d'Or, while freezing drizzle may occur on occasions during the fall.

Glossary of Weather Terms

anabatic wind - a local wind which blows up a slope heated by sunshine.

advection - the horizontal transportation of air or atmospheric properties.

air density - the mass density of air expressed as weight per unit volume.

air mass - an extensive body of air with uniform conditions of moisture and temperature in the horizontal.

albedo – the ratio of the amount of solar radiation reflected by a body to the amount incident on it, commonly expressed as a percentage.

anticyclone - an area of high atmospheric pressure which has a closed circulation that is anticyclonic (clockwise) in the Northern Hemisphere.

blizzard - a winter storm with winds exceeding 40 km/h, with visibility reduced by falling or blowing snow to less than one kilometre, with high windchill values and lasting for at least three hours. All regional definitions contain the same wind speed and visibility criteria but differ in the required duration and temperature criterion.

cat's paw – a cat paw-like, ripple signature on water given by strong downdrafts or outflow winds. A good indication of turbulence and wind shear.

ceiling - either (a) the height above the surface of the base of the lowest layer of clouds or obscuring phenomena (i.e. smoke) that hides more than half of the sky; (b) the vertical visibility into an obstruction to vision (i.e. fog).

chinook - a warm dry wind blowing down the slopes of the Rocky Mountains and over the adjacent plains.

clear air turbulence (CAT) - turbulence in the free atmosphere not related to convective activity. It can occur in cloud and is caused by wind shear.

clear icing - the formation of a layer or mass of ice which is relatively transparent because of its homogeneous structure and smaller number and size of air spaces; synonymous with glaze.

climate - the statistical collection of long-term (usually decades) weather conditions at a point; may be expressed in a variety of ways.

cold front - the leading edge of an advancing cold air mass.

convection - atmospheric motions that are predominately vertical, resulting in the vertical transport and mixing of atmospheric properties.

convergence - a condition that exists when the distribution of winds in a given area is such that there is a net horizontal inflow of air into the area; the effect is to create lift.

cumuliform - a term descriptive of all convective clouds exhibiting vertical development.

cyclone - an area of low atmospheric pressure which has a circulation that is cyclonic (counterclockwise) in the Northern Hemisphere.

deepening - a decrease in the central pressure of a pressure system; usually applied to a low. Indicates a development of the low.

deformation zone - an area in the atmosphere where winds converge along one axis and diverge along another. Where the winds converge, the air is forced upward and it is in these areas where deformation zones (or axes of deformation as they are sometimes referred to) can produce clouds and precipitation.

disturbance - applied loosely: (a) any small-sized low pressure system; (b) an area where the weather, wind, and air pressure show signs of cyclonic development; (c) any deviation in flow or pressure that is associated with a disturbed state in the weather; and (d) any individual circulatory system within the primary circulation of the atmosphere.

divergence - a condition that exists when the distribution of winds in a given area is such that there is a net horizontal outflow of air from the area.

downdraft - a small scale downward current of air; observed on the lee side of large objects that restrict the smooth flow of air or in or near precipitation areas associated with cumuliform clouds.

downburst - an exceptionally strong downdraft beneath a thunderstorm usually accompanied by a deluge of precipitation.

filling - an increase in the central pressure of a pressure system; applied to a low.

Föhn wind (foehn wind)- a warm dry wind on the lee side of a mountain range, whose temperature is increased as the wind descends down the slope. It is created when air flows downhill from a high elevation, raising the temperature by adiabatic compression.

front - a surface, interface or transition zone of discontinuity between two adjacent air masses of different densities.

Fujita Scale – a scale used to rate the intensity of a tornado by examining the damage caused by the tornado after it has passed over a man-made structure (see Table 1).

Table 1 - The Fujita Scale

F-Scale Number	Intensity Phrase	Wind Speed (kts)	Type of Damage Done
F0	**Weak** Tornado	35-62	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.
F1	**Moderate** Tornado	63-97	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
F2	**Strong** Tornado	98-136	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.
F3	**Severe** Tornado	137-179	Roof and some walls torn off well constructed houses; trains overturned; most trees in forest uprooted
F4	**Devastating** Tornado	180-226	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large-object missiles generated.
F5	**Incredible** Tornado	227-285	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile-sized missiles fly through the air in excess of 100 meters; trees debarked; steel re-inforced concrete structures badly damaged.

funnel cloud - a tornado cloud or vortex cloud extending downward from the parent cloud but not reaching the ground.

gust - a sudden, rapid and brief increase in wind speed. In Canada, gusts are reported when the highest peak speed is at least 5 knots higher than the average wind and the highest peak speed is at least 15 knots.

gust front - the leading edge of the downdraft outflow ahead of a thunderstorm.

high - an area of high barometric pressure; a high pressure system.

hurricane – an intense tropical weather system with a well defined circulation and maximum sustained winds of 64 knots or higher. In the western Pacific, hurricanes are called “typhoons,” and similar storms in the Indian Ocean are called “cyclones” (see Table 2 for hurricane intensitites).

Table 2 - Saffir-Simpson Hurricane Scale

Category #	Sustained Winds (kts)	Damage
1	64-82	Minimal
2	83-95	Moderate
3	96-113	Extensive
4	114-135	Extreme
5	>155	Catastrophic

icing - any deposit of ice forming on an object.

instability - a state of the atmosphere where the vertical distribution of temperature is such that a parcel displaced from its initial position will continue to ascend.

inversion - an increase of temperature with height - a reversal of the normal decrease of temperature with height.

isothermal layer - equal or constant temperature with height.

jet stream - a quasi-horizontal stream of wind concentrated within a narrow band; generally located just below the tropopause.

katabatic wind - downslope gravitational flow of colder, denser air beneath the warmer, lighter air. Also known as "drainage wind" or "mountain breeze". Strength can vary from gentle to extremely violent winds.

knot - a unit of speed equal to one nautical mile per hour.

lapse rate - the rate of change of an atmospheric variable (usually temperature) with height.

lee wave - any stationary wave disturbance caused by a barrier in a fluid flow; also called mountain wave or standing wave.

lightning - any and all forms of visible electrical discharge produced by a thunderstorm.

low - an area of low barometric pressure; a low pressure system.

meridional flow – airflow in the direction of the geographic meridians, i.e. south-north or north-south flow.

meteorology - the science of the atmosphere.

mixed icing - the formation of a white or milky and opaque layer of ice that demonstrates an appearance that is a composite of rime and clear icing.

occluded front - a front that is no longer in contact with the surface.

orographic - of, pertaining to, or caused by forced uplift of air over high ground.

outflow - a condition where air is flowing from the interior land area through mountain passes, valleys and inlets onto the coastal areas; used most commonly in winter when cold Arctic air spreads onto the coastal area and adjoining sea.

overrunning - a condition when warm air overtakes or is lifted by colder denser air.

parcel - a small volume of air, small enough to contain uniform distribution of meteorological properties, and large enough to remain relatively self-contained and respond to all meteorological processes.

plow wind - usually associated with the spreading out of a downburst from a thunderstorm; a strong, straight-line wind in advance of a thunderstorm that often results in severe damage.

precipitation - any and all forms of water particles, whether liquid or solid, that fall from the atmosphere and reach the surface.

quasi-stationary front - a front that is stationary or nearly so; commonly called stationary front.

ridge - an elongated area of relatively high atmospheric pressure; also called ridge line.

rime icing - the formation of a white or milky and opaque granular deposit of ice formed by the rapid freezing of supercooled water droplets.

saturation - the condition in the atmosphere where actual water vapour present is the maximum possible at the existing temperature.

shower - precipitation from cumuliform cloud; characterized by suddenness of beginning and ending, by rapid changes in intensity, and usually by rapid changes in the appearance of the sky.

squall - essentially gusts of longer duration. In Canada, a squall is reported when the wind increases by at least 15 knots over the average speed for a duration of at least 2 minutes and the wind reaches a speed of at least 20 knots.

squall line - a non-frontal line or narrow band of active thunderstorms.

stability - a state of the atmosphere where the vertical distribution of temperature is such that a parcel will resist displacement from its initial position.

stratiform - term descriptive of clouds of extensive horizontal development; flat, lacking definition.

stratosphere - the atmospheric layer above the tropopause; characterized by slight increase in temperature from base to top, very stable, low moisture content and absence of cloud.

subsidence - the downward motion of air over a large area resulting in dynamic heating.

supercooled water - liquid water at temperatures below freezing.

thunderstorm - a local storm invariably produced by a cumulonimbus cloud, and always accompanied by lightning and thunder.

tornado - a violently rotating column of air, shaped from a cumulonimbus cloud, and nearly always observed as “funnel-shaped;” other names are cyclone and twister.

tropopause - the transition zone between the troposphere and the stratosphere; characterized by an abrupt change in lapse rate.

troposphere - the portion of the earth's atmosphere from the surface to the tropopause; characterized by decreasing temperature with height and appreciable water vapour. Often referred to as the weather layer.

trough - an elongated area of relatively low atmospheric pressure; also called trough line.

trowal - a trough of warm air aloft; related to occluded front.

turbulence - any irregular or disturbed flow in the atmosphere.

updraft - a localized upward current of air.

upper front - any frontal zone which is not manifested at the surface.

virga - water or ice particles falling from a cloud, usually in wisps or streaks, and evaporating completely before reaching the ground.

warm front - the trailing edge of retreating cold air.

weather - the instantaneous conditions or short term changes of atmospheric conditions at a point; as opposed to climate.

wind - air in motion relative to the earth's surface; normally horizontal motion.

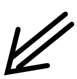
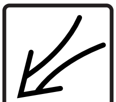
wind direction - the direction from which the wind is blowing.

wind speed - rate of wind movement expressed as distance per unit time.

wind shear - the rate of change of wind direction and/or speed per unit distance; conventionally expressed as vertical and horizontal wind shear.

zonal wind - a west wind; conventionally used to describe large-scale flow that is neither cyclonic or anticyclonic; also called zonal flow.

Table 3: Symbols Used in this Manual

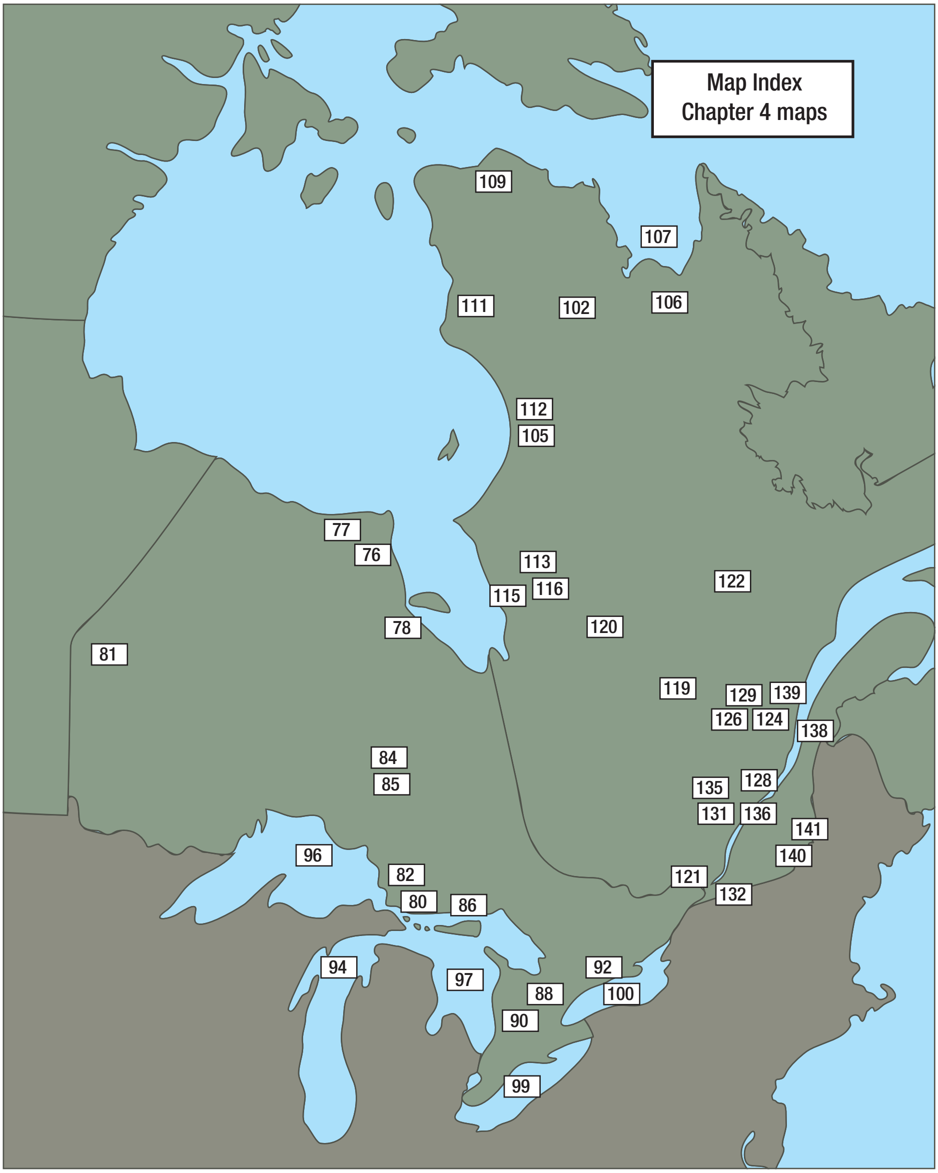
	**Fog Symbol (3 horizontal lines)** This standard symbol for fog indicates areas where fog is frequently observed.
	**Cloud areas and cloud edges** Hatched lines show areas where low cloud (preventing VFR flying) is known to occur frequently. In many cases, this hazard may not be detected at any nearby airports.
	**Icing symbol (2 vertical lines through a half circle)** This standard symbol for icing indicate areas where significant icing is relatively common.
	**Choppy water symbol (symbol with two wavelike points)** For floatplane operation, this symbol is used to denote areas where winds and significant waves can make floatplane operation dangerous or impossible.
	**Turbulence symbol** This standard symbol for turbulence is also used to indicate areas known for significant windshear as well as potentially hazardous downdrafts.
	**Strong wind symbol (straight arrow)** This arrow is used to show areas prone to very strong winds and also indicates the typical direction of these winds. Where these winds encounter changing topography (hills, valley bends, coastlines, islands, etc.), turbulence, although not always indicated, can be expected.
	**Funneling / Channeling symbol (narrowing arrow)** This symbol is similar to the strong wind symbol except that the winds are constricted or channeled by topography. In this case, winds in the narrow portion could be very strong while surrounding locations receive much lighter winds.
	**Snow symbol (asterisk)** This standard symbol for snow shows areas prone to very heavy snowfall.
	**Thunderstorm symbol (half circle with anvil top)** This standard symbol for cumulonimbus (CB) cloud is used to denote areas prone to thunderstorm activity.
	**Mill symbol (smokestack)** This symbol shows areas where major industrial activity can impact on aviation weather. The industrial activity usually results in more frequent low cloud and fog.
	**Mountain pass symbol (side-by-side arcs)** This symbol is used on aviation charts to indicate mountain passes, the highest point along a route. Although not a weather phenomenon, many passes are shown as they are often prone to hazardous aviation weather.

Appendix


Sanikiluaq
BELCHER
ISLAND
Fontanges
Kuujjuarapik
Fort Severn
La Grande IV
Peawanuck
JAMES
BAY
La Grande Riviere
QUÉBEC
Big Trout Lake
Attawapiskat
Eastmain
Nemiscau
Sandy Lake
Lansdowne House
Moosonee
Chibougama
Pickle Lake
Matagami
Red Lake
ONTARIO
Armstrong
Hearst
Kapuskasing
Parent
Geraldton
Sioux Lookout
L. NIPIGON
Timmins
Val-d'Or
Kenora
L. of the
WOODS
Terrace Bay
Earlton
Thunder Bay
Wawa
Chapleau
Maniwaki
Atikokan
LAKE SUPERIOR
Sudbury
Petawawa
North Bay
Ottawa
Sault Ste Marie
Muskoka
LAKE
HURON
Wiarton
Trenton
Kincardine
L. ONTARIO
Toronto
LAKE MICHIGAN
London
Sarnia
Windsor
L. ERIE


Killinek
Kangiqsujuaq
Salluit
Quaqtaq
Ivujivik
PÉNINSULE
D'UNGAVA
Kangirsuk
UNGAVA
BAY
LABRADOR
SEA
Puvirnituq
Kuujjuaq
Inukjuak
Schefferville
Sanikiluaq
BELCHER
ISLAND
Fontanges
Wabush
Lac Eon
Chevery
Kuujjuarapik
La Grande IV
Natashquan
anuck
JAMES
BAY
La Grande Riviere
QUÉBEC
Port-Menier
Sept-Iles
Manicouagan
Gaspe
Attawapiskat
Eastmain
Nemiscau
Baie-Comeau
Mont-Joli
House
Moosonee
Chibougamau
Matagami
Roberval
Riviere-du-Loup
Hearst
Kapuskasing
Parent
ldton
Timmins
Val-d'Or
Quebec
ace Bay
Earlton
Trois-Rivieres
Wawa
Chapleau
Maniwaki
Sherbrooke
RIOR
Sudbury
Petawawa
Montreal
North Bay
Ottawa
Sault Ste Marie

Notes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NAV CANADA

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