The Weather of The Canadian Prairies

Graphic Area Forecast 32

NAV CANADA

The Weather of The Canadian Prairies

Graphic Area Forecast 32

by
Glenn Vickers
Sandra Buzza
Dave Schmidt
John Mullock

NAV CANADA

Copyright

Trademarks

Relief Maps

Ideas in Motion

Design and illustration by
Ideas in Motion
Kelowna, British Columbia
ph: (250) 717-5937
ideasinmotion@shaw.ca

The Weather of the Prairies
Graphic Area Forecast 32 Prairie Region

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 Prairies Local Area Knowledge Aviation Weather manual is one of a series of six publications prepared by the Meteorological Service of Canada (MSC) 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 that covers two GFA Domains. These manuals form 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 GFACN32 (Alberta – Saskatchewan – Manitoba). This area offers beautiful open spaces 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 Foothills of Alberta to the Canadian Shield area of Manitoba, 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 the Prairies 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 Glenn Vickers, Sandra Buzza and Dave Schmidt, Prairie Aviation and Arctic Weather Centre, Edmonton, and John Mullock, Mountain Weather Centre, Kelowna. Glenn's, Sandra's, and Dave's regional expertise has been instrumental for the development of the Prairie 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 who 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.

Roger M. Brown
January, 2002

Readers are invited to submit any comments to:

NAV CANADA
Customer Service Centre
77 Metcalfe St.
Ottawa, Ontario
K1P 5L6

Toll free phone line: 1-800-876-4693-4
(within North America disregard the last digit)
Toll-free fax line: 1-877-663-6656
E-mail: service@navcanada.ca

NAV CANADA

SERVING A WORLD IN MOTION

AU SERVICE D'UN MONDE EN MOUVEMENT

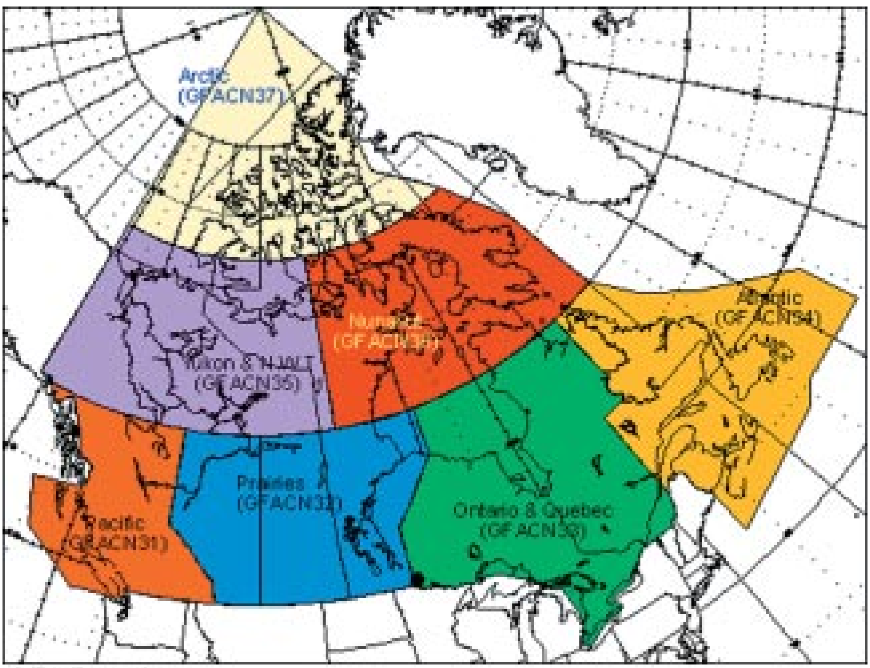
TABLE OF CONTENTS

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 Prairie 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 GFACN32 Prairie. This area often has beautiful flying weather but can also have some of the toughest 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 flat plains of Southern Saskatchewan to the rising mountains of Western Alberta, 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 the Prairies could result in a publication several 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.

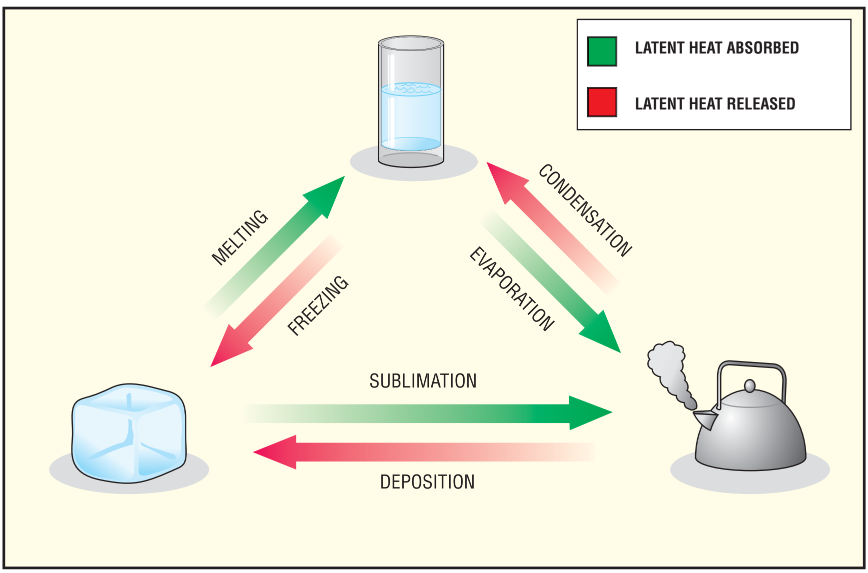


Fig. 1-1 - Heat transfer and water vapour

How much water the air contains in the form of 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 water 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.

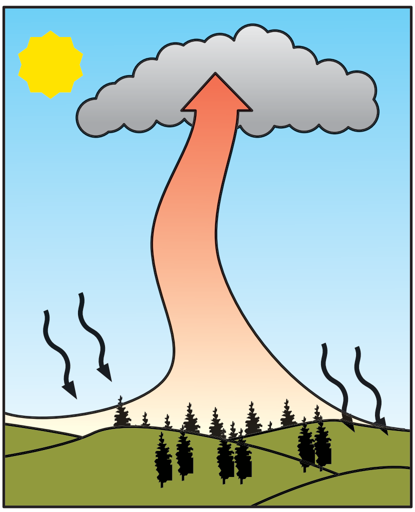


Fig. 1-2 - Convection as a result of daytime heating

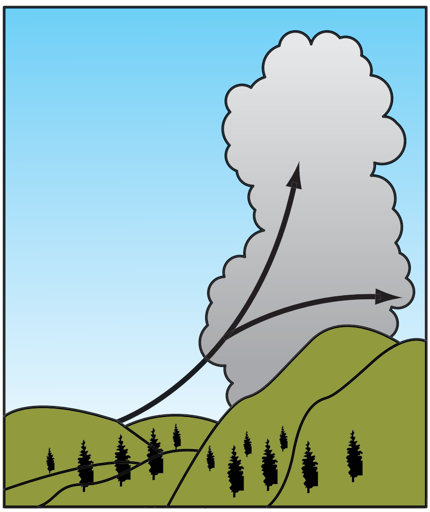


Fig.1-3 - Orographic (upslope) lift

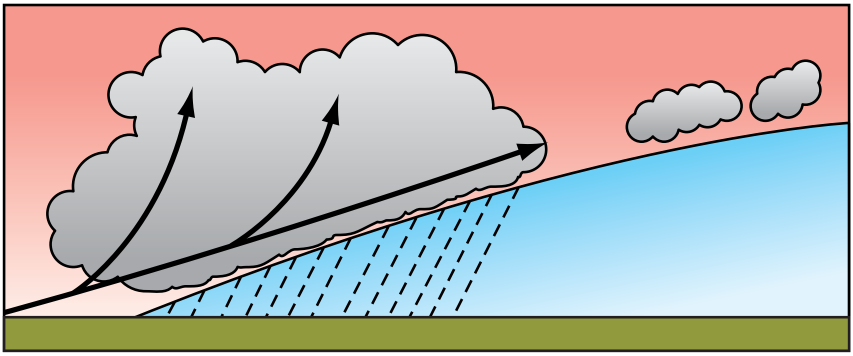


Fig.1-4 - Warm air overrunning cold air along a warm front

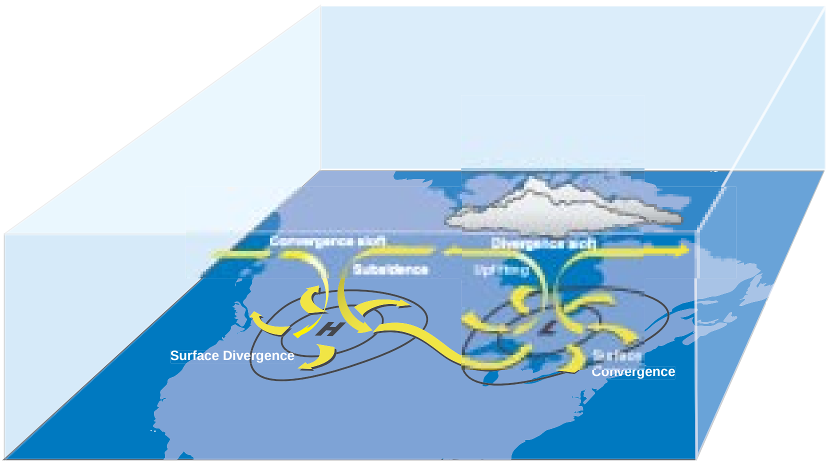


Fig. 1-5 - Divergence and convergence at the surface and aloft in a high low couplet

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.

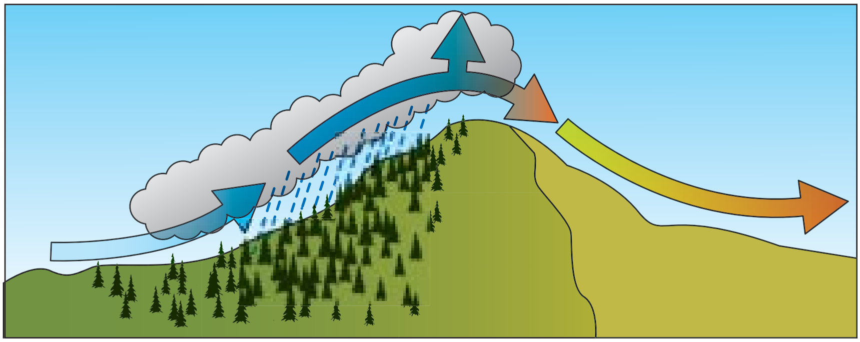


Fig.1-6 - Moist air moving over mountains where it loses its moisture and sinks into a dry subsidence area

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.

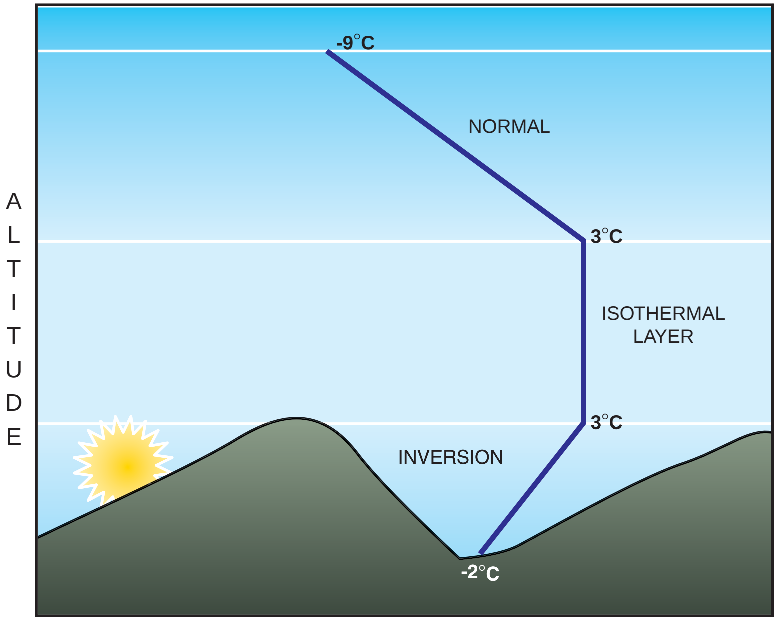


Fig. 1-7 - Different lapse rates of the atmosphere

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.

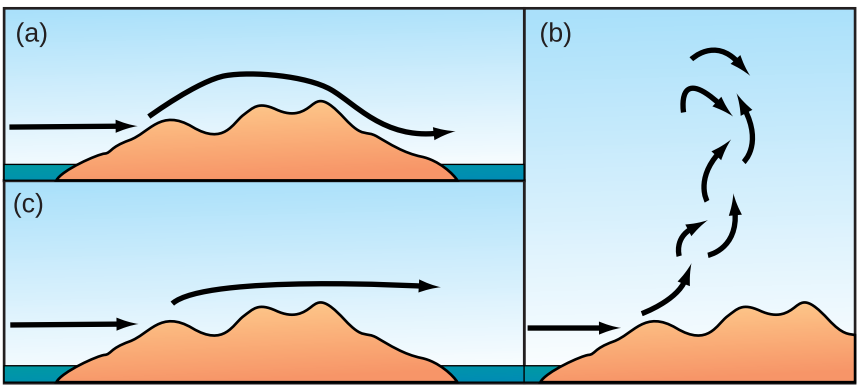


Fig. 1-8 - Stability in the atmosphere - (a) Stable (b) Unstable (c) Neutral

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.

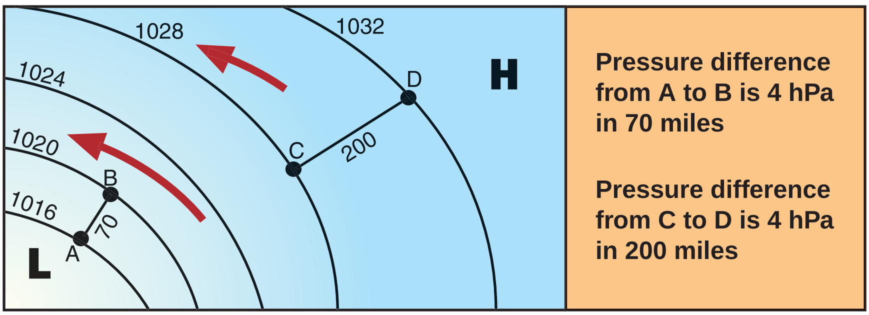


Fig. 1-9 - The greater pressure changes with horizontal difference, the stronger the wind

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 quasi-stationary fronts although there usually is some small-scale localized motion occurring.		
Trowal - Trough of warm air aloft.		

Table 1-1

More will be said about frontal weather later in this manual.

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 exact 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:

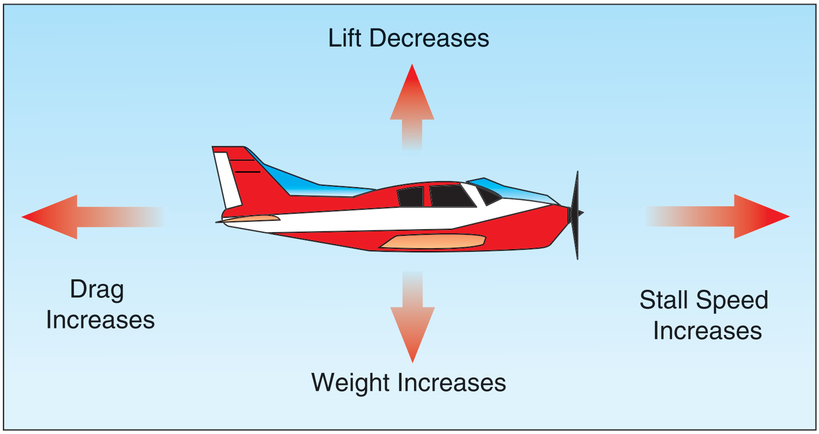


Fig. 2-1 - Effects of icing

- 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 windshear 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 .

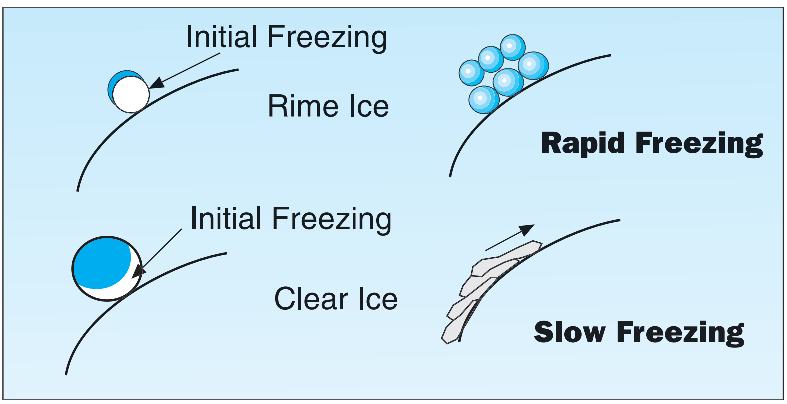


Fig. 2-2 - Freezing of supercooled droplets on impact

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.

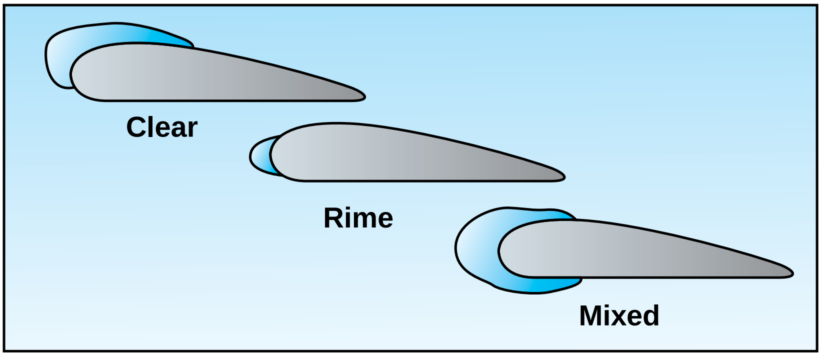


Fig. 2-3 - Accumulation patterns of different icing types

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:

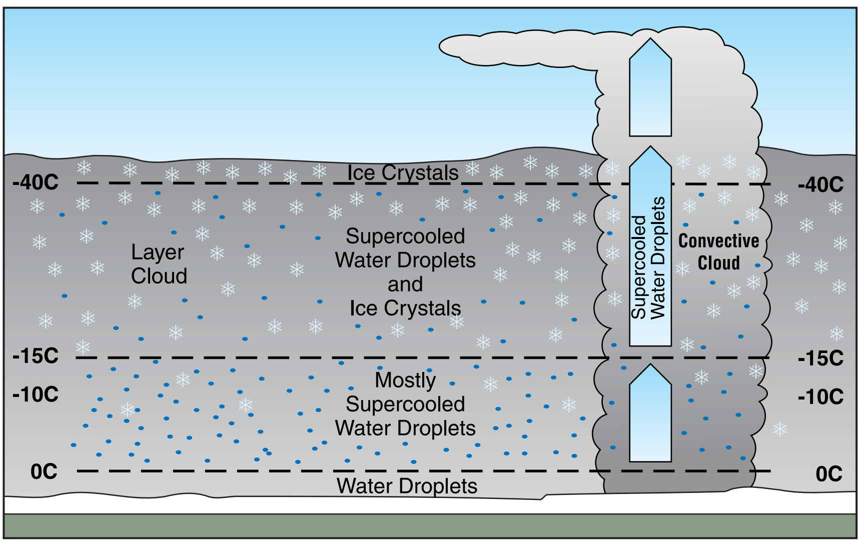


Fig. 2-4 - Distribution of water droplet-ice crystals in cloud

(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.

Over the Prairies, SLD icing-producing clouds are common in a easterly to northeasterly flow off Hudson Bay, in north-eastern Manitoba, in northern Saskatchewan, and in Alberta. 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.

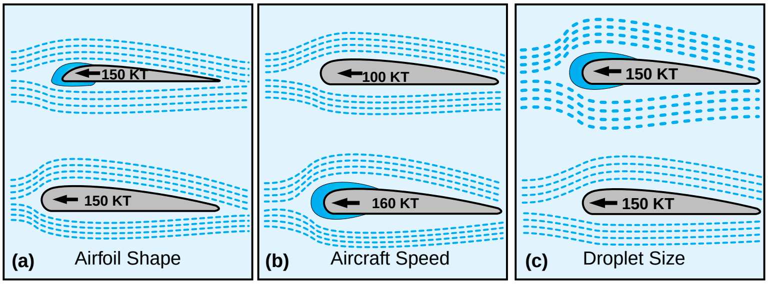


Fig. 2-5 -Variations in collection efficiency

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 Western 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 especially if cold air continues to drain into the area from the surrounding terrain. 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, favorable 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.

(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.

(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.

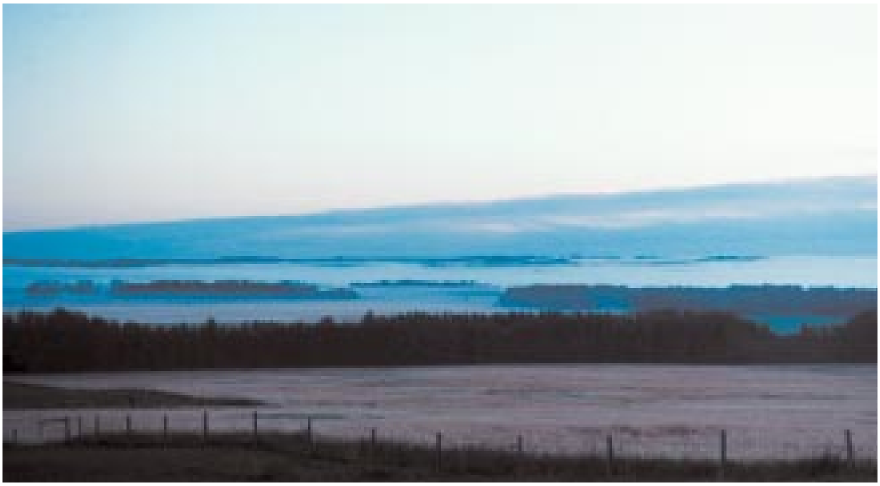


Photo 2-2 - Radiation fog in a valley credit: Alister Ling

(ii) 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.

(iii) 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.

(iv) Advection Fog

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

(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

Snow squalls are relatively small areas of heavy snowfall. They develop when cold arctic air passes over a relatively warm water surface, such as Lake Winnipeg, 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.

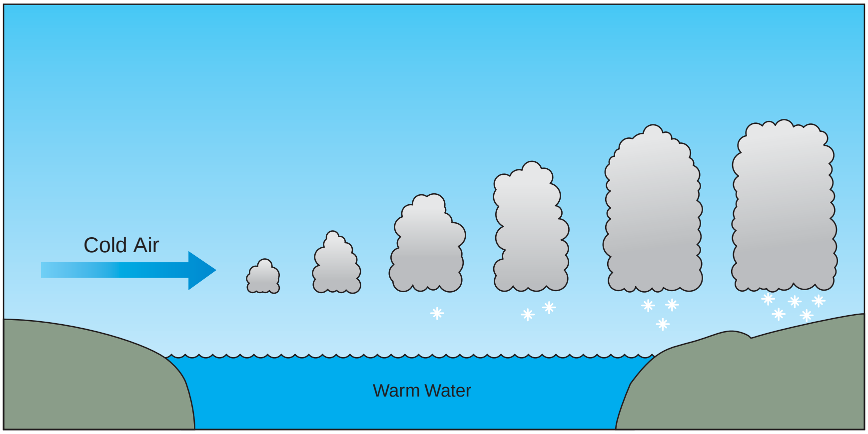


Fig. 2-6 - Snowsqualls building over open water

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 mountainous terrain.

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.

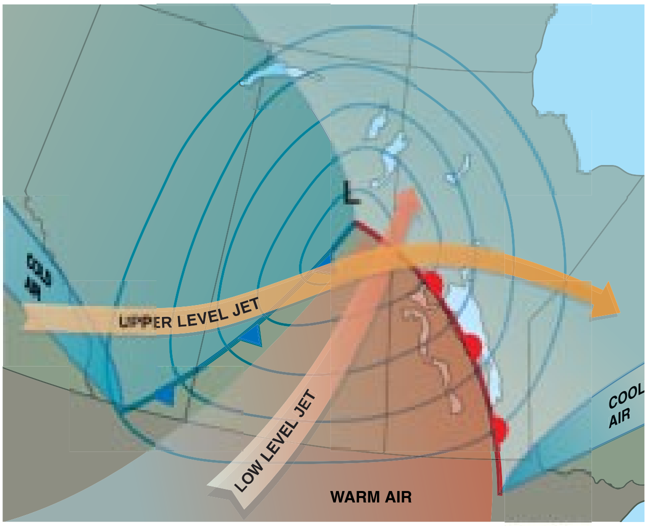


Fig. 2-7 - Idealized low and frontal system showing the position of the low-level and upper-level jet

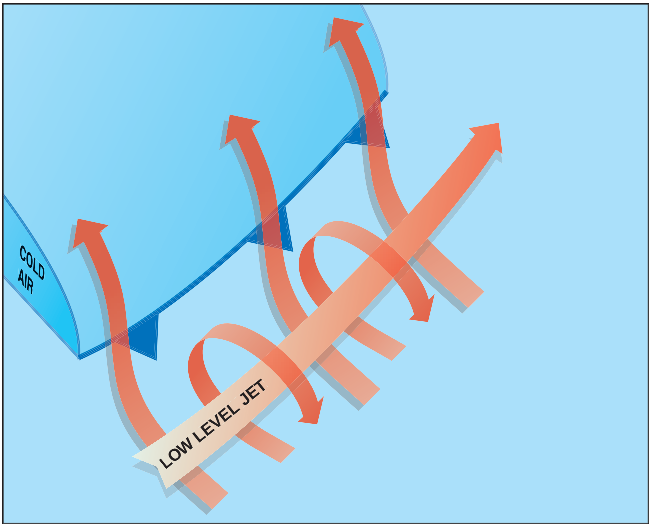


Fig. 2-8 - Complex winds around a low-level jet can result in significant low-level wind shear and turbulence

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 hills, 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 hills. In the lee of the hills, the wind is usually gusty and the wind direction is often completely opposite to the wind blowing over the top of the hills. Smaller reverse eddies may also be encountered close to the hills. The Livingstone Range to the west of Claresholm, Alberta produces areas where the wind can be calm but, a short distance away, the winds will be strong westerly.

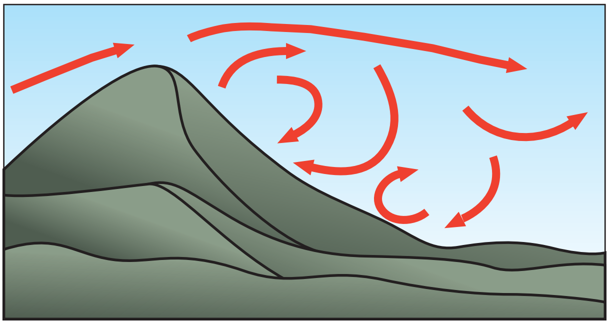


Fig. 2-9 - Lee effects

(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.

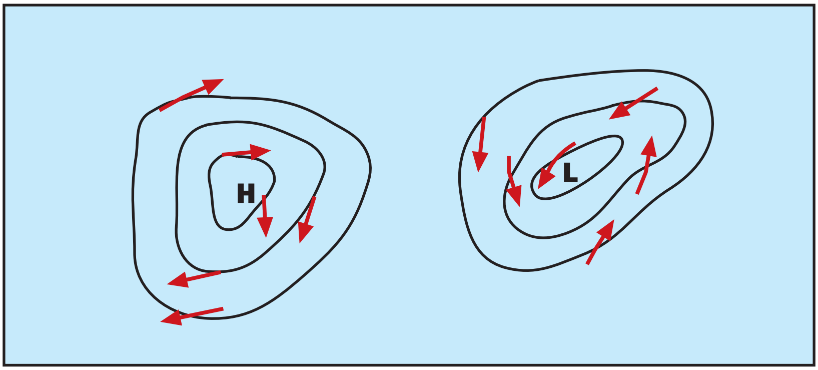


Fig. 2-10 - Friction effects

(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.

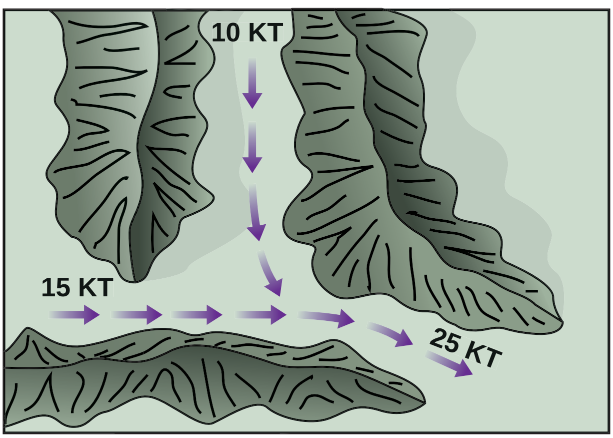


Fig. 2-11 - Converging winds

(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.

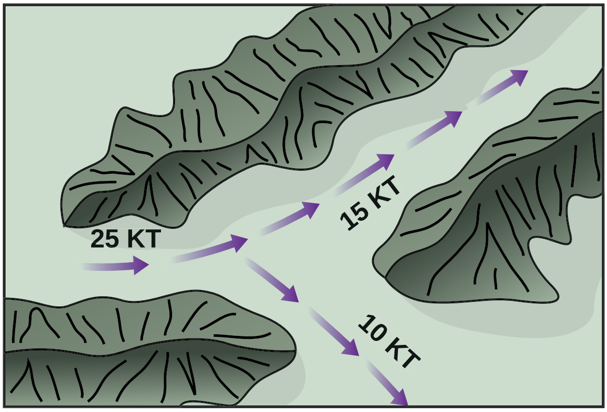


Fig. 2-12 - Diverging winds

(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 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.

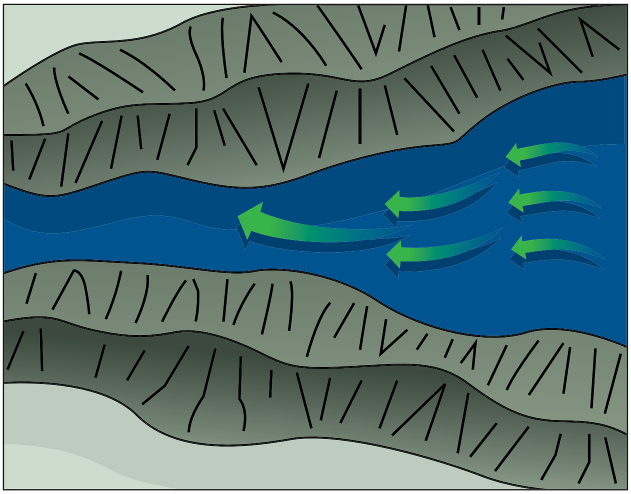


Fig. 2-13 - Funnelled winds

(g) Channelled Winds

The topography can also change the direction of the winds by forcing the flow along the direction of a pass or valley. 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.

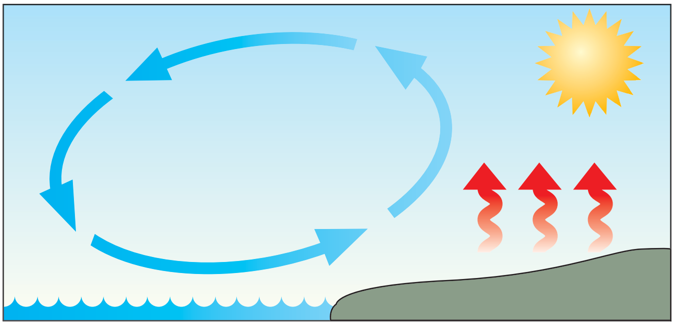


Fig. 2-14 - Sea breeze

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.

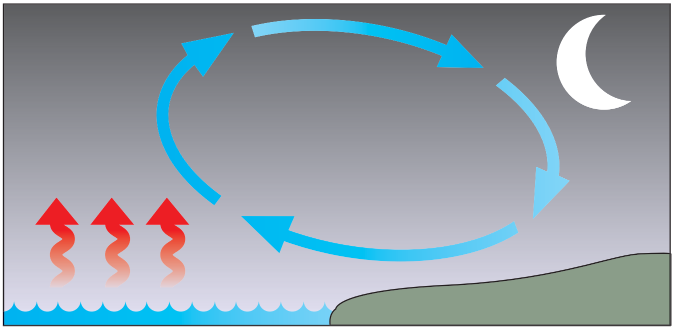


Fig. 2-15 - Land breeze

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. Example of this can be found near the larger lakes in the Prairies and are often referred to as “lake effect winds”.

(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. This effect occurs in the Oldman River Valley, to the west of the Lethbridge Airport, where a westerly flow is enhanced by this heating of the valley sides making it quite turbulent on the bluffs on the east side of the valley. This is generally a low-level effect and only noticeable up to 200 to300 feet above the bluffs.

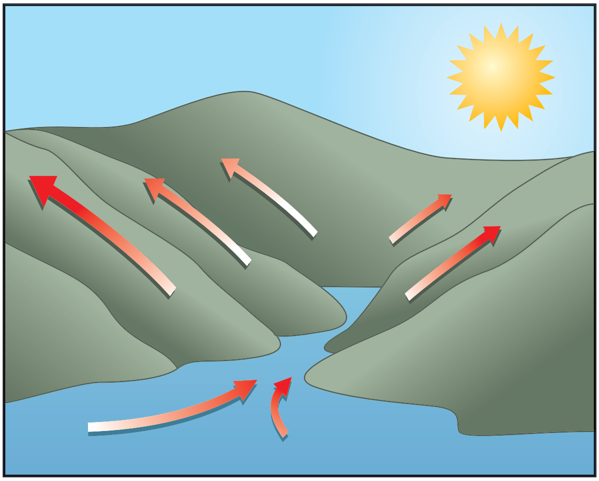


Fig. 2-16 - Anabatic winds

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. Katabatic winds are observed frequently in locales such as Banff or Jasper.

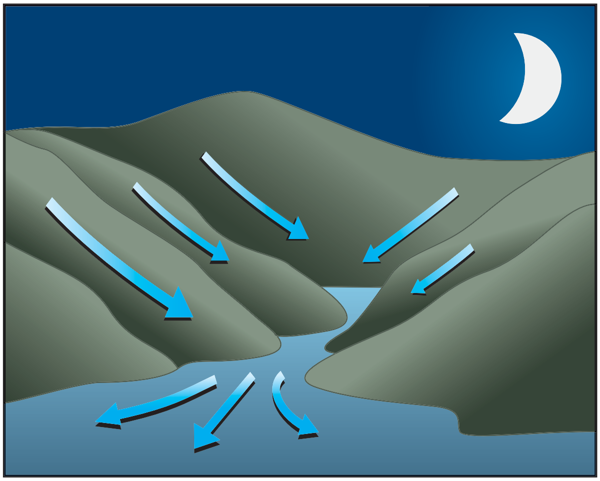


Fig. 2-17 - Katabatic winds

(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. In some locations the katabatic flow "pulsates" with the cold air building up to some critical value before being released to rush downslope.

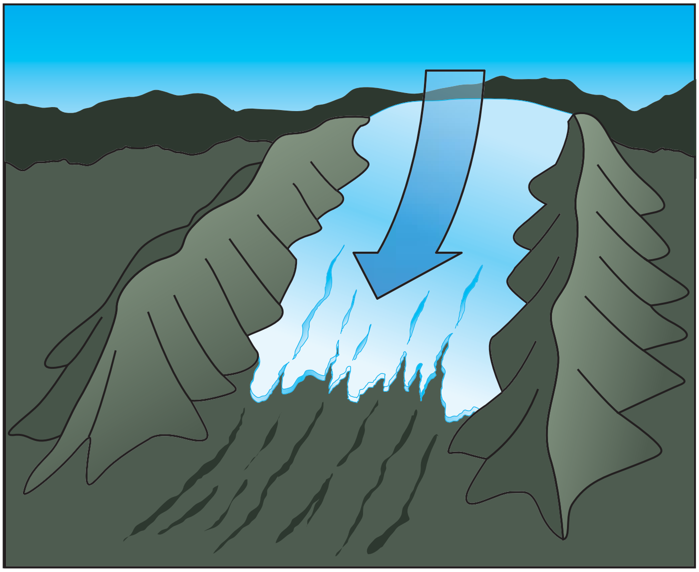


Fig. 2-18 - Glacier winds

It is important to recognize that combinations of these effects can operate at any given time. Katabatic winds are easily funnelled resulting in winds of unexpected directions and strengths in narrow passes. Around glaciers in the summer, wind fields can be chaotic. Katabatic winds from the top of the glacier struggle for dominance with localized convection, or anabatic winds, induced by heated rock slopes below the ice. Many sightseeing pilots prefer to avoid glaciated areas during the afternoon hours.

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 Rocky 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.

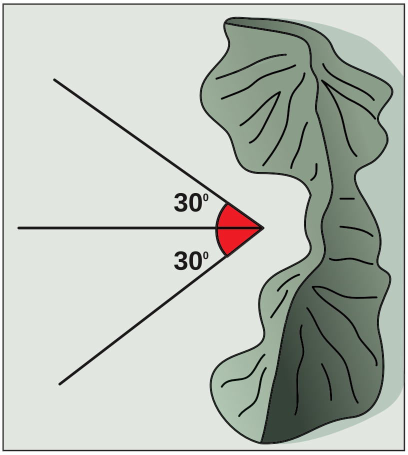


Fig. 2-19 - Angles for lee wave development

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.

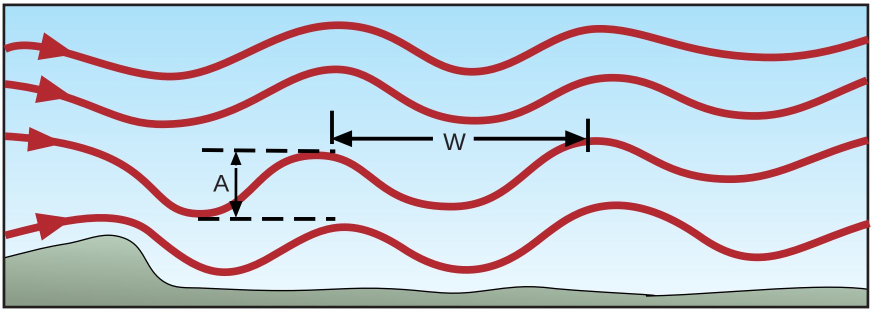


Fig. 2-20 - Amplitude (A) and wavelength (W) in lee waves

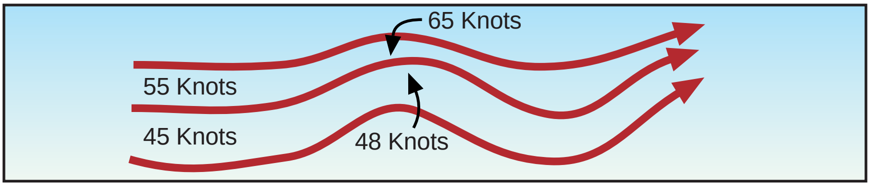


Fig. 2-21 - Stronger wind in wave crest in lee waves

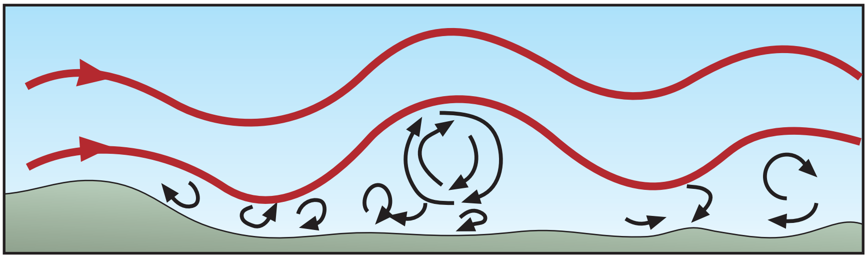


Fig. 2-22 - A rotor may form beneath wave crests

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.

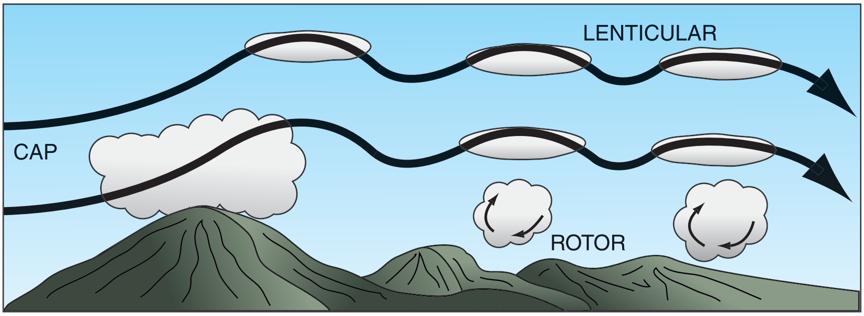


Fig. 2-23 - Characteristic clouds formed by lee waves

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.

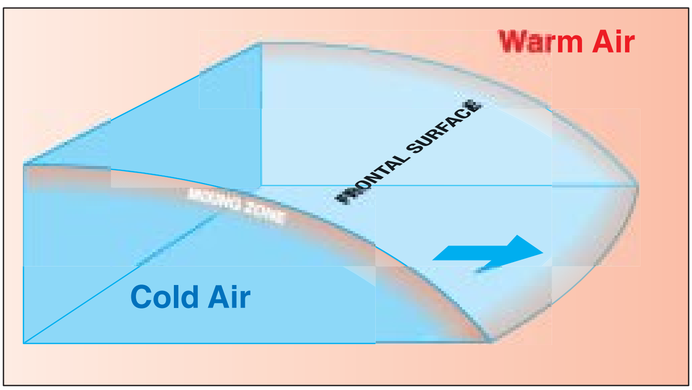


Fig. 2-24 - Cross-section of a cold front

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.

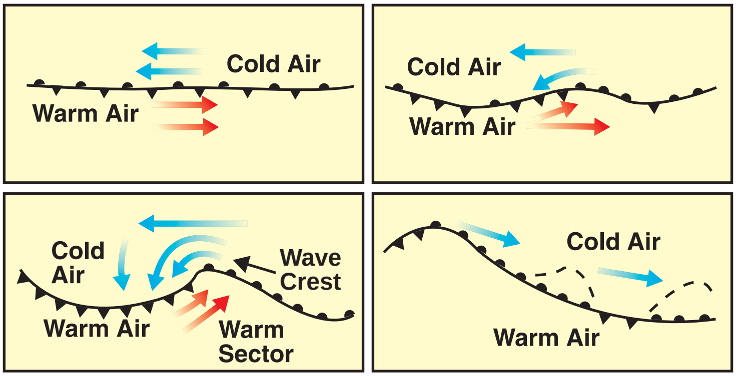


Fig. 2-25 - Stable wave

(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.

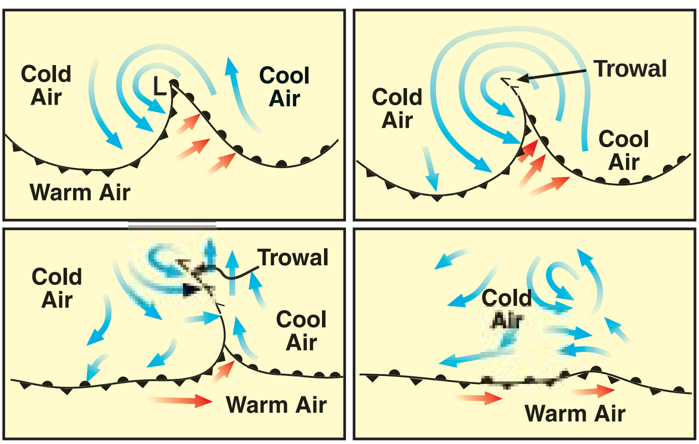


Fig. 2-26 - Formation of an occluding wave

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 farther and farther away from the low that initially formed it .

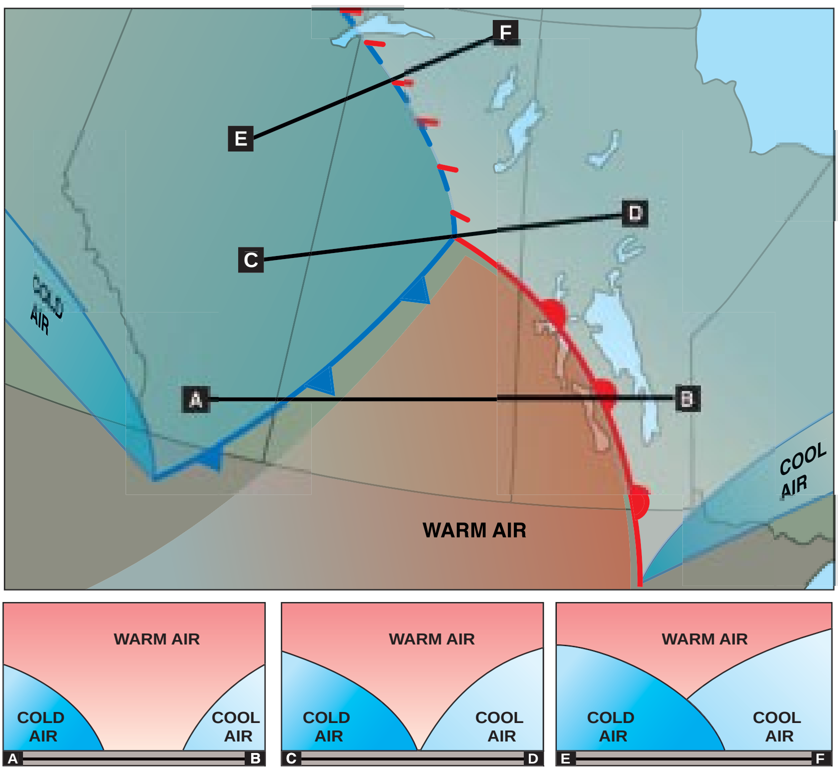


Fig. 2-27 - Frontal cross-sections

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:

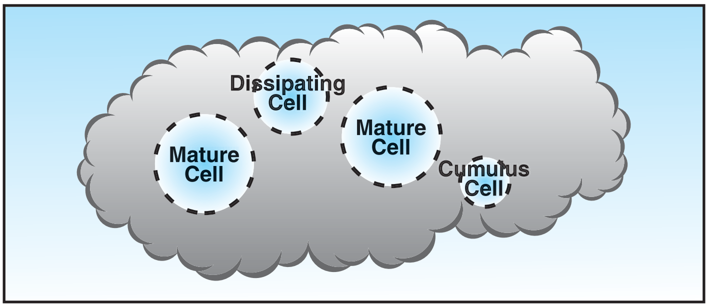


Fig. 2-28 -Top-down view of a thunderstorm "family" containing cells in different stages of development

(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.

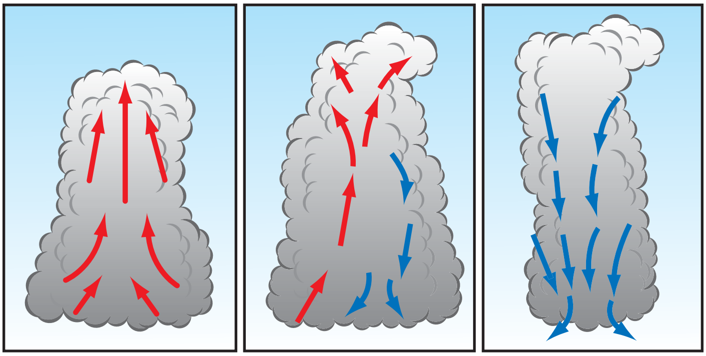


Fig. 2-29 - Cumulus stage Fig. 2-30 - Mature stage Fig. 2-31 - Dissipating Stage

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 farther, 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 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.

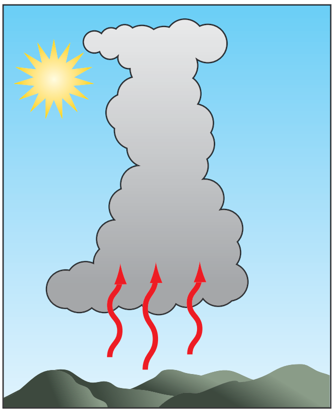


Fig. 2-32 - Air heated by warm land

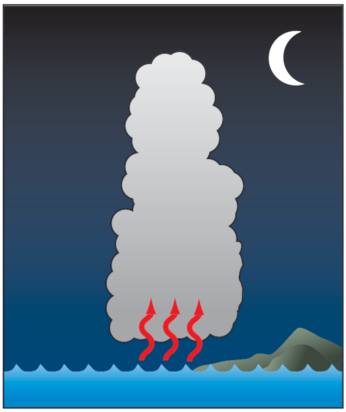


Fig. 2-33 - Cool air heated by warm water

(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.

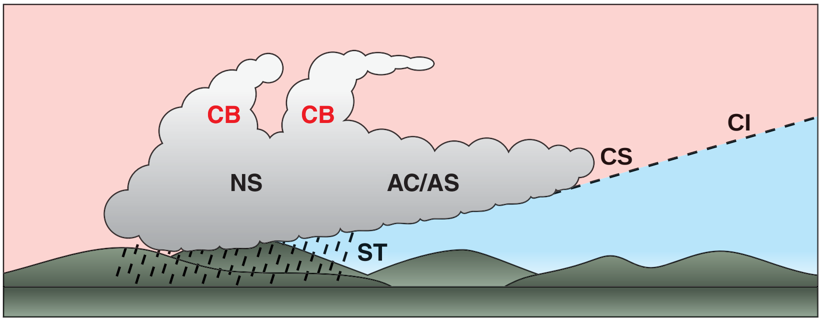


Fig. 2-34 - Warm frontal thunderstorms

(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 make 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 mountain slope. These are common in the foothills of the Rocky Mountains where, on a typical summer day, they form due to a combination of upslope flow and daytime heating. When they get high enough, the prevailing west-southwest flow aloft carries them eastwards. If conditions are favourable, they can persist for several hours, otherwise they dissipate fairly rapidly. Typically, they will begin to develop in mid-morning and can continue to form well into the afternoon. In such situations, these storms frequently produce copious amounts of hail across central Alberta.

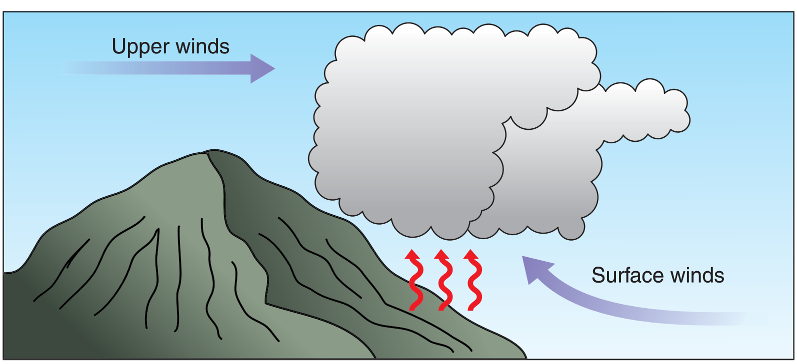


Fig. 2-35 - Orographic thunderstorms form on the foothills of the Rocky Mountains

(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.

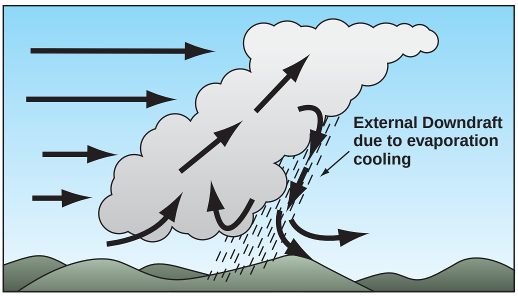


Fig. 2-36 - "Steady state" tilted thunderstorm

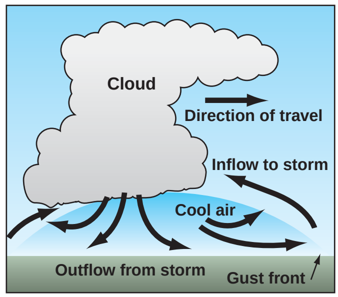


Fig. 2-37 - The gust front

(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 2-3 - Severe thunderstorm credit: Alister Ling

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.

Table 2-1 - The Fujita Scale

Waterspouts can occur over large lakes but are rare. 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 to 100 feet.

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 radiation 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 forming vortices that rotate upwards. 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 Cold Lake, 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 but poses the greatest risk away from the forested areas of the Prairies. As winds increase, blowing snow can, in extreme conditions, reduce horizontal visibility at runway level to less than 100 feet.

Whiteout

"Whiteout" is a phenomena that can occur 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. For example, when Mt. St. Helens, Washington, erupted, there was ash fallout and limited visibility across southern Alberta and Saskatchewan.

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.

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 support thunderstorms 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.

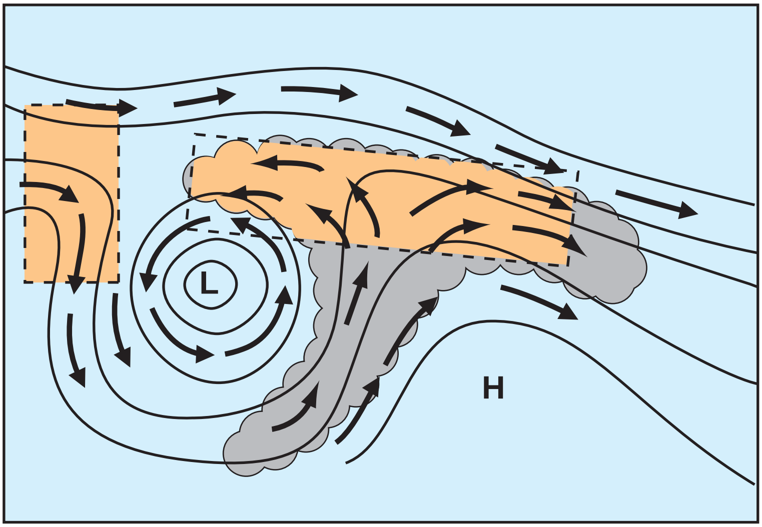


Fig. 2-38 - Deformation zones

Chapter 3

Weather Patterns of the Prairies

Introduction

"Weather is what you get; climate is what you expect" - (anon.)

Weather is what is happening at any given time; it is transitory and subject to constant change. Climate speaks of the history and long term averages of weather and can tell a great deal about a specific location. It will show how the weather, on average, is both similar and different from what could be expected and this imparts valuable information about a site. Significant deviations from the mean suggest the influence of factors such as topography, vegetation, or land use, and understanding these factors is crucial to forecasting the weather. Meteorologists must consider both weather and climate when writing a forecast; there is a constant conflict between "what you expect" and "what you get." The objective of this chapter is to explain some of the large-scale influences on climate and weather in the Prairies. Chapter four is a more detailed account of weather influences on a local scale.

Geography of the Prairies

Map 3-1 - Topography of GFACN 32 Domain

The three provinces of Alberta, Saskatchewan and Manitoba are referred to as the Prairie Provinces. They cover a total of 196 million hectares and, of this about 20 million hectares, or 10 percent, is surface water.

Province	Land Area	Water Area	Total Area
Alberta	64.4	1.7	66.1
Saskatchewan	57.0	8.2	65.2
Manitoba	54.8	10.2	65.0
Total	**176.2**	**20.1**	**196.3**

Table 3-1 - Surface area of Alberta, Saskatchewan and Manitoba (millions of hectares)

All three provinces have the 49th parallel as their southern border and the 60th parallel as their northern border. The western boundary of the prairies extends northward along the continental divide to 53°N and then along the 120°W meridian. The eastern boundary follows the 95°W meridian to 52° 50°N and then takes a northeasterly course to Hudson Bay.

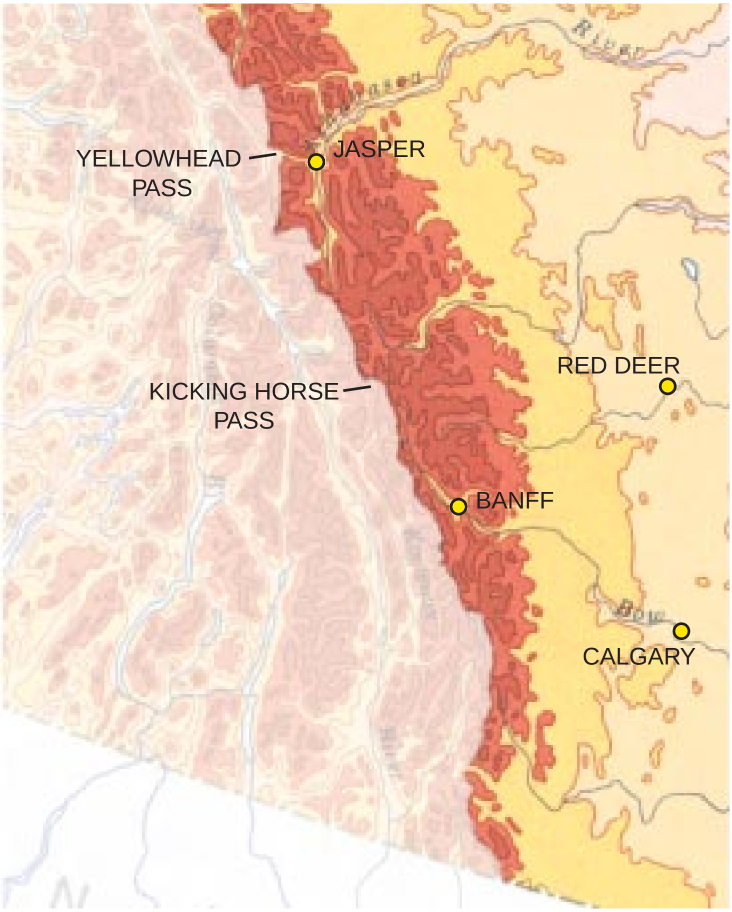
Land elevations are highest in southwestern Alberta and gradually decrease to sea level in northeastern Manitoba, along the Hudson Bay coast. Prominent ranges of hills that influence the weather can be found in all three provinces. These include the Cypress Hills, Swan Hills and Caribou Mountains in Alberta, the Cypress, Pasquia, and Mostoos Hills in Saskatchewan, and the Riding and Duck Mountains in Manitoba.

In Alberta the major river systems are the North and South Saskatchewan, and the Slave. The Slave River comprises 90 percent of the province's water outflow and has the Athabasca and Peace Rivers as its major tributaries. In southern Saskatchewan, the two Saskatchewan Rivers join together to form one, which flows eastward into Lake Winnipeg. The Churchill River, interlaced with numerous tributaries, provides the main drainage system in the northern part of the Province, as well as much of northern Manitoba, before flowing into Hudson Bay. Manitoba's other major river systems include the Assiniboine, Red, Nelson, and Seal.

Ancient glacial passages have left their mark on the surface of the Prairie Provinces in the form of abundant, and generally shallow, lakes. This is especially evident over northern Saskatchewan and Manitoba. These lakes can have a significant impact on local weather including greater leeward cloudiness, a longer but cooler growing season, lake-induced snowsqualls in the fall season, and a complex local wind regime.

There are three principal topographical areas on the Prairies: the Rocky Mountains and Foothills to the west, the Prairie Region covering most of the southern portions of the provinces, and the Canadian Shield to the northeast.

The Rocky Mountains and Foothills



Map 3-2 - The Rocky Mountains and Foothills

The Rocky Mountains and Foothills area follows the British Columbia - Alberta boundary from 49°N to 55°N latitude. The eastern extent of this area is not well marked as the foothills gradually blend into the Prairie Region to the east. However, if the 3,500-foot contour is used as the eastern edge, the width of the area varies from less than 40 nautical miles near the Crowsnest Pass to over 100 miles in the district north of Jasper.

Within this area are many glaciers and snow capped peaks that rise over 10,000 feet. Melt water from the glaciers forms the source for many of the eastward flowing rivers that provide moisture to the plains. Over time, many deep and narrow valleys have been cut into the mountains. Since most of these valleys generally open to the east and northeast over Alberta, they tend to funnel and intensify easterly upslope flows. Therefore, they are typically locations of enhanced cloud and precipitation when under the influence of such a wind regime. Conversely, when the flow is westerly, these valleys are sites of enhanced subsidence drying. Either way, winds funnelled through these narrow channels are usually strengthened and quite turbulent. Valleys that run between and parallel to the ranges of mountains, such as the one between Jasper and Banff, are comparatively sheltered from most strong and moisture-laden flows.

Some mountain passes, such as the Crowsnest Pass, are important meteorologically as they provide an opening through the Rocky Mountain barrier, allowing air to be exchanged fairly easily from one side to the other. Moist air originating over the Pacific can make its way into Alberta though these passes with less modification than air that has been forced up and over the divide. The open passes are also notorious locations for strong winds and turbulence. It should also be noted that a relative decrease in the height of the Rockies to the north of Jasper provides an easier entrance into Alberta for moist pacific air masses. As a result, when the flow is westerly, the country around Peace River and Grande Prairie receives a greater amount of precipitation than it otherwise would if the barrier were higher.

The Prairie Region

Map 3-3 - The Prairie Region

The Prairie Region is the largest topographic area of the Prairie provinces and lies between the Rockies on the west and the Canadian Shield to the northeast. The eastern boundary runs from the southeastern corner of Manitoba through Lake Winnipeg, then northwestward to the Alberta - Saskatchewan boundary at 57°N. From there the boundary passes through the western end of Lake Athabasca and then north to the 60°N parallel.

Most of the population and almost all of the agriculture of the Prairie provinces lies within this region. The bulk of the agriculture is south of a line that extends from the southern tip of Lake Winnipeg northwestward to the region that is between the Hay and Peace Rivers on the British Columbia - Alberta border. North of this line, the land cover changes from open plains to mixed boreal forest, and agricultural activity rapidly diminishes.

Although the Prairies are famous for flatness, the terrain is far from uniform and this has a significant impact on the weather. Generally the area can be described as a wedge, with the thinnest edge over eastern Manitoba, and a gradual upward slope towards the Rocky Mountain foothills. Glaciation is responsible for most of the land-forms, including the numerous shallow lakes and occasional ranges of hills. The river valleys change in nature from province to province. In Alberta they are very deep and sharp sided, cut by the fast flowing and plentiful water supply from the Rockies. In Saskatchewan, they tend to become broader and shallower, and this tendency increases in Manitoba. Here the rivers are in gently sloping valleys, and flow just slightly below the level of the surrounding land.

The Canadian Shield

Map 3-4 - The Canadian Shield

Northeast of the Prairie Region lies the heavily glaciated expanse of rock known as the Canadian Shield. The elevation slopes gradually from near 2,000 feet in north central Saskatchewan to 700 feet north of Lake Athabasca and down to sea level along the Hudson Bay coast. This area is more than half covered by numerous lakes, of which Lakes Athabasca and Winnipeg are the largest.

The Canadian Shield region includes the extreme northeastern part of Manitoba, which is strongly influenced by Hudson Bay. During the summer months, Churchill and other coastal communities are beset by frequent sea breezes from the cold, and sometimes ice covered bay, resulting in cooler temperatures and greater cloud cover than for stations farther inland. In winter, the influence of the bay diminishes as the ice cover becomes established, but outbreaks of cold Arctic air often surge across this vegetation-sparse area. Strong northwesterly winds, which typically accompany such outbreaks, cause dangerous windchills and restricted visibilities in blowing snow.

Mean Upper Atmospheric Circulation

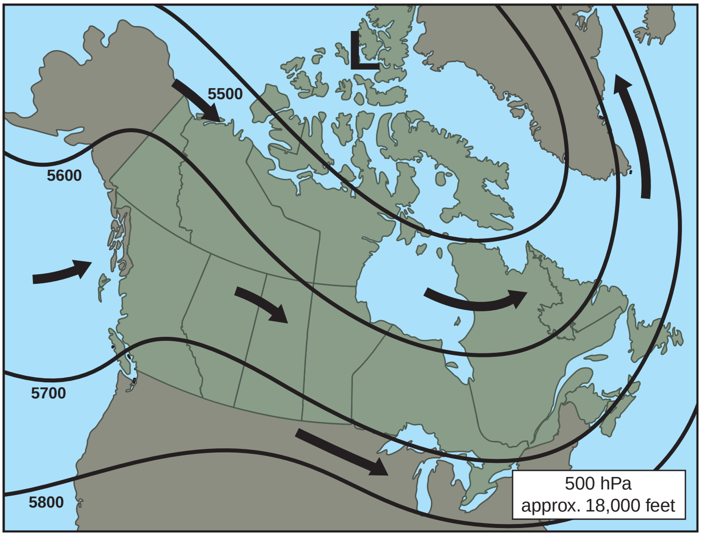


Fig. 3-1 - Mean summer upper winds

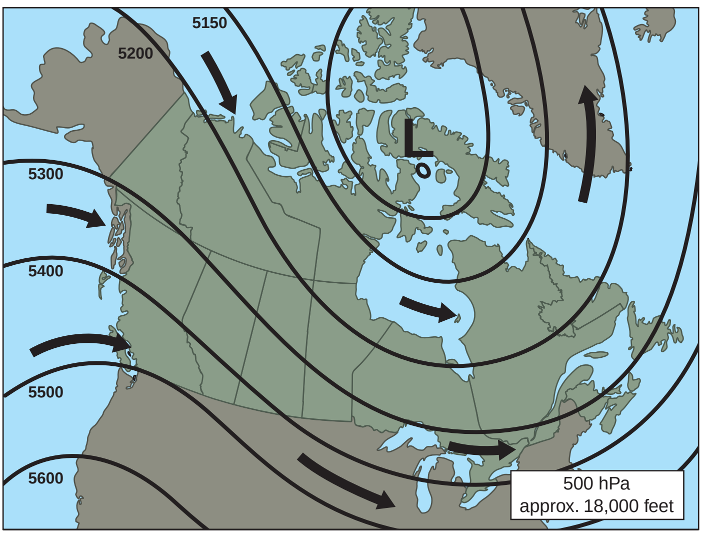


Fig. 3-2 - Mean winter upper winds

The prairies lie in a broad band of global circumpolar westerly winds. This mean westerly flow is much stronger in winter than summer In general, there is a low over the Arctic Islands with a broad trough extending southward across the eastern portions of Hudson Bay or Northern Quebec. In winter, the mean upper flow across most of the Prairies is strong northwesterly. The Polar jet stream extends southeastwards from the Mackenzie Valley into the northern Prairies. This means that many of the weather features that affect the Prairies during winter have an Arctic origin. During winter, frigid air masses, which form in the Arctic source region, flow southward across the Prairies. Such outbreaks occur in the wake of migratory disturbances and frequently produce blowing snow.

As the year progresses, the upper flow becomes weaker with the polar vortex shifting closer to the pole and winds becoming more westerly. In summer, the mean flow across the Prairies is from the west or southwest indicating that many of the weather features that affect the Prairies have a pacific origin and are usually mild and moist. The position of the jet stream is across the northern parts of the U.S. just to the south of the Canadian border.

If it were not for the Rocky Mountains over the western portion of the continent, these mild and moist winds would flow eastward across North America, much as they do in Europe. However, the Rockies has a pronounced effect on the climate of the Prairies. These mountain ranges deflect, block and greatly modify the incoming air masses from the Pacific. Air masses that do cross the Rockies lose much of their moisture and undergo adiabatic warming as they flow onto the plains. Throughout the year, warm and moist air from the U.S. Midwest affects the southern Prairies and occasionally leads to large precipitation events.

Upper Troughs and Upper Ridges

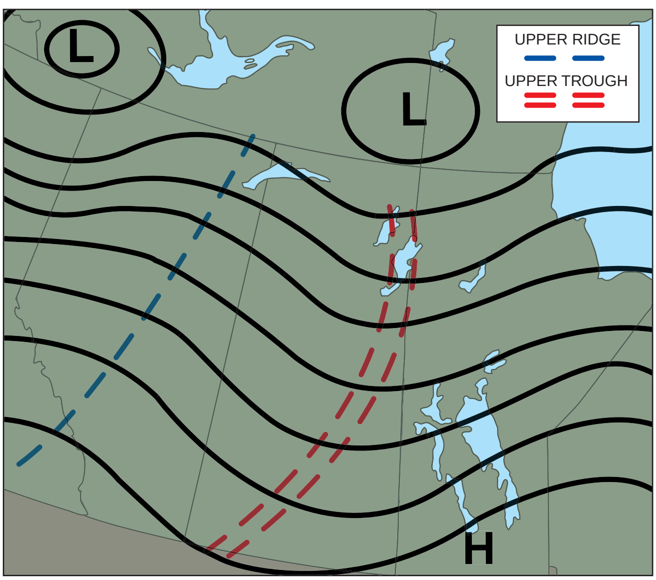


Fig.3-3 - Typical winter pattern with upper troughs and ridges added

While the mean upper flow is northwesterly, there frequently are upper troughs and ridges embedded in this flow. The upper troughs, which tend to be cold, produce areas of cloud and precipitation because of the induced vertical lift. They also tend to be strongest in the winter and often have broad cloud shields and widespread precipitation, particularly in upslope areas along the windward slopes of the mountain ranges. During the summer months, the cloud shields associated with upper troughs are narrower, usually quite convective and produce mainly showers and thundershowers. Upper troughs may have a surface low-pressure system or a frontal system associated with them, further enhancing the cloud and precipitation. Clearing behind an upper trough can be gradual in winter but tends to be quite rapid in the summer.

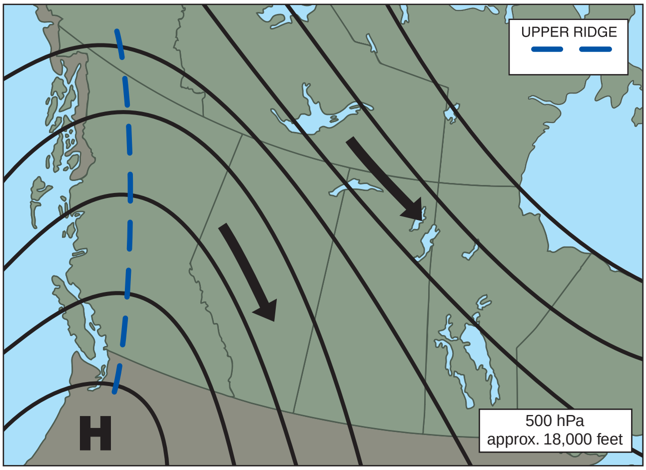


Fig. 3-4 - Upper ridge over BC giving northwest flow to the Prairies

Frequently, there is a north-south upper ridge over BC which can remain stationary for many days. The flow to the west of this ridge is from the west or southwest. The flow to the east is from the northwest. This occurs very frequently in summer and winter, and usually means fine weather for the Prairies. Naturally, in winter, skies will be clear but the temperatures will be frigid. One notable exception to this generalized statement occurs when an Arctic front is lying along the foothills. In such a situation, impulses moving along the front will give widespread cloudiness along with periods of snow.

Semi-Permanent Surface Features

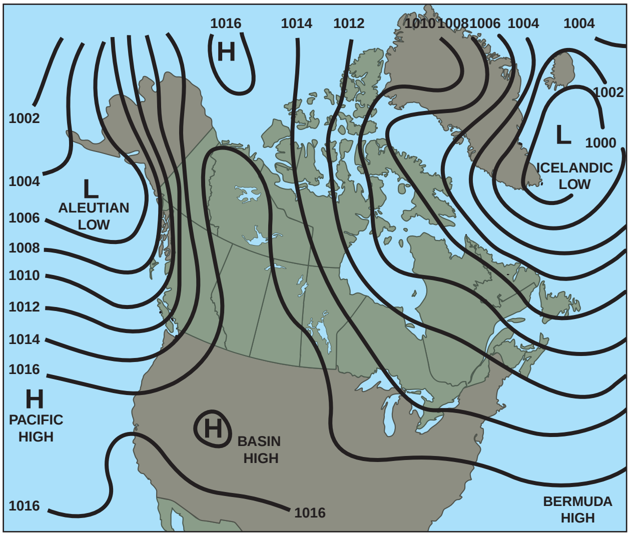


Fig. 3-5 - January mean sea level pressure

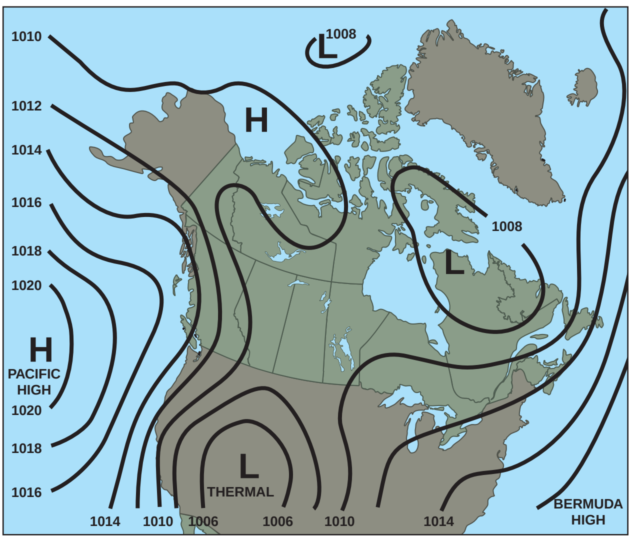


Fig. 3-6 - July mean sea level pressure

The mean January pressure chart shows the Aleutian low well out in the Pacific Ocean and the Icelandic Low southeast of Greenland. A ridge of high pressure extends from the Beaufort Sea, southeastward across the Mackenzie Valley into northern Alberta, to southern Saskatchewan. This means that there is a northerly flow across the Prairies through the winter period, allowing frequent incursions of polar air across the Prairies.

As the year goes on, the Aleutian low weakens a little and drifts southward while the Icelandic low dissipates. A thermal low develops in the southwestern US as the result of the extreme heat in this area. A weak low forms over the northern Quebec/ Baffin Island area leaving the Prairies in a climatological weak flow for the summer. This hints at the likelihood of lows from the Pacific, the Arctic and the U.S. south-west as having about the same probability of invading the Prairies.

Migratory Surface Weather Systems

Fig. 3-7 - Major Prairie storm tracks

The Prairie provinces are affected by a number of migratory weather systems that can be loosely categorized depending on the region and circumstances of their formation. All these storms can occur at any time of year, but it is the winter storms that tend to be more intense due to the greater temperature difference between the northern and southern latitudes.

Gulf of Alaska Low

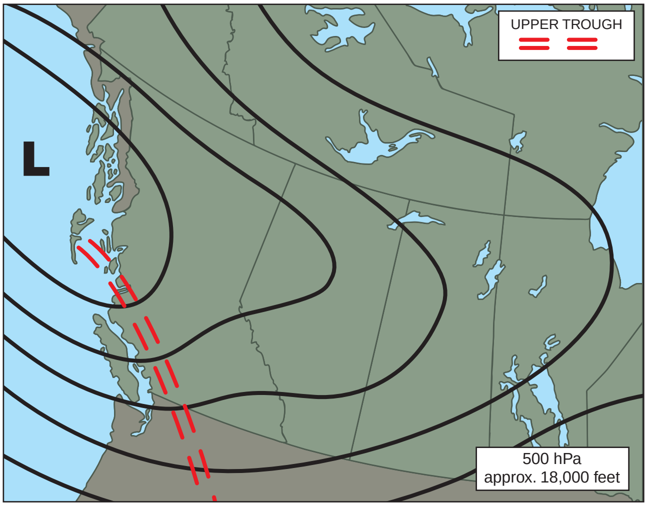


Fig.3-8 - Upper trough moving across BC

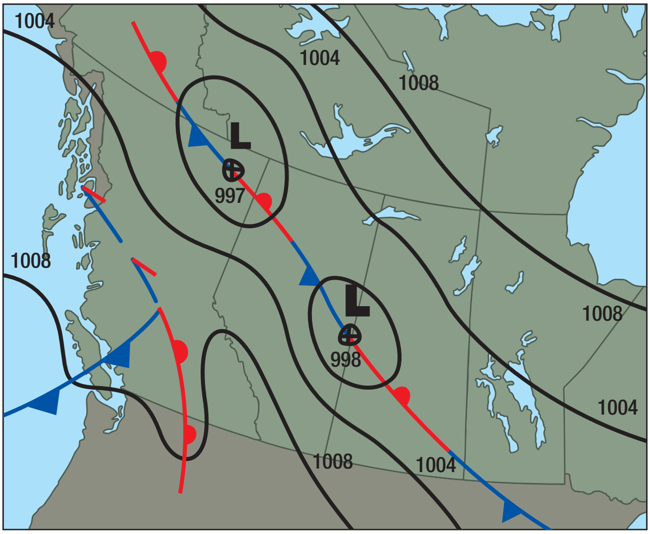


Fig. 3-9 - Surface Analysis

Low pressure systems can move across BC into Alberta and give lots of precipitation in the process. A fairly typical scenario will have an upper low anchored in the Gulf of Alaska. A series of upper troughs rotates around the southern portion of this upper centre and then move eastward across BC. At the surface, a low and frontal wave tracks across BC into Alberta, just ahead of the upper trough. When the low and wave crosses BC, the system weakens because of the interfering effect of the mountains in the low levels. At this point, there is only cloud and perhaps a small amount of precipitation in Alberta. As the low and frontal wave move out of the mountains and onto the plains, the system are rejuvenated as "Alberta" or "lee" lows and track eastwards. As they do so, the precipitation intensifies in its vicinity. To the north of the surface low, the flow is easterly and, hence, upslope into the foothills and mountains of Alberta. These are the areas which are particularly hard-hit by these events. Precipitation in excess of 50 mm a day are fairly common from these systems. This pattern can occur at any time of the year but are more common in winter, when there are stronger temperature gradients involved.

Colorado Low

Colorado Lows form by much the same process as the Alberta Low, except that they originate farther south, generally in the vicinity of Colorado as the name implies. Often the upper flow will direct these lows along a trajectory that pushes them towards the Canadian border. The extreme southern portion of Manitoba receives an extra measure of annual precipitation as it is often clipped by these systems as they head into Ontario.

Mackenzie Low

Mackenzie Lows tend to develop in the Mackenzie River Valley of the Northwest Territories. Once developed, they follow a southeastward track but usually stay north of the Prairie provinces. On occasion, they will affect the northernmost parts of Saskatchewan and Manitoba during the winter.

Winter Weather

Blizzards

Blizzards are the most destructive winter storms encountered on the Prairies. The occurrence of blizzards varies greatly over the Prairies. They rarely occur in the forested areas of Northern Saskatchewan, Manitoba or Alberta. In contrast, the maximum number of blizzards occur over barren southwestern Saskatchewan, with 1.6 episodes a year at Swift Current. The evolution of storms which will create a blizzard is much like what has been described above for Migratory Systems. The differences in migratory systems that will produce blizzards is mostly to do with the origins of these lows rather than their development or movement. There are three main sources for these blizzards are Colorado Lows, Gulf of Alaska Lows, and the Mackenzie Valley Lows.

The Mackenzie Valley Lows tend to have stronger winds and colder temperatures while the Colorado Lows, due to milder temperatures, are more likely to have large snowfall amounts. All these systems will produce widespread poor flying conditions that will persist for many hours and even days. Low ceilings, poor visibilities and severe turbulence associated with the strong winds are common to all types. With blizzards from the Colorado source region, temperatures are likely to be somewhat milder and so heavy icing can also be a concern

Arctic Outbreaks

During winter, a strong area of high pressure can form in the cold air over Alaska, the Yukon and the Mackenzie Valley. In the tight pressure gradient to the east of this high, the cold arctic air is pushed southeastward onto the Prairies. Generally, along the leading edge of this cold air, flurries will occur and flying conditions will be marginal for a short time. Of greater concern to aviation are the gusty northwest winds that will likely produce significant mechanical turbulence in the low levels. One of the methods that Mother Nature uses to end these cold outbreaks is described next.

Cold Air Damming

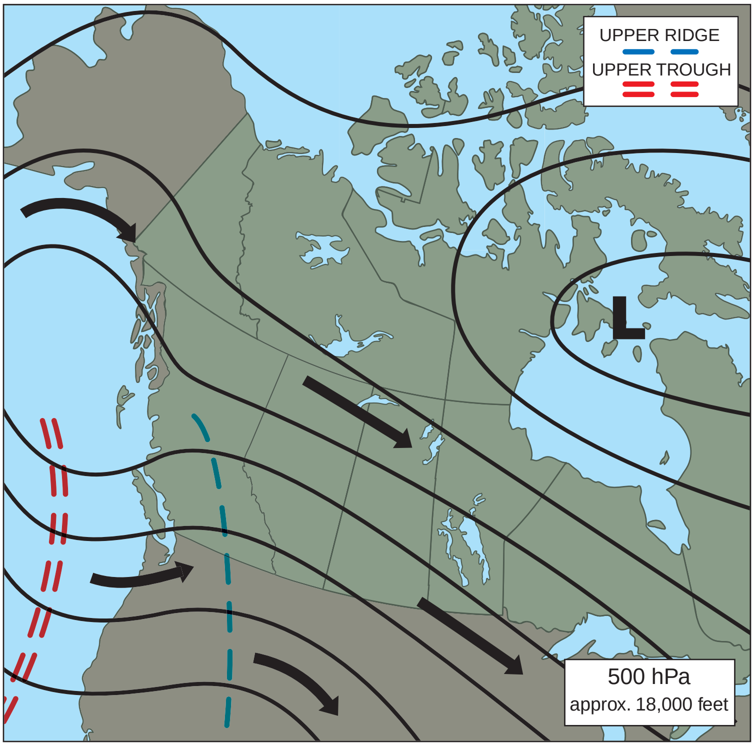


Fig. 3-10 - Upper air pattern for Cold Air Damming

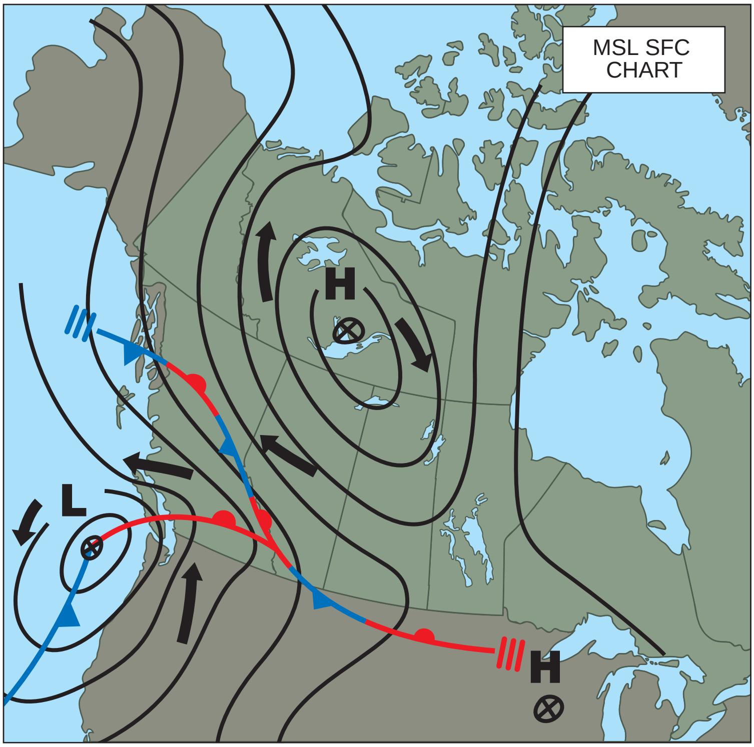


Fig. 3-11 - Surface map for Cold Air Damming

A type of storm, which can produce a lot of precipitation over Alberta, has a surface area of high pressure over the Yukon or Southern Mackenzie Valley with a ridge into Saskatchewan. Very cold air covers the Prairies and a strong southeasterly gradient to the west of the ridge over Alberta pushes this cold air up against the mountains. This is a process called "cold-air damming". This cold air acts as a "dam" to milder air from a different source region. In this case, a deep low over the west coast of British Columbia generates a push of much milder and moister Maritime air which moves eastward and is forced to rise over the "dam" of cold air in Alberta.

Chinooks

Chinook is a Blackfoot word that translates to "snow eater", referring to, its ability to make winter snow packs vanish over a short time. The Chinook is a foehn wind; a generic term for all winds that have been warmed and dried by descent off a slope. The Chinook occurs over the front range of the Rocky Mountains and western plains of North America. They usually blow from the southwest to west and are quite strong, often 25-40 knots with gusts as high as 80 knots. Their effects are most strongly felt in southwestern Alberta where they funnel through the Crowsnest Pass before fanning out across southern Alberta and Saskatchewan. They are frequent all along the foothills, from Beaverlodge (west of Grande Prairie) to Rocky Mountain House. On average, there are 30 Chinook days each winter in the Crowsnest Pass, 25 in Calgary, 20 in Medicine Hat and only 10 at Swift Current.

To understand any foehn phenomena, consider an air parcel embedded in a flow of air forced over a topographical barrier. As it ascends the barrier, water vapour in the parcel condenses and falls as rain or snow releasing heat into the atmosphere. This release of heat limits the cooling rate to about 1°C for every 650 feet of rise. Once over the barrier, the subsiding parcel is warmed and dried by compression, but at a rate that is twice that of the cooling rate on the windward (ascent) side of the mountains. In the case of the Chinook, moist Pacific air driven over the mountain ranges of western North America is warmed as much as 8-10°C by the time it reaches the foothills of Alberta, and is much drier.

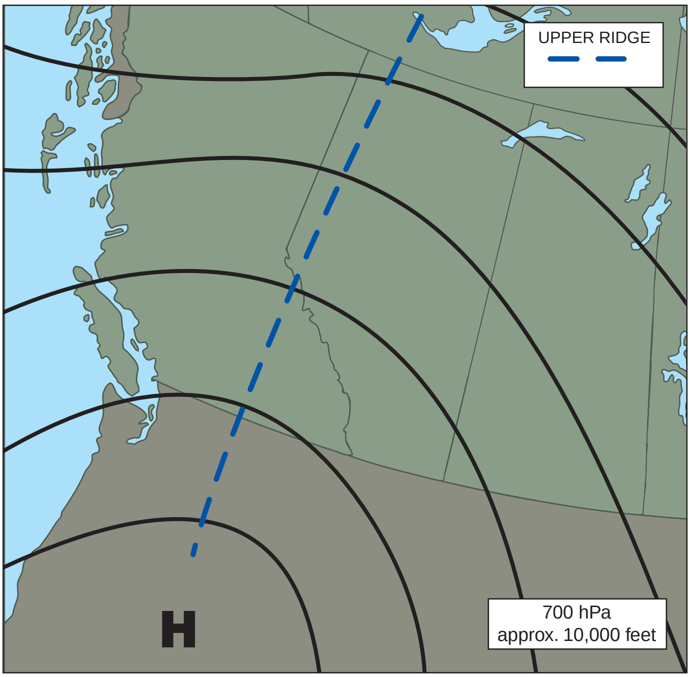


Fig. 3-12 - Upper level Chinook flow

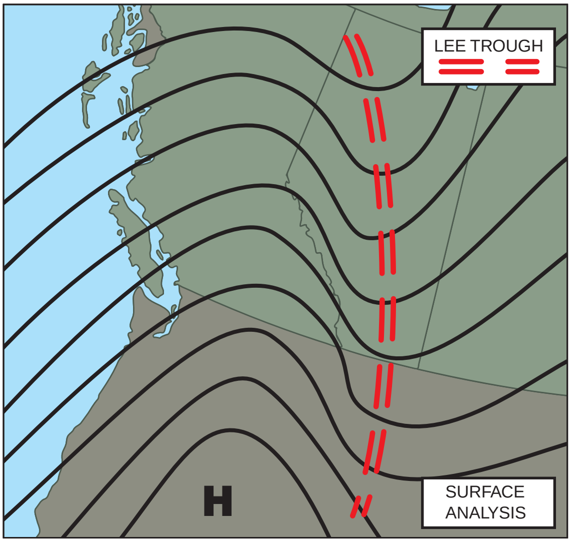


Fig. 3-13 - Basin high surface Chinook flow

A typical upper air pattern is shown, with a "Basin High" over the northwestern United States and a westerly flow across central British Columbia. The corresponding surface pattern is also shown with a high over the northwestern United States are created. The strong northwesterly flow between these two features produces chinook conditions as the winds blow into the lee trough that lies to the east of, and parallel to, the mountains. The lee trough marks a boundary between subsiding air to the west and ascending air to the east. High level cloud, often present in such situations, is dissipated on the subsident side, forming a clear area that parallels the barrier. The edge of the cloud, usually well defined, appears as an arch to an observer on the ground. This is known as a "Chinook Arch."

During Chinook events, a light southeasterly flow of cool air east of the lee trough can produce generally poor flying weather. Conditions tend to be much better west of the Chinook arch but turbulence can be problematic in the strong winds.

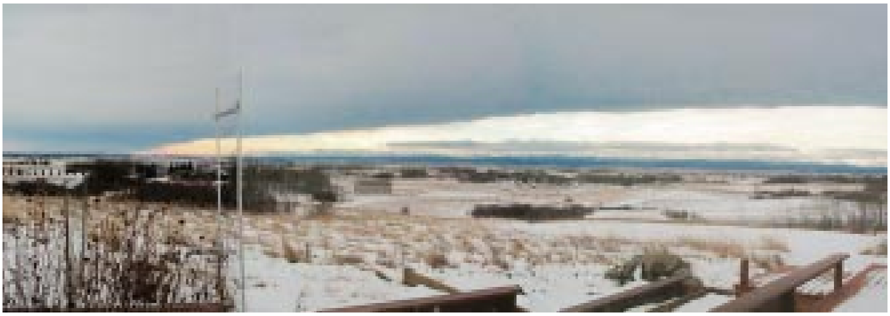


Photo 3-1 - Chinook Arch credit: Patrick Spencer

Summer Weather

In the summer, the frequency and severity of storms is reduced. The main source of adverse weather is the cold lows mentioned below. Apart from these, the main concern in the summer on the Prairies is convection.

The convective weather season coincides with the summer season and this runs from May through to early September. During this time, the main area of activity is centred along an axis which extends from the Peace Country through Rocky Mountain House, to just northwest of Calgary. The following graph is based on the output of the Canadian lightning detection network. The most active month for convection is July. June and August are equally as active but less so than July. The most active time of day for convection is near 5:00 PM local time. The average convective weather day in Alberta starts with clear skies in the morning and a band of low level moisture over the foothills. With daytime heating, cumulus and towering cumulus develops during the morning and are seen easily on satellite imagery and weather radars in the area. As the morning progresses, the convection continues and thunderstorms form and move off to the northeast, in the southwesterly upper flow seen earlier. Unless there is some significant upper level dynamics to support the thunderstorms, they dissipate before moving too far to the northeast.

Over the U.S. Midwest at this time of year, there frequently is a southerly low level flow that brings very moist air northwards across the United States and into the southern portions of the Prairies. This band of moisture frequently extends from southeastern Saskatchewan, northwestwards across the southern portions of Saskatchewan, to Edmonton. When this very warm and moist air in the low levels is combined with a mean westerly flow aloft over western Canada, it produces a fairly unstable air mass. This is how the maxima over southern Saskatchewan and extending to the Edmonton area occurs.

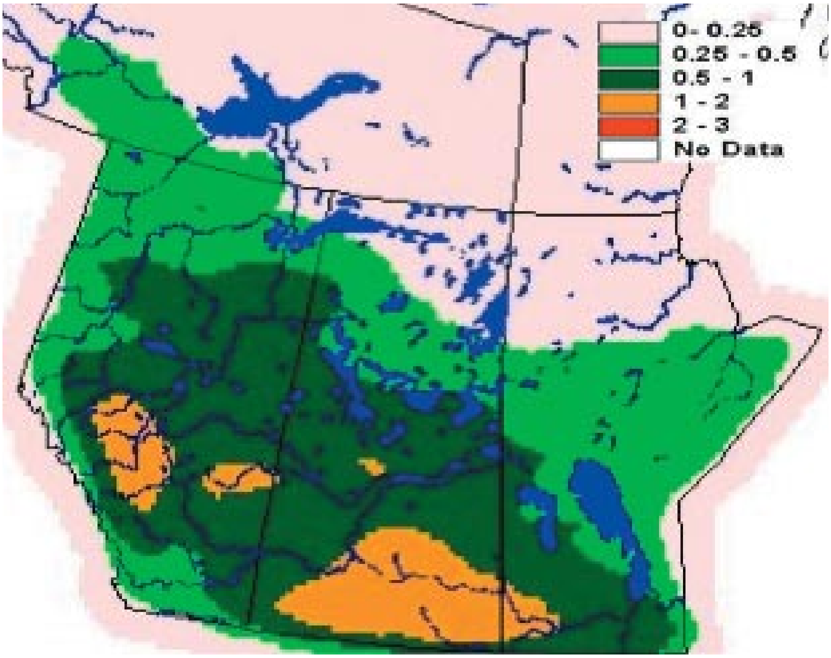


Fig. 3-14 - Lightning strike data for 1998-2000 (lightning strikes per square km)

Cold Lows

A cold low is a large, nearly circular area of the atmosphere in which temperatures get colder towards the centre, both at the surface and aloft. While a surface low pressure centre is usually present beneath the cold low, its true character is most evident on upper charts. The significance of cold lows is that they produce large areas of cloud and precipitation, tend to persist in one location for prolonged periods of time and are difficult to predict. Typically, slow moving upper lows, together with a surface reflection, move from the Pacific across BC and onto the Prairies. Rain is primarily associated with the northeast quadrant of the 500 hPa closed low. Rain is of lighter intensity in the northwest and southwest quadrants of the low. These systems can produce days of very poor conditions over large areas of the Prairies. When the low is close to the mountains, it sets up upslope effects to the north of the low. This is where the most intense precipitation and lowest flying conditions will occur. As it moves away from the mountains, the winds to the north of the low back into the west, which is downslope and subsident, allowing precipitation to end and conditions to improve quickly.

Cold lows can occur at any time of the year but the most frequent occurrence, "cold low season," is from the end of May to mid-July. At this time, pools of cold air break away from the Aleutian Low and move eastwards across British Columbia or Washington.

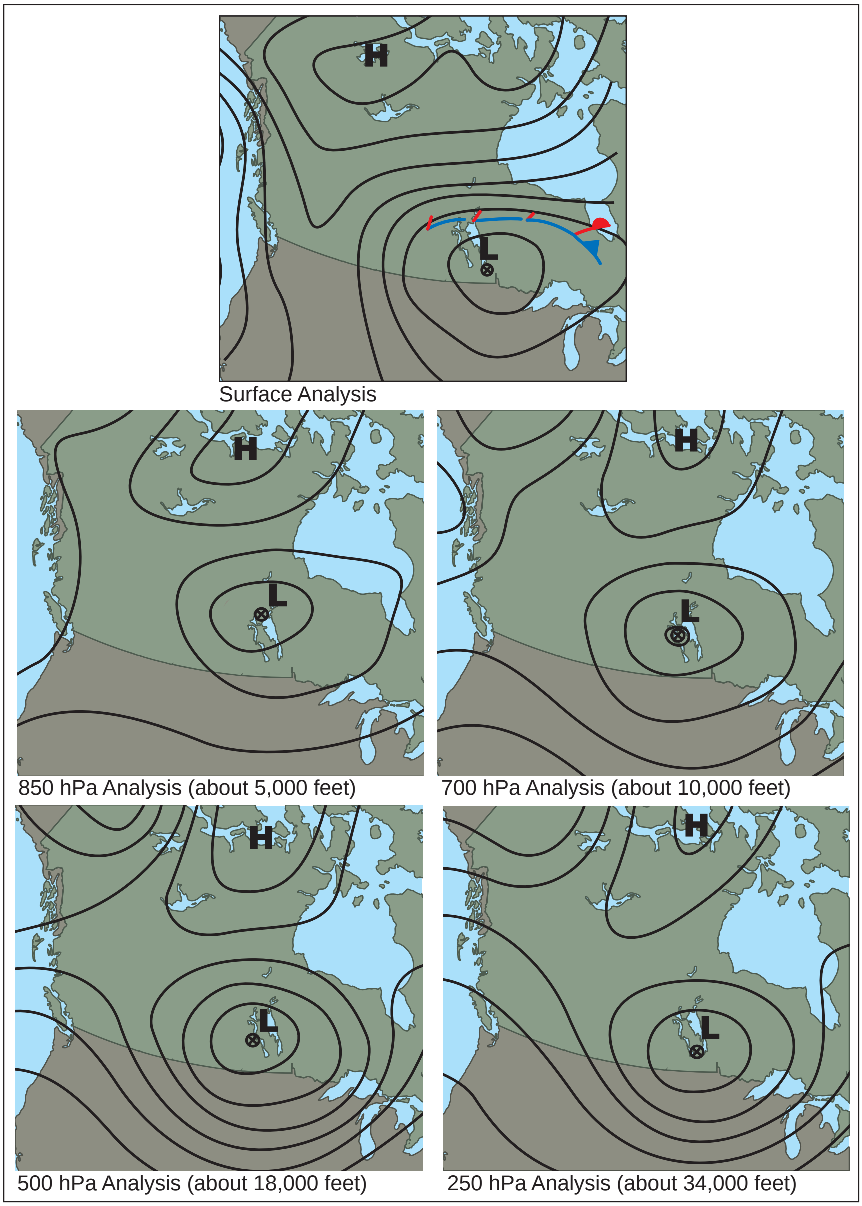
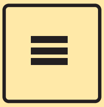
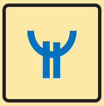
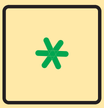
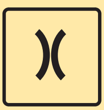


Fig. 3-15 - Typical surface and upper level pattern for a cold low event

The overall effect is to produce a widespread area of cool, unstable air in which bands of cloud, showers and thundershowers occur. Along the deformation zone to the northeast of the cold low, the enhanced vertical lift will thicken the cloud cover and produce widespread steady precipitation. In many cases, the deformation zone is where widespread and prolonged thunderstorm activity occurs. Frequently, with this situation, cold air funnels and even tornadoes can form.

A favorite track is across southern British Columbia and northeastward, along a line from southwestern BC to Fort St. John, where it becomes very slow moving. As it crosses Alberta, widespread rain and thundershowers can occur for a period of 24 to 48 hours.

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

Seasonal Weather and Local Effects

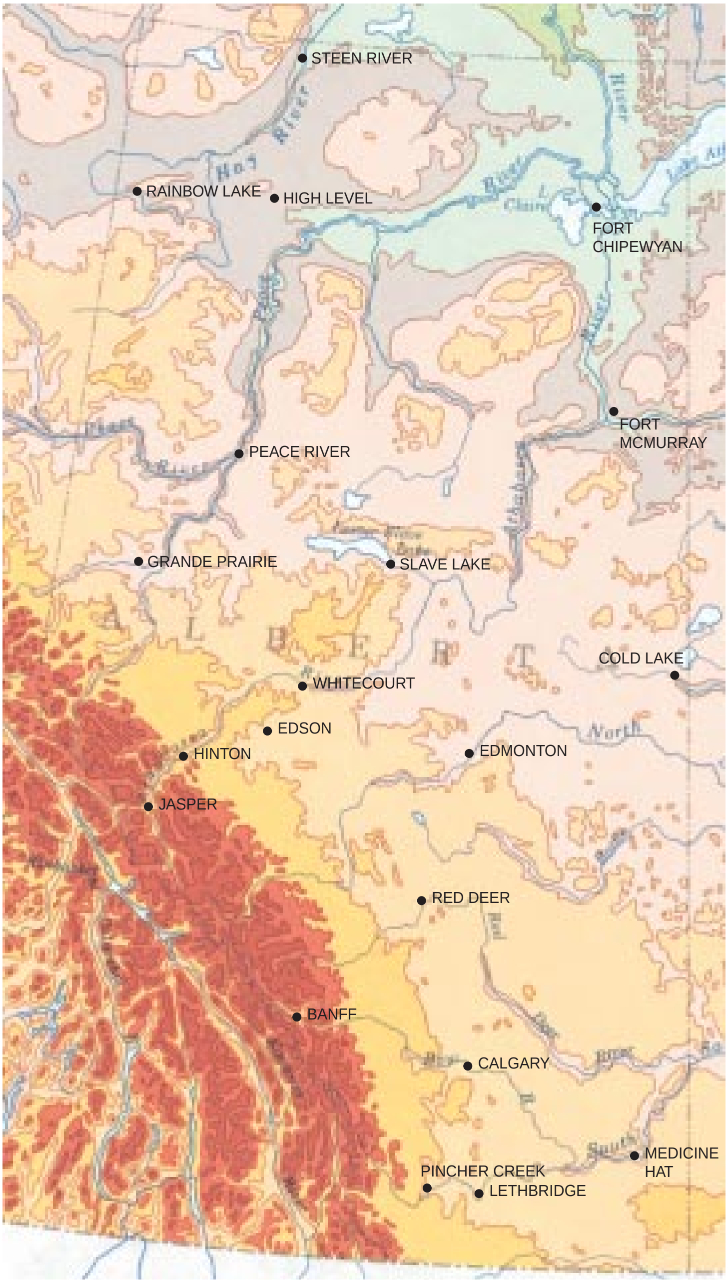
Introduction

Map 4-1 - GFACN 32 Domain

This chapter is devoted to local weather hazards and effects observed in the GFACN32 area of responsibility. After extensive discussions with weather forecasters, FSS personnel, pilots and dispatchers, the most common and verifiable hazards are listed.

Most weather hazards are described in symbols on the many maps along with a brief textual description located beneath it. In other cases, the weather phenomena are better described in words. Table 3 provides a legend for the various symbols used throughout the local weather sections.

Weather of Alberta



Map 4-2 - Topographical overview of Alberta

The climatic regimes of the Prairie province are classified as either cold-temperate or sub-arctic and range from dry continental type conditions, in the southwest, to sub-arctic conditions in the northeast along the Hudson Bay coastline. The western mountain ranges have a pronounced effect on the precipitation patterns across the region and on winter temperatures. This is one reason why most areas of the Prairie provinces receive their heaviest precipitation from storms that are fed by moisture flowing northward from the US mid-west. With no east-west mountain range to act as a barrier for air masses, such as the Alps do in Europe, cold dry Arctic air and warm moist air from the American southwest collide here on a regular basis.

The Rocky Mountains, however, are an effective barrier to the maritime influences of the Pacific Ocean and the air is greatly modified by the time it makes its way into Alberta. Cool, north pacific air loses considerable moisture coming over the mountains and is then warmed as it descends the eastern slopes of the Rockies before arriving on the "rain-shaded" Prairies. However, this air is still associated with rather cloudy, mild and windy weather for Alberta. Precipitation can be relatively heavy in the foothills and in the Peace District, where the altitude decreases and precipitation-bearing air masses enter the province more freely from the west. Nowhere, however, is the yearly total precipitation excessive. In fact, Montreal's annual average total of 1,070 mm exceeds that of any Alberta station.

(a) Summer

Summers in Alberta are fairly short, warm and usually quite dry. There are some main precipitation producing patterns. Cold lows bring prolonged precipitation and poor flying conditions and extensive thunderstorm activity on hot unstable days make severe weather a concern. Summer in Alberta is generally considered to be from late April, or early May, to late August and perhaps into September. During this time the weather is normally pleasant as it requires a well-developed weather system with plenty of moisture and significant upper dynamics to generate widespread low ceilings and visibility.

The principal situation that will produce a prolonged period of low flying weather (two or more days) is the passage of a cold low. These systems usher in very moist unstable air and are typically slow moving, if not stationary. Poor weather conditions are usually found north of the low's center where a persistent east to northeasterly flow, which is upslope in Alberta, has plenty of time to build up a large area of low level moisture. The lowest ceilings and visibilities generally occur within 60 to 100 nautical miles north of the center. Cold low scenarios are most prevalent in June and July, during which two or three such passages typically occur each month.

Similar conditions can develop in an easterly flow to the west of a high pressure system over the central prairies. If the flow persists long enough, stratus, drizzle and fog will eventually develop in the upslope areas and over the foothills.

Throughout the warm summer days, thunderstorms are common. While air mass thunderstorms occur most frequently, the passage of a cold front can also initiate the development of a thunderstorm. In fact, the most severe thunderstorms are those associated with cold fronts. This is exemplified by the Edmonton tornado in 1987 and again by the Holden tornado in 1993, both of which were the result of a cold frontal passage. Typically, in the summer, convective activity commences during the morning in the foothills and moves off to the east (includes northeast, east and southeast directions) during the remainder of the day. Most of these convective clouds dissipate as they move away from the foothills. However, if a source of low-level moisture is located further east or a means of initiating or maintaining convection is present, then the activity will persist late into the afternoon or evening. Nocturnal thunderstorms can also occur during Alberta summers but are much rarer than over the rest of the prairies. The normal thunderstorm season coincides with the summer period with the maximum activity occurring in July.

Another phenomenon typical to Alberta is the low-level nocturnal jet, most common during the spring and summer months. This feature forms on clear nights after there have been strong, gusty winds in the late afternoon. As the sun sets, a low-level temperature inversion (created by radiation cooling) develops near the ground causing the surface wind to diminish. The area of stronger winds has not disappeared. Rather, it has been effectively decoupled from the surface by the inversion and remains in the warmer layer aloft. In some cases, the winds at the top of the inversion can be stronger than the gusts observed the previous afternoon. The depth of the cold layer increases to as much as 1,000 feet during the night before it is destroyed by daytime heating the following morning.

Low level turbulence is a common occurrence during Alberta summers. Thermal updrafts are always present on sunny days and can become quite noticeable near lakes, where they are contrasted with downdrafts over the cooler water. These paired updrafts and downdrafts can even create a lake breeze circulation over larger bodies of water. In southwest flows of 30 knots or greater over the mountains, severe turbulence will occur in any of the valleys located on the east side of the Rockies. Grande Cache is a prime location for such turbulence events.

(b) Winter

Winter in Alberta is generally considered to be from late November to late March, or early April. During this period, good flying weather is common but it is possible to identify two patterns that produce generally poor conditions. The first of these is a cold trough scenario. These troughs are not as frequent in the winter as they are during the summer months and tend to be drier but, when associated with a frontal area or jet stream, can still bring prolonged periods of very low flying conditions and significant snowfalls when they pass.

The other situation producing poor weather is the phenomenon referred to as a "dirty ridge." It occurs when a north to south upper ridge builds over BC, an Arctic surface front lies along the foothills, and a maritime frontal wave has developed along the BC coast. Since the cold air is dammed up against the mountains with no where to go, the warmer, moister air associated with the maritime system overruns the cold as it moves into Alberta. Depending on the temperatures aloft and the depth of the cold air, this pattern can result in large amounts of snow for Alberta and extended periods of poor flying conditions. Freezing rain can occur if the temperatures in the maritime air are conducive to producing liquid precipitation.

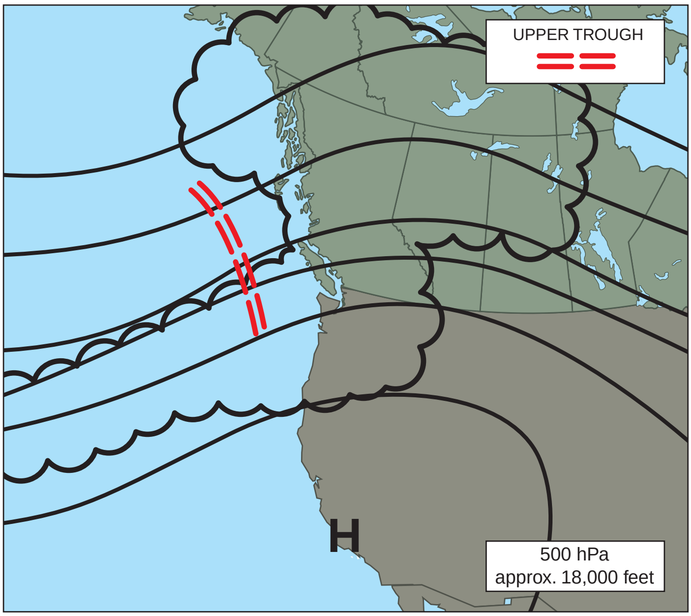


Fig. 4-1 - Upper pattern showing a typical "Dirty Ridge"

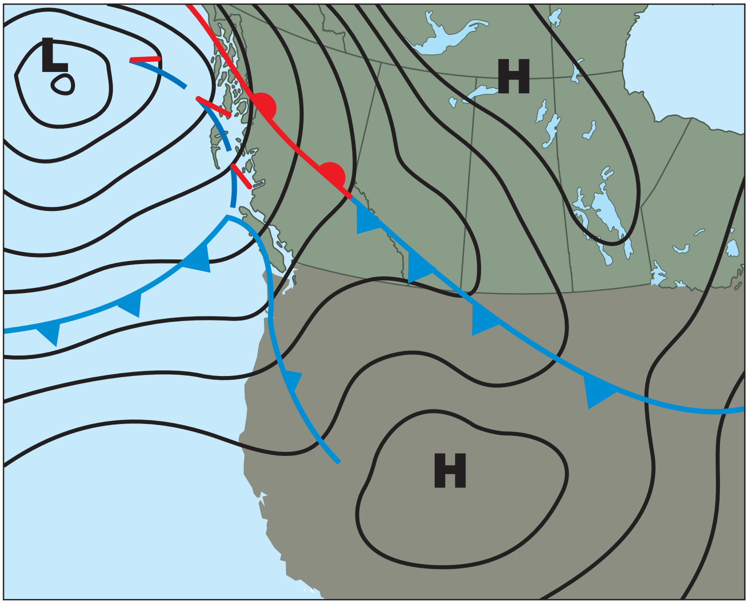


Fig. 4-2 - Surface analysis under a “Dirty Ridge”

During the winter, a strong area of high pressure can form in the very cold air found over Alaska and the Yukon. This frigid air mass will often spread southeastwards onto the Prairies with an Arctic front marking its leading edge. Depending on the strength of this front, winds can shift abruptly into the northwest with its passage and be gusty for several hours. Coupled with local snowfalls ahead of the front, these winds can produce short lived blizzard-like conditions. Once the ridge of high pressure is established over the area, widespread clear, cold weather dominates.

As mentioned in Chapter 3, Southern Alberta is noted for its winter Chinooks. Chinooks occur most often from November to January, and have been known to persist for up to 10 days. The position of the lee trough at any given time determines the weather at a specific site. To the east of the trough, a light southeast flow pushing up continually rising terrain will result in cool temperatures and generally low ceilings and visibilities, whereas to the west of the trough, the moderate to strong westerly Chinook flow quickly clears the skies and significantly warms the temperatures. This strong westerly flow is, however, notorious for producing significant turbulence.

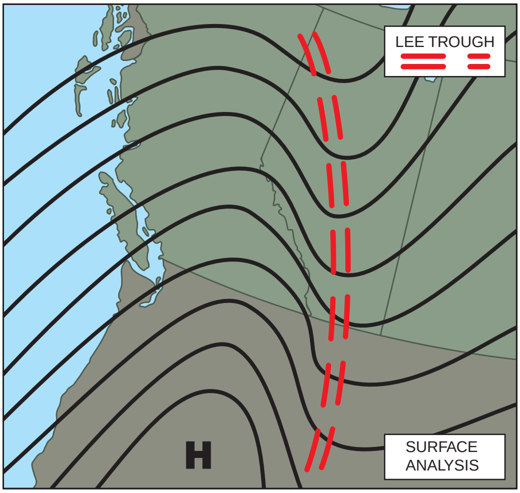


Fig. 4-3 - Basin high surface chinook flow

Within about 50 miles east of the Continental Divide, moderate to severe lee waves are common below 18,000 feet when there is a strong flow from the southwest (i.e. nearly perpendicular to the Rocky Mountain range). The favoured levels for waves to develop are between 8,000 and 15,000 feet. In strong westerly flows (greater than 60 knots above 25,000 feet), clear air turbulence will form near the mountains followed downwind by a relative lull and a secondary turbulence area. Sometimes these areas are marked by the presence of lenticular clouds forming on the upslope side of the wave but, when the air is very dry, there can be little or no indication of their presence. A westerly flow of 20 knots or greater at 9,000 feet can produce a similar effect in the lower levels. Lee waves are most common in the winter when the upper flow is strongest, but can also occur in the summer.

Transition Periods

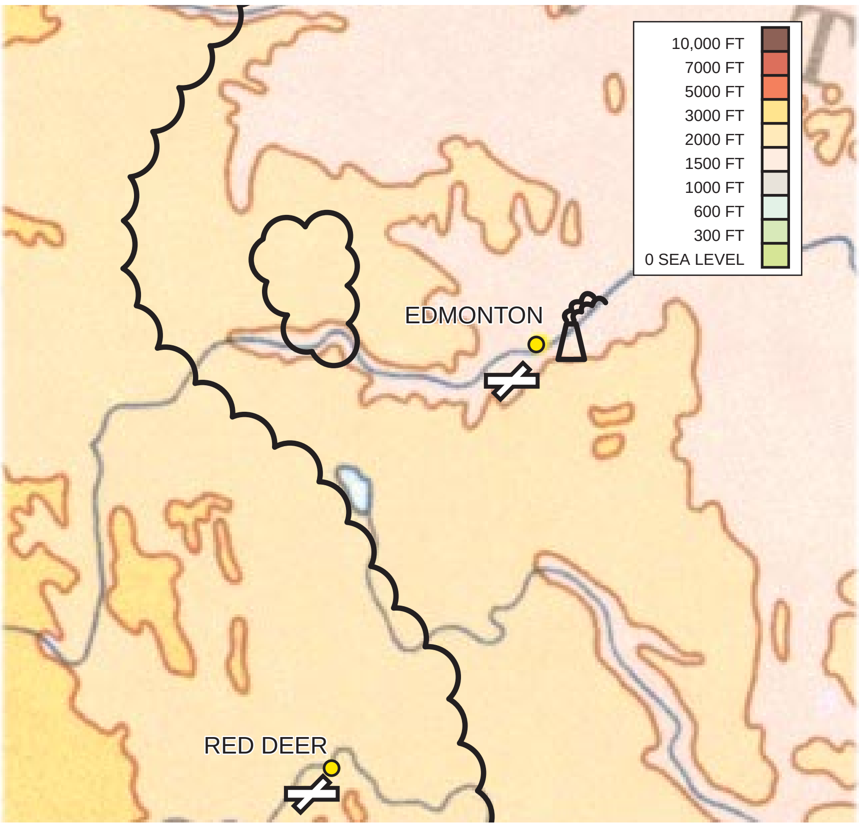
Occurrences of stratus and fog constitute the primary aviation hazard during the transition seasons of spring and fall, when poor flying weather is fairly common. Spring across the prairies is generally short and includes the period from when the snow begins to melt in earnest to when it has completely disappeared, and the lakes have thawed. During this time, good flying conditions occur more often as the days get longer and warmer, allowing the moisture from the melting snow to dissipate easily into the air. However, on nights relatively free of cloud, nocturnal inversions develop and effectively trap the moisture near the surface, often resulting in early morning fog and stratus which lingers until insolation is strong enough to break down the inversion.

The springtime “cold lows” can often be a problem. Moving normally across the northern U.S., the easterly upslope flow to the north of the low can produce heavy, wet snow across southern Alberta.

The fall, on the other hand, is a time of lengthening nights, falling temperatures, and plentiful moisture supplied by the still-open lakes. The passage of cold air over the relatively warm water frequently produces low level cloud and instability downwind that can continue for as long as the cold flow persists. Conditions begin to improve as lakes freeze up, generally by mid to late November, for most prairie sloughs. Cold lows also make an appearance during this time of year producing heavy showers.

Local Effects

Edmonton and Area



Map 4-3 - Edmonton and area

The area around Edmonton is generally flat with a gradual slope upwards towards the southwest. The local weather is affected by the North Saskatchewan River, flowing through Edmonton from the southwest to the northeast, and by a number of small lakes in the vicinity. The West Practice Area, 30 miles west of Edmonton just to the southeast of Lac St. Anne, is a student pilot training area and its weather is very similar to that of Edmonton.

In an upslope east to northeasterly flow, fog and stratus can form in the area at any time of the year, although it is much more likely in the fall months due to the plentiful moisture supplied by open water. After freeze-up, fog and stratus become much less common.

Lake Wabamun lies about 40 miles west of Edmonton and has three large power plants situated around it. These plants release heated water back into the lake throughout the year, keeping it open during much of the winter. This leads to frequent and localized stratus development in the area, especially when the temperatures are cold and the surface flow is light, as is common in the winter.

In a northeasterly flow, fog and stratus can form and linger in the North Saskatchewan River Valley. Normally in this flow, conditions will be slightly lower and winds somewhat stronger at Namao than at the City Centre Airport, likely due to urban effects.

A light northerly flow in the spring typically yields a band of stratus and low ceilings south of the Edmonton, between Wetaskawin and Ponoka. Observations from Red Deer and Edmonton International will not provide any hint of this cloud.

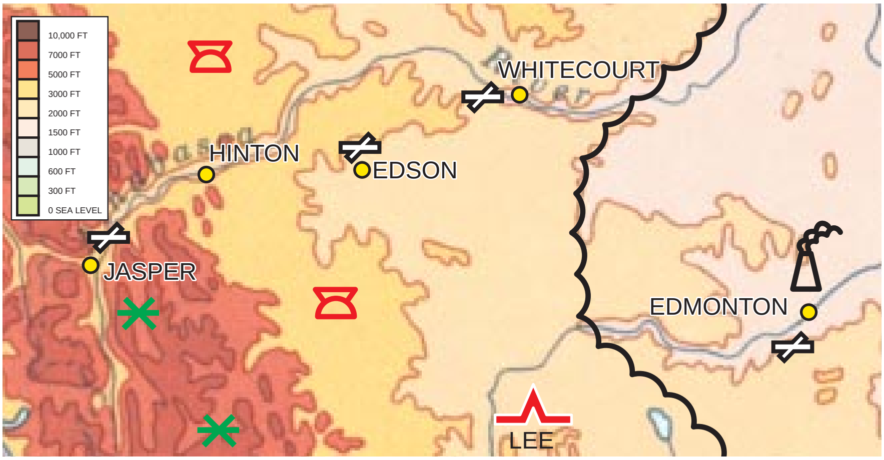
A depression in the land, extending southeast of Edmonton to Lake Miquelon, forms a shallow valley. In a northwesterly flow, stratus can form in this valley and linger well into the afternoon.

In a moderate to strong surface flow, independent of direction, there will be significant mechanical turbulence over the city of Edmonton. A 30-knot wind will produce severe turbulence for aircraft flying into the City Centre Airport. An updraft over the adjacent Kingsway Garden Mall, just to the south of the airport, frequently extends the turbulence up to 4,000 feet.

In a moderate or stronger west to northwesterly flow, low level turbulence occurs over the long narrow lakes to the southeast of Edmonton (e.g. Driedmeat Lake and Coal Lake). Similarly, the northwest flow off Big Lake, northwest of the city, can be quite turbulent.

In temperatures colder than -30° C, ice fog develops over eastern sections of the city due to the warm output from the refineries situated there. With a very light easterly flow, the City Centre Airport will be engulfed by this fog. When the flow is slightly stronger and more northeasterly, all of Edmonton, as well as the International Airport to the south, can be affected. These reduced visibilities can be very persistent, often taking until mid afternoon to clear.

Edmonton to Jasper



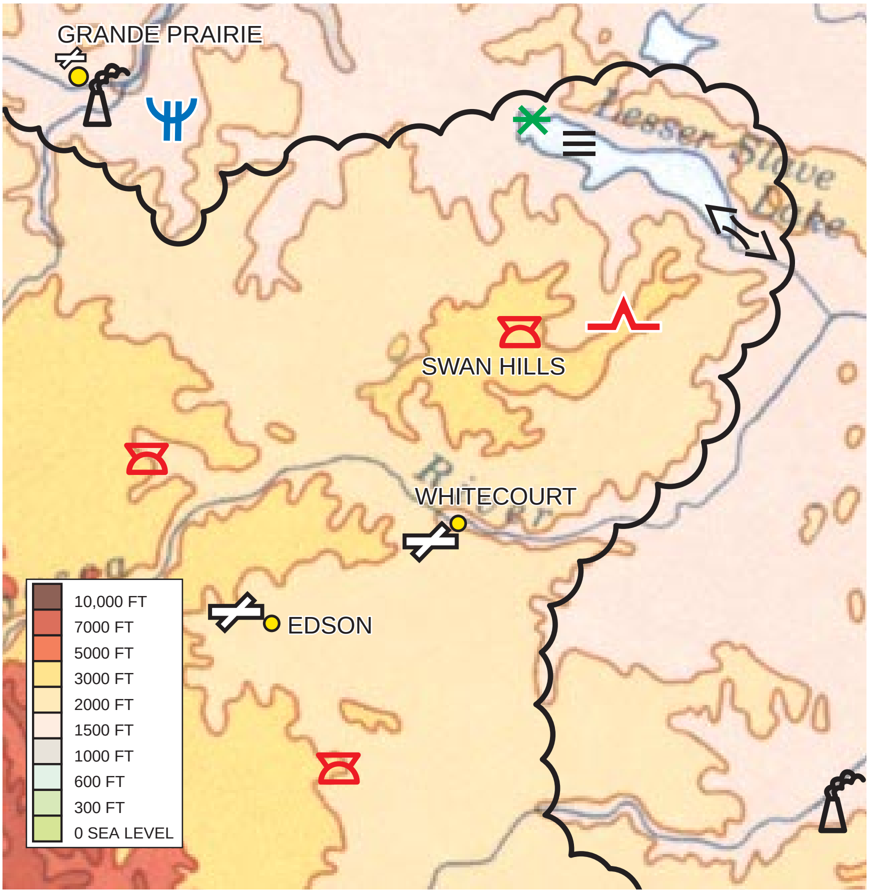
Map 4-4 - Edmonton to Jasper

From Edmonton heading westward to Jasper, the terrain rises gradually to about 3,000 feet above sea level in the vicinity of Edson. To the west of this line, there is a more abrupt increase in elevation due to an escarpment that exists west of a line from Edson to Drayton Valley and southeastwards along the Battle River towards the Ponoka area (note: the location of the 3,000 foot mean sea level contour is an important marker for low cloud development). In an east to southeasterly flow over Alberta, a band of stratus forms along and west of this escarpment and will persist for some length of time. This stratus thickens westward and typically extends in this direction as far as the Continental Divide. Weather observations taken at Edson, located in a small valley, and Drayton Valley, just to the east of this escarpment, are not representative of the weather in this area, and if marginal conditions are occurring at these two towns, worse weather can be expected further west. These low conditions are rare in the summer, but in the fall this stratus can persist all day. Some diurnal improvement will occur during the afternoon but conditions will lower once again in the evening. Any PIREP from the Rocky Mountain House area is usually quite indicative of the weather. The Obed Hills to the west of Edson will have cloud right down to the ground in such a situation, and Jasper's weather cannot be used as a reliable planning tool since it also is located in a valley where conditions can be quite different.

In the summertime, convective cells form in the foothills west of Edson due to enhanced warming by the sun along the slopes. These clouds build during the day to a height of about 18,000 feet and then begin to move eastward. Unless there is some other factor to support their development, they will usually dissipate before reaching Edmonton. If the mean flow is northwesterly, thunderstorms can also form on the windward side of the Swan Hills and move towards Edmonton. Again, these cells usually dissipate before reaching the city due to subsidence on the lee side of the hills.

There have been cases where these weakened cells have passed over Edmonton to once again rebuild to the southwest over the higher ground around Lake Miquelon.

Whitecourt, Edson, and the Swan Hills Area to Grande Prairie



Map 4-5 - Whitecourt, Edson, and the Swan Hills area

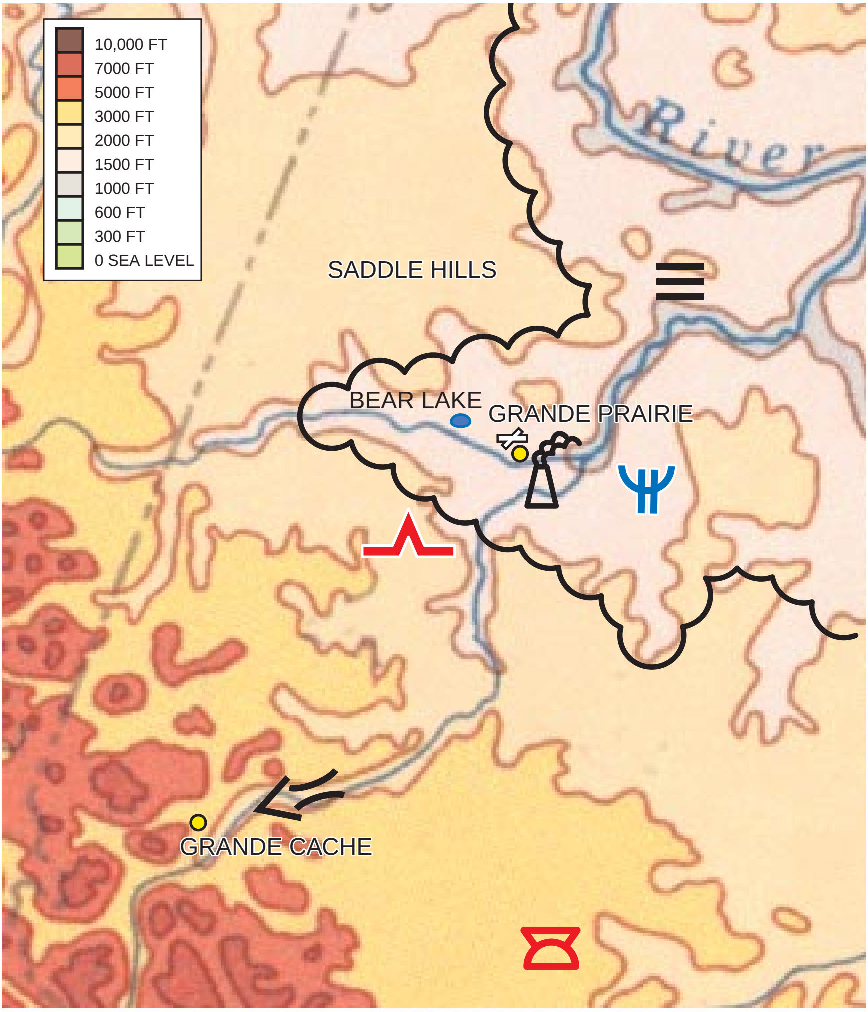
The Swan Hills extend from the Rocky Mountains near Hinton, northeastward through the Whitecourt area to the east end of Lesser Slave Lake. These hills are topped at around 3,500 to 4,000 feet and contribute greatly to the weather along this route. In an upslope southeasterly flow, the foothills of the Rockies, on the west, combine with the Swan Hills, to the northwest, and the Pelican hills, to the northeast, to form a C-shaped barrier to the winds. This can produce stratus that will persist in the area for days, sometimes requiring a complete change of flow to dissipate. While the band shown on the map is hugging only the upslope areas, it is quite possible for the entire C-shaped area to be obscured by cloud in a persistent southeast flow. This cloud will then scatter out to the northwest of the Swan Hills, as the flow becomes subsident. In a northwesterly flow, often associated with the passage of a cold front, the pattern is reversed. The stratus and fog associated with the front will be thick to the northwest of the hills, but will scatter out on the southeast side.

About 40 miles northwest of Whitecourt lies Fox Creek, which is situated in a sheltered depression in the land. This is an area where stratus can easily form in an east to northeasterly flow and be very slow to leave, since it is protected from light flows from most directions. A strong flow from some direction, usually from the northwest, is required to clear it out.

In the summertime, the ridge of the Swan Hills supplies enough orographic lift to produce a great number of thunderstorms. Their development is further enhanced by the sun's heating action on the higher terrain on top of the hills but these cells are frequently dissipated by subsidence as they move away from their source. In a northwesterly flow, the convection tends to originate in the Chetwynd area, build to approximately 18,000 feet, and then dissipate due to subsidence as it moves away from the hills. These cells will quickly redevelop if there are any other factors present to support convection. The ridge of the Swan Hills also supplies enough lift to produce moderate turbulence up to about 7,000 feet.

The route from Whitecourt to Grande Prairie is, for the most part, over a basin formed by the Smoky and Little Smoky drainage systems. It has a tendency to fill with low cloud in moist northeasterly flows, especially those associated with low pressure systems moving eastward south of the area. The terrain rises between Fox Creek and Whitecourt due to a ridge of hills connecting the foothills near Obed, with the Swan Hills to the northeast. This ridge is usually shrouded in cloud whenever Grande Prairie and Whitecourt report ceilings less than 1,600 feet above ground level. It can also be an area of enhanced convection on unstable days and mechanical turbulence on windy days.

Grande Prairie and Southward



Map 4-6 - Grande Prairie and southward

The Grande Prairie airport is in natural bowl with the foothills of the Rocky Mountains to the south and west, the Saddle and Birch Hills to the north, and minor rises to the east. The fairly deep valleys of the Wapiti and Smoky Rivers lie south and east of the airport. Upslope flows from the north and east tend to fill the area south of the Saddle Hills, up to the foothills west and south of Grande Prairie, with stratus. This cloud will often remain until it is cleared by a change in the wind. It can be enhanced, especially in winter, by exhaust emissions from the city, which lies just east of the airport, and from a plywood plant and pulp mill to the southeast.

The surrounding soils tend to be quite moist due to a high water table, with a fairly large body of water, Bear Lake, just northwest of the site. Shallow inversions, bolstered by light easterly surface winds, are frequent year round and trap moisture in the low levels. As a result, overnight fog tends to persist here longer than other sites in the region, especially from late fall to early spring.

Freezing rain is fairly common in the Grande Prairie area because of frequent shallow inversions during the winter which are intensified by the passage of low pressure systems just to the south. When an inversion is in place, even strong southwest to west winds aloft do not erode it quickly and significant wind shears and associated turbulence tend to occur within a few hundred feet above ground level.

Lenticular cloud is common with strong southwest to west wind flows aloft and can be a good indication of the existence of hazardous low level wind shears when the station is reporting variable, or light easterly winds, at the surface. These winds have likely surfaced over higher terrain, especially to the south and west, and mechanical turbulence also can be a problem for low flying aircraft over these areas. Furthermore, during strong southwest to west wind events, subsiding air off the Rocky Mountains can make it difficult for helicopters and small fixed wing aircraft operating in the area to maintain altitude. The turbulence associated with these winds tends to be worse over the eastern slopes and the foothills area but is generally not as severe among the mountain ranges themselves.

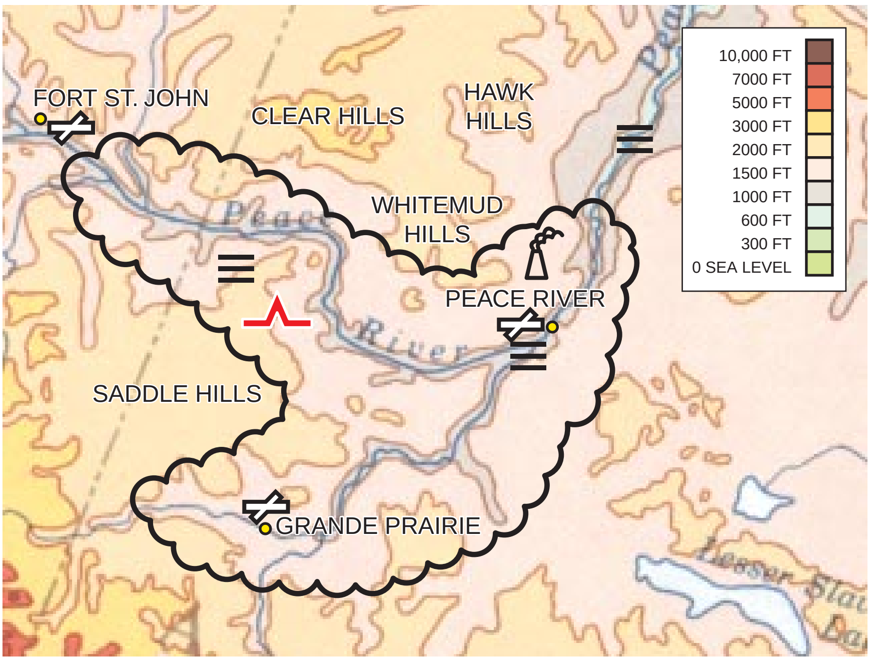
Convective cells that develop in the foothills to the west and southwest of Grande Prairie and approach the town are usually dissipated by subsidence as they approach. They will often show some redevelopment in the vicinity or east of Grand Prairie as the land begins to level.

Birds in flight have been noted as a problem near the airport, especially during migratory seasons.

Routes southward from Grande Prairie encounter rising terrain and mountain weather. Mechanical turbulence can be expected within 5,000 feet or more of the surface with gusty winds from any direction over this area. However, winds flowing perpendicular to mountain ridges tend to be somewhat broken up and are not as strong in the low levels as winds which flow parallel to the openings in mountain barriers. In a typical southwest to westerly flow, funneling in southwest to northeast valleys increases the wind speed which can result in locally severe mechanical turbulence. The valleys of the Kakwa, Smoky, Athabasca, Brazeau and North Saskatchewan Rivers are prime locations for this phenomena, and it has also been noted in lesser valleys like that of the Embarras River. Light fixed wing aircraft can expect difficulties at aerodromes situated in such valleys (e.g. Grande Cache), especially with winds 20 knots or greater from the southwest.

Orographic mechanisms causing enhanced convergence and lift make the foothills a prime area for the onset of convective activity in unstable airmass situations. Cells tend to form along ridges and then move downwind. Heading south from Grande Prairie, the forest changes from a largely mixed deciduous canopy to a predominantly coniferous one, roughly along 54.5° N latitude. Differences in albedo and evapotranspiration can account for enhanced convection south of this line. This is particularly true in spring and fall when snow is covering the ground and deciduous trees are without leaves. The lower albedos of the coniferous forest can create pockets of enhanced daytime heating, which in turn can create convective currents and heightened snow flurry activity in unstable situations. Visibility can fluctuate greatly when these snow flurries occur.

Grande Prairie - Peace River and Area Westward



Map 4-7 - Grande Prairie - Peace River and area westward

The elevation of the land gradually decreases heading north from Grande Prairie, and the Smoky and Peace River Valleys are the dominant topographic features. These valleys are quite sharp and the terrain tends to fall off with sudden drops up to 1,000 feet from the top of the valley to the level of the river. In strong wind situations, turbulent eddies and funneled currents are common along these trenches, which can cause problems for low flying aircraft.

Flows of moist air from the north through to the east are responsible for widespread upslope stratus which is bounded by the Clear Hills to the northwest of Peace River.

The Saddle and Birch Hills form a minor east to west barrier north of Grande Prairie but are high enough to create local effects of their own. Ceilings are usually lower on the windward (upslope) side, and markedly better on the lee (downslope) side, with winds out of the north or south.

It has been noted that the Peace River Valley, west of the town of Peace River, is where many cold fronts advancing from the north, behind an eastward moving low pressure system, tend to slow or stall. When this happens, poorer weather conditions can be anticipated at the north end of the route between Grande Prairie and Peace River, especially in winter.

The Peace River Airport is located about 5 miles west of the town, which is situated in the Peace River Valley. The immediate valley is deep, and a climb of roughly 800 feet is necessary when traveling from the town to the airport, most of which is in the first mile and a half. Because of this, striking differences in weather conditions can be expected between the two places. For example, a cloud ceiling of 1,500 feet above ground in town would constitute a ceiling of 700 feet at the airport, everything else considered equal. As well, the deep part of the valley near the river is often completely filled in with stratus and fog, while the airport is clear. Due to cold air drainage into the valley, the temperature at the town is usually lower than that at the airport and, of course, winds in the town would be biased to the north and south by the orientation of the river, whereas the airport is more exposed to other directions.

The Peace River and its valley and, to a lesser extent its tributaries the Smoky and Heart Rivers, are responsible for most of the local effects peculiar to the airport at Peace River. When stratus or fog (typically formed by radiational cooling overnight, especially in the fall) has filled the valley, it can "spill out" and spread across the aerodrome, especially when winds are light and variable, or light southeasterly. This condition can be fairly persistent but, since the terrain is well sloped overall, daytime heating will usually dissipate the moisture, even if it lingers for longer periods in the valley. A good rule of thumb is to expect improvement to begin at the airport roughly two hours after sunrise, maybe a little longer in winter.

The Peace River is wide and fairly fast moving in the vicinity of the town of Peace River. As a consequence, stretches of water can remain unfrozen well into the winter, and sometimes they don't freeze at all. If conditions are clear and cold, stratus and fog can be expected along and downwind of these stretches. A large pulp mill near the river, and about 8 miles north-northeast of town, can further enhance the low cloud and lower the visibility if winds are from that direction.

Another local source of low level moisture is Lake Cardinal, about 12 miles west of the airport. Cool flows out of the west to north in the fall can create low cloud and fog, over and downwind of the lake. West winds can occasionally advect this moisture as far as the airport, but this is rare.

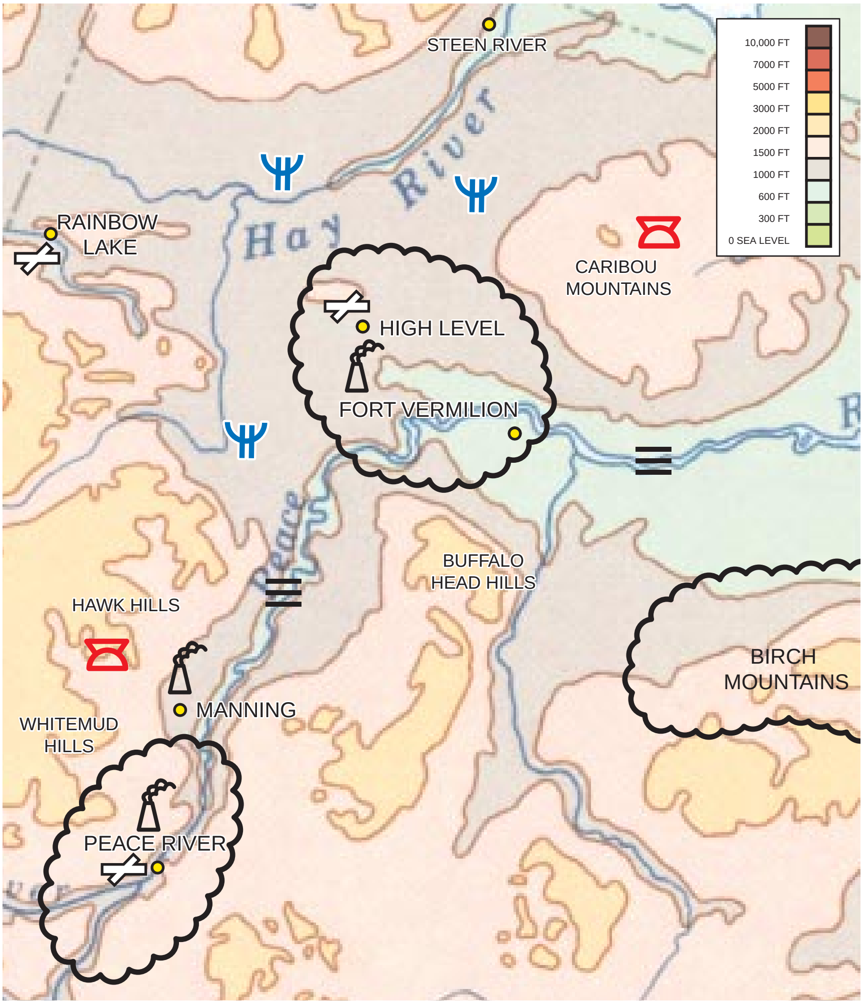
On the larger scale, the Peace River area is susceptible to widespread poor weather conditions in easterly (upslope) flows of moist air associated with organized low pressure systems passing to the south. However, conditions tend to be slightly better here than at other centers in northwestern Alberta under such a situation, and this is due to the slope of the land. A study of the terrain within a 60 mile radius of the airport shows the only true upslope direction into the airport is from the north, heading upstream along the Peace River. The Buffalo Head Hills and Utikima Uplands to the east of the airport would introduce a slight downslope component to winds from that direction, thus allowing some measure of drying in the low levels. That said, northerly winds tend to bring the worst weather into Peace River. This is especially true in the fall, when the cool northerly flow passes over still open water, and in the winter, when a northerly flow often brings cloud and snow from arctic outbreaks. Flows with a westerly component subside off the Rocky Mountains and, more locally, the Clear, Whitemud, Saddle and Birch Hills provide drier conditions and typically good flying weather. Although lenticular cloud and short-lived “Chinook” conditions are common, severe turbulence in these flows is a rarity.

Birds can be a problem near the airport during migratory seasons. Also, local agricultural practices such as tilling can attract large numbers of seagulls to the airport area.

The route between Peace River and Fort St. John is along the Alaska Highway and is dominated by the Peace River Valley. There is a gradual rise in the elevation of the valley westbound, with higher terrain on either side; to the south, the Birch and Saddle Hills and, to the north, the Whitemud and Clear Hills. This area tends to fill with low cloud and fog when there is a moist, upslope easterly flow, while subsident west winds are dry and give typically good conditions. Moist air moving from the north or south can give variable conditions due to the alternating upslope and downslope circulations produced by the terrain. There can be marked differences in weather from one side of the valley to the other in such situations. Winter cold fronts moving southward behind an eastward moving low pressure system often slow or stall through this valley, with poorer conditions in low cloud and snow to the north of the front.

Deep trenches formed by the Peace and its main tributaries, the Montagneuse, Eureka, Clear and Pouce Coupe Rivers, can produce local turbulence and wind changes in the low levels. Mechanical turbulence can be a problem within a few thousand feet of the ground over more rugged sections of the Clear Hills, especially with strong northwest to northerly winds.

Peace River - High Level and Area



Map 4-8 - Peace River - High Level

The Peace River Valley connects these two towns and is the main navigational landmark. The valley is flanked by the Clear, Whitemud, Hawk and Naylor Hills on the west side and by the Buffalo Head Hills on the East. A gradual decrease in elevation is encountered in the northbound direction. The valley broadens northeast of Manning, where the surface cover is predominantly muskeg, and, on a synoptic scale, north to northeast circulations of moist air can create widespread low cloud and fog over the gradually rising terrain. In recent years, beavers have dammed many of the minor tributaries flowing into the Peace River in this area, creating much standing water. This provides plenty of low level moisture to aid the formation of radiation fog in the summer and advection fog with cool northerly flows in the fall.

There can be stretches of open water on the Peace River well into the winter, allowing stratus to form. Exhaust from a lumber mill north of Hotchkiss can enhance fog formation in that area. The Peace River "trench" decreases in depth as the river flows northward, but can still cause turbulent eddies resulting in variations in wind direction and speed horizontally and vertically at low levels.

As with many of the ranges of hills in northern Alberta, those flanking the valley tend to develop "weather of their own." In situations where ceilings are 1,000 to 1,500 feet in Peace River and/or High Level, the cloud can be "down to the trees" over these hills. One particularly hazardous location is where Highway 35 crosses the eastern reaches of the Hawk Hills. The highway is used by many pilots, especially novices, as a landmark to follow between Peace River and High Level. Unfortunately, the highway rises over 500 feet within a distance of about 20 miles north of the Meikle River, with even higher terrain (and communication towers) to the east and west. These hills, like others in the area, can be shrouded by cloud when conditions at Peace River and High Level are marginal or better. They are also susceptible to local obscuration on the upslope side under moist flows from practically any direction. Seasoned pilots usually opt for a route following the Peace River itself to avoid sharp changes in elevation.

Easterly winds are not necessarily "upslope" winds everywhere in northwestern Alberta. Local topography must be taken into account when resolving areas of upslope from downslope areas. Dramatic changes in weather conditions can occur across a river valley, on opposite sides of a range of hills, or from one valley to the next. One particularly good example occurs to the northwest and southeast of the Halverson Ridge, a rise of land extending northeast of the Clear Hills. When the winds are from the east or southeast, conditions can be poor over the rising terrain of the Notikewin River valley west of Manning, but can be wide open to the northwest of the ridge into the valley of the Chinchaga River. Conversely, the weather is typically, but less dramatically, better to the southeast of the ridge, especially in the fall and winter when the winds are north or northwesterly. These same phenomena can occur, to a lesser degree, over the smaller Milligan Hills to the northwest of the Chinchaga Valley, so conditions can change across the valley itself, as the general flow changes from subsident to ascending.

When the air mass over the region is unstable, the hills are a favoured region for convective initiation. There are three main mechanisms responsible for this: orographic lift, stronger sensible (daytime) heating of sunward slopes, and earlier realization of convective temperatures at higher elevations (especially when inversions are present at lower elevations early in the day). If winds are relatively strong, then orographic ascent is the main mechanism for cell formation, with convective currents being initiated on the windward side of the hill. In a weaker flow, local heating is the dominant trigger.

Finally, the hills can be expected to produce, or intensify, mechanical turbulence when winds are strong in the low levels. Some ridge lines can even generate local lee wave activity when the flow across their tops is close to perpendicular.

High Level is situated in a wide, shallow depression within an area of fairly flat terrain, with the Hay River drainage system to the west and north, the Peace River valley to the south and east, the Caribou Mountains to the northeast, and a gradual slope up into the Hawk, Naylor and eastern Milligan Hills to the southwest. This "bowl" has a tendency to trap cold air beneath shallow inversions and to hold it there for prolonged periods, earning High Level a reputation for low cloud, fog and freezing precipitation.

When cold arctic air floods the area behind one of a family of easterly migrating low pressure systems, it has a tendency to pool into the low lying land. When a warmer east to southeasterly flow develops ahead of the next low in the series, it does not clear out this cold air but instead rides over it. If the air temperature below is subzero, and rain is falling from the overrunning warm air, then freezing rain and severe clear icing are the result. This is most common in the spring and fall when it is likely that the overrunning warm air is supporting liquid precipitation. During the winter, these same cold fronts push well south of High Level during an arctic outbreak, and then they stall or begin a slow retreat. As a result, the town endures more frontal weather with low cloud, snow and gusty northerly winds than do places further south.

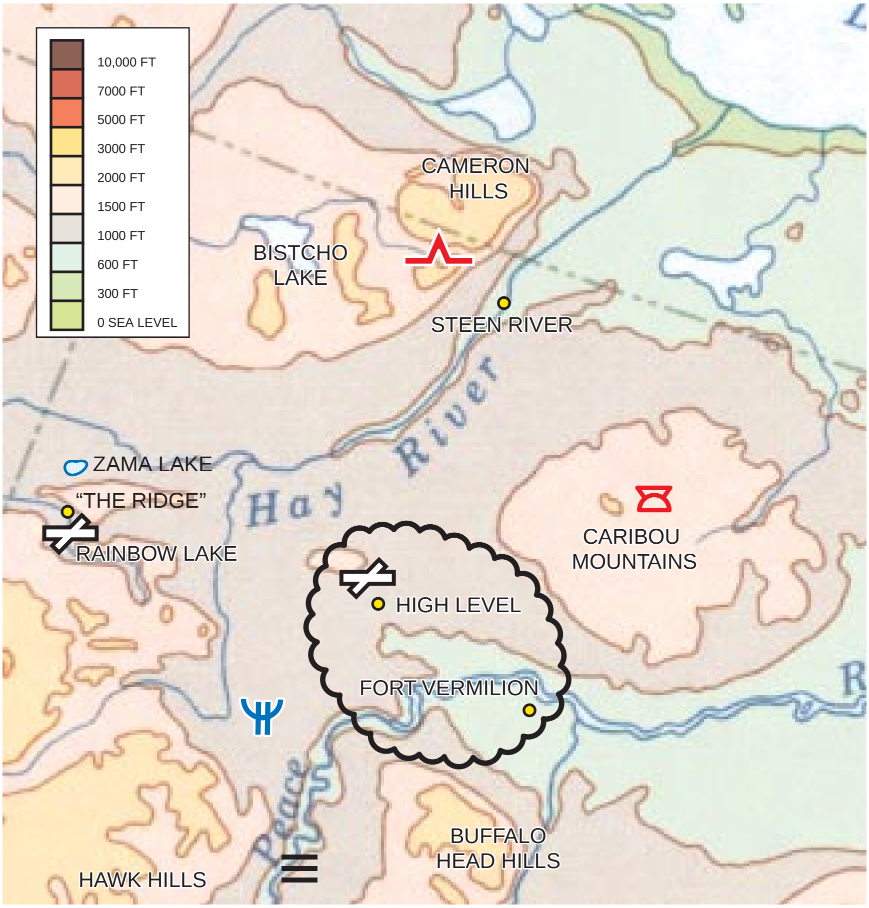
Mount Watt is a dominant topographic feature disrupting the otherwise smooth terrain near High Level. It is seven miles west of the airport, rising more that 1,000 feet above it, and has several communication towers situated on top. Mount Watt is blamed for many local effects, including the generation of upslope cloud from winds out of the northwest or southeast, and turbulent eddies downwind, especially when the flow is from the northwest.

Most of the poor weather in High Level occurs when the synoptic flow is out of the northeast quadrant. However, these winds are effectively blocked by the Caribou Mountains and are forced to stream in from the north up the Hay River Valley, or from the east up the Peace River Valley. In both cases, persistent upslope conditions usually result. The best weather can be expected with winds from the south through to west, and even from the southeast, with the Buffalo Head Hills providing some protection.

There are two local mill operations, a saw mill in town and a plywood plant just to the south. Both can accentuate fog conditions, especially under an inversion, with their addition of moisture and particulate into the lower atmosphere.

There are two small lakes near the airport. Hutch Lake lies about 6 miles north and Footner Lake, the local water aerodrome, is just to the west. Both act as moisture sources and can generate fog, especially in the fall. As well, much of the surrounding terrain is muskeg and beaver ponds. After major rainfall events, the water table can remain quite high for several weeks, leading to an increase in standing water and a similar increase in the chance of low ceilings and poor visibilities.

Northwestern Alberta
including Rainbow Lake, Fort Vermilion and Steen River



Map 4-9 - The main routes northwestward from High Level

This route follows the Hay River Valley and gradually increases in elevation westbound. The valley is flanked to the south by the Naylor and eastern Milligan Hills, and to the north by the Cameron Hills, and easily fills with stratus and fog under moist easterly flows. The surface is typically quite wet when not frozen, as it is dominated by muskeg and beaver ponds. Because of the fluctuations in the water table depth, Zama Lake varies greatly in size and, when the table is high, it can rival Bistcho Lake in the Cameron Hills for surface area. All of these moisture sources contribute to the formation of widespread radiation and advection fogs, especially in fall and late spring.

A landform, known locally as “The Ridge”, rises over 1,000 feet from the valley floor and separates Rainbow Lake from Zama Lake. It is over 40 miles long and oriented east to west, similar to Mount Watt near High Level. It is also a generator of turbulence and upslope cloud and is a prime location for the early onset of convective activity on sunny, unstable summer days.

Weather from northeastern British Columbia moves fairly easily through this corridor when the controlling flow is westerly. When this is the case, the rule of thumb is “Fort Nelson today, High Level tomorrow.”

The Cameron Hills are situated in extreme northwestern Alberta and stretch into the North West Territories. They are similar in many respects to the Caribou Mountains but on a smaller scale. Elevations rise abruptly about 800 to 1,000 feet into a ridge on the southeast side and then gradually diminish northwestward with the terrain wrapping around Bistcho Lake. The wind direction that produces the most upslope stratus in this area is from the northwest, simply because of the broader, more gentle incline from that direction, and the moisture that is added from Bistcho Lake. The lake is also a frequent generator of fog and stratus in the fall when the air is generally cooler than the water. Upslope stratus can occur from the southeast as well but is usually confined to a narrower area between the Hay River and the summit of the southeast ridge. There can be significant turbulence to the lee of the southeastern ridge, especially with strong northwest winds.

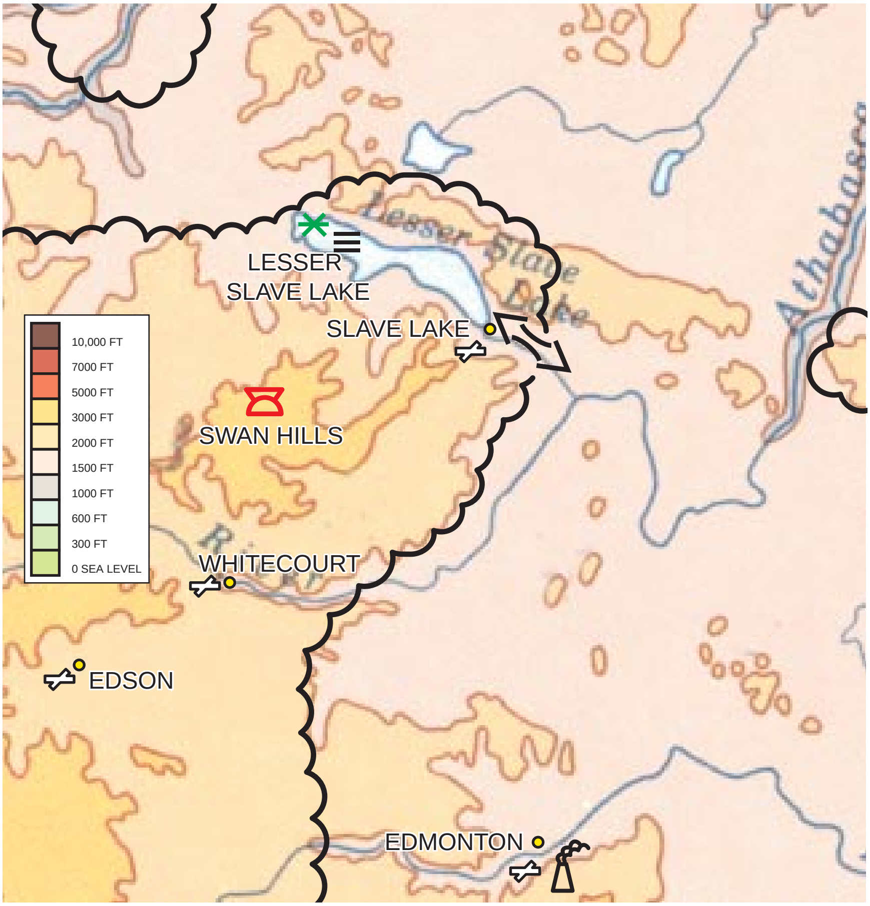
The Peace River turns eastward to the southeast of High Level and flows past Fort Vermilion. The river’s “trench” is basically nonexistent east of Fort Vermilion as the drainage basin becomes broad and uniformly flat. It is bounded on the north by the Caribou Mountains and to the south by the Buffalo Head Hills, as far as the Wabasca River Valley, and then the Birch Mountains further east. The surface is again dominated by muskeg and is ordinarily moist when not frozen. Rainfall does not run off quickly. Shallow radiation fog can form over these moisture sources on clear nights and advection fog is common in the fall when cool west to northwesterly winds are present (north winds are typically weak and not very common in this area as they are effectively blocked by the Caribou Mountains). Effluent from a sawmill plant near La Crete can add to the problem locally. Moist east and southeasterly winds tend to funnel up the slope through this area and pick up additional moisture from the surface, thus generating widespread stratus and fog. Flows from the west, however, usually have the opposite effect and are associated with good flying weather.

The Caribou Mountains make up one of the largest upland regions in Alberta away from the Rocky Mountains. The “mountains” are actually a nearly circular plateau that rises more than 2,000 feet above the surrounding terrain. There is a ring of higher, terraced hills in the center of the plateau that form a bowl containing several lakes, the largest of which is Margaret Lake. The rest of the plateau is mostly muskeg, described by some to be “the wettest place in Alberta.” Strong inversions, and thus radiation fog, are a rarity over the plateau and are quite short lived when they do occur, due to cold air drainage katabatic down the slopes into the surrounding valleys. Because the crest of the plateau is usually situated well above the top of any inversion, below (nocturnal, arctic), temperatures can be considerably warmer there, sometimes as much as 25 to 30 Celsius degrees in the winter. This is one of the reasons that convection commences much earlier over the Caribou Mountains on unstable summer days; less heating is required to reach the temperature where upward convective currents are generated. Slope heating and orographic lift around the perimeter can also speed up this process.

The worst weather over the Caribou Mountains occurs when the entire plateau is obscured by widespread low cloud, usually associated with the passage of an organized low pressure system. Local upslope and downslope flows around the perimeter can further augment or dissipate this cloud. Turbulence can be a problem when strong winds from any direction encounter the steep perimeter. Winds can swirl over the edge in both ascending and descending currents, generating rolling circulations and violent eddies that can be very dangerous to low flying aircraft. Wind directions can fluctuate radically over short distances.

The route northward from High Level follows the Hay River downstream, flanked on the east by the Caribou Mountains and on the west by the Cameron Hills. The valley is broad and flat with few obstructions; very similar to the Peace River Valley east of Fort Vermilion. It is the preferred northern route in and out of Alberta as it has good visual references, including Highway 35. Moist north to northeasterly winds are upslope and can produce lower conditions. In the winter, outbreaks of arctic air can progress rapidly southward, unimpeded by any terrain barriers, bringing an onrush of cloud, snow and wind to points south. Widespread low cloud associated with passing low pressure systems can shroud the higher terrain to the east and west.

Edmonton - Slave Lake and Area

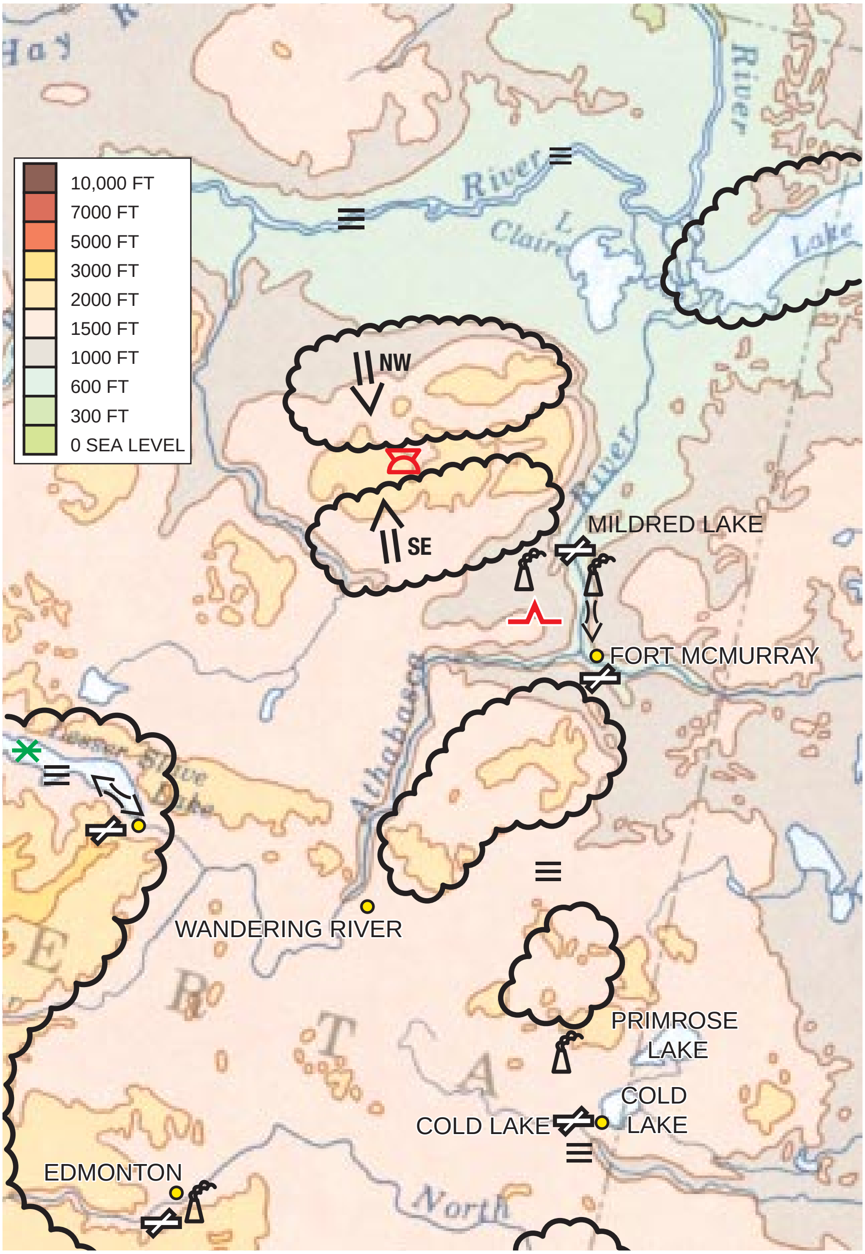


Map 4-10 - Slave Lake and area

Flying from Edmonton to Slave Lake, the terrain is relatively flat until it begins to rise over the Swan Hills to the southwest of Lesser Slave Lake. These hills, combined with the Pelican Hills to the northeast, act to funnel the winds through the eastern end of Lesser Slave Lake in either a west/northwest, or east/southeast direction. The town and airport of Slave Lake are situated between these hills and are the recipient of these strong funneled flows. This creates significant mechanical turbulence near the end of the lake, often reaching to approximately 5,000 feet above sea level.

In the spring and fall, a west or northwesterly onshore flow over the east end of Lesser Slave Lake will produce a layer of stratus up to 1,000 feet thick. This will typically extend down the valley of the Lesser Slave River, almost as far as Smith, and frequently engulfs the town of Slave Lake.

Edmonton to Ft. McMurray and Northward



Map 4-11 - Edmonton to Fort McMurray and northward

The region between Edmonton and Fort McMurray is known for its high frequency of poor flying conditions. This is because a ridge of slightly higher terrain existing between the two points provides uplope conditions for almost all wind directions. Also present is an abundant moisture supply in the form of swamps and small lakes throughout the area. The region between the Marianna Lakes and the Wandering River is most notorious for low conditions. Ceilings are often down to the trees and precipitation is enhanced in this area, particularly in a northwesterly flow. The highway between Edmonton and Fort McMurray runs along this ridge, but because of its generally poor conditions, pilots often choose the Athabasca River to the west, or the railway clearing to the east, for visual navigation. As a general rule of thumb, when Fort McMurray is reporting a ceiling in the 1,000 to 1,500 range, expect low ceilings from Fort McMurray to the Lac la Biche area.

Another point of danger is Stony Mountain. It is 18 miles to the south of Fort Mcmurray and rises abruptly some 1,350 feet above the surrounding terrain. Pilots flying under low ceilings will generally avoid this area completely as the top of the hill is frequently obscured.

The town of Fort McMurray is situated at the junction of two rivers, the Clearwater and the Athabasca. The Athabasca River pours in from the west-southwest and turns north at the point it meets the Clearwater, flowing from the east. The Fort McMurray airport is situated on the south side of the Clearwater River, and its weather is influenced by the Clearwater Valley. The surrounding land is generally flat muskeg except for Stony Mountain, which lies to the south.

The two rivers can create localized fog and stratus between the months of May through October when the water is open. During the overnight period, cooler air tends to pool in the valley which can lead to fog and stratus formation, especially in the fall. These conditions usually improve during the day but will often spill over the sides of the valley into the airport, especially in the morning hours. However, in the absence of this localized phenomena, the river valleys are preferred routes.

Within the airport boundaries there are a few local effects created by specific conditions. The first is the frequent occurrence of turbulence during a strong westerly flow of 20 knots or greater, causing higher than normal sink rates on a final approach. It is speculated that this is created by the difference in albedo between the surrounding forest and the cleared area of the airport, combined with the influence of the westerly flow making a transition from the treetops down to the aerodrome.

Another local phenomena is restricted to winter months only and is the result of snowmaking at a ski hill 3 miles east-northeast of the airport. If the surface flow is towards the airport, visibility is often reduced to half a mile or less by ice crystals. This persists until the snow making is ended.

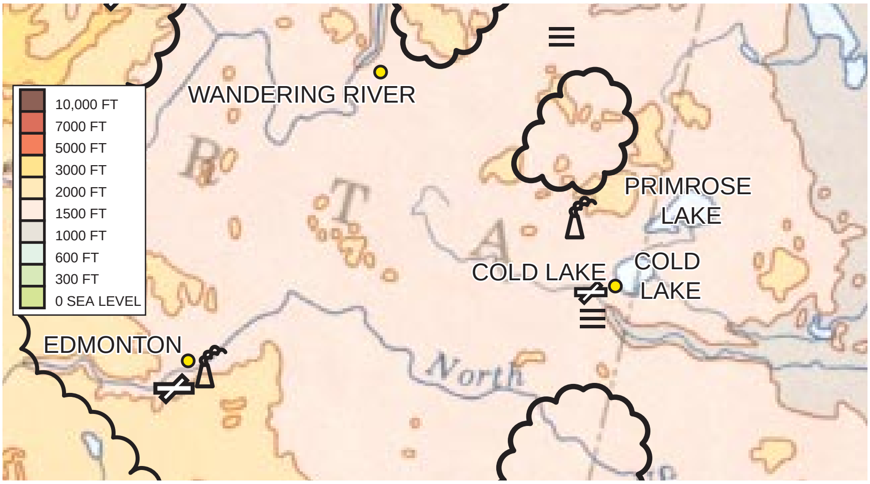
The airport can also experience locally reduced conditions in a northerly flow. Such a flow, coming along the Athabasca River Valley, is funneled as the valley becomes progressively more narrow. When this strengthened flow meets the southern slope of the Clearwater Valley, it is forced abruptly upslope and can give low conditions at the airport sitting at the top of the valley. This situation can also produce significant low level turbulence.

There is a landing strip at Mildred Lake, about 28 miles to the north of the Fort McMurray Airport, that is used to service the oilsands activity in the area. Because of the emissions from local plants, as well as the warmer effluent emitted into the tailing ponds, this strip will often be fogged in when conditions elsewhere are fine. Although this localized fog never reaches as far as the Fort McMurray Airport, it is often possible to see distant plumes of steam to the north.

There is a great deal of flight activity to points north of Fort McMurray due to the oilsands activity and the abundance of fishing and hunting lodges in the area. The local topography is the result of ancient glacial activity and consists of relatively flat land dotted by numerous small lakes, many low-lying hills and acres of swampland and muskeg. This area, with its abundant low level moisture, can often be blanketed in stratus and stratocumulus, regardless of wind direction and especially in the transition seasons of spring and fall. There is a definite lack of weather reports to aid flight planning. Experienced local pilots use their familiarity with the terrain to avoid higher ground that most likely will be obscured by low cloud.

Other features that stand out from the surrounding level terrain are the Birch Mountains, 50 miles to the northwest of Fort McMurray, and Trout Mountain, 80 miles to the west. Together these two form a physical barrier, with just a narrow pass in between, that effectively blocks flows from both the east to southeast and from the north to northwest. The terrain in this area also has sufficient elevation to initiate convective cloud on warm summer days.

Edmonton to Cold Lake



Map 4-12 - Edmonton to Cold Lake

The flight path from Edmonton to Cold Lake takes a pilot over mainly agricultural lands with many small shallow lakes and gently rolling hills. Otherwise, there are no significant geographical features. The land slopes gradually downhill from west to east, losing about 500 feet of elevation between the two, and in the absence of any major synoptic weather feature there is very little to affect the enroute weather until Cold Lake. The Cold Lake region is a continuation of the gently rolling topography that extends off the north-northwest and sits on the dividing line between mainly farm and grasslands to the south and Boreal Forest to the north. The major influences on the weather in the Cold Lake region are two large lakes to the northeast (Cold Lake and Primrose Lake) and the Beaver River Valley running through the town.

The Beaver River is a fairly small waterway with an east-west orientation that flows just south of the military base and airport. It has carved out a very broad and shallow valley in which the airport is situated. This valley, despite its shallowness, has a significant influence on the weather. Winds are frequently channelled by the valley into either an easterly or westerly flow. Indeed, a wind rose of the area shows these two directions to be predominant, with westerly having a slighter greater frequency than easterly. Winds channelled from the west are almost invariably associated with good flying weather as they have been dried in the lower levels by the continual down-slope progression from the mountains. The one exception to this is when the westerly wind is due to the wrap-around flow from a cold low to the east or northeast of Cold Lake. In this case, there is an abundant supply of moisture and instability. A persistent easterly flow is gradually forced upslope and is more likely to give lower stratus or fog, but even this is mitigated to a great extent by the presence of a small sharp ridge rising 200 feet just to the east of the military base. This ridge acts as a block and can often keep the stratus scattered at the airport, or at least raise it up a bit, before reaching the observing site. So, in essence, the Beaver River Valley helps to keep the weather at Cold Lake suitable for low-level operations in the absence of other weather influences.

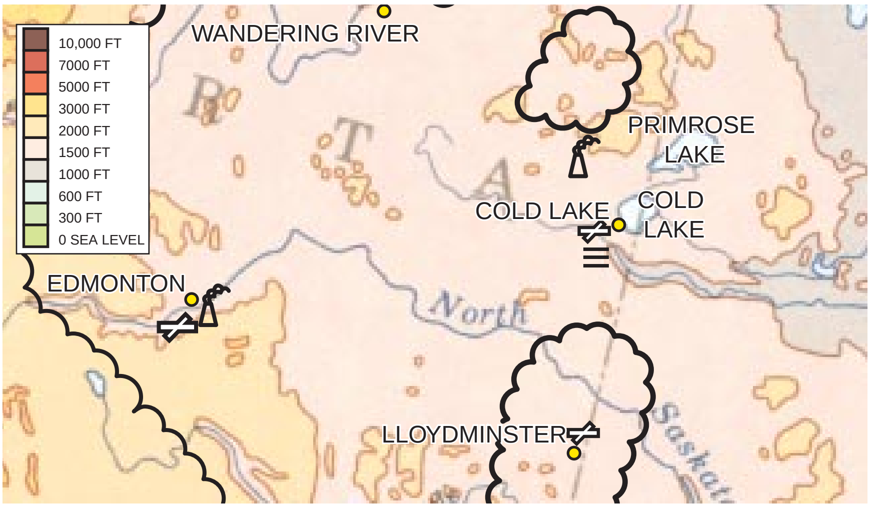
Cold Lake, the nearer of the two lakes, is about 5 miles northeast of the airport site. It acquired its name because an unusual depth, nearly 300 feet at maximum, keeps the water temperature much colder than that of surrounding lakes. Primrose Lake is a further 20 miles to the northeast and is much shallower. These lakes create an abundant moisture supply for stratus and fog formation, especially when the wind flow is from the northeast quadrant and, conversely, the lowest occurrence is when the wind flow is from the southeast. Fortunately, a northeasterly flow is one of the least common wind directions for this site.

The greatest influence from Cold Lake, and to a much lesser extent Primrose Lake, is felt in the fall and early winter. At this time, the lake water is still retaining a great deal of warmth from summer heating while the air above it is becoming progressively cooler. Any northeasterly flow will become saturated in the low levels bringing stratus, fog, drizzle, freezing drizzle, or even snow to the airport. This is further enhanced by the slight upslope component of this flow. If the northeasterly flow is particularly cold, the relatively warm water can create low level instability leading to the formation of cumulus and towering cumulus that can give localized heavy snow squalls over the airport. Poor flying conditions tend to peak in November and then come to a halt in December, when Cold Lake completely freezes over. Primrose Lake freezes over much earlier.

The area around Cold Lake, being part of a Prairie climatic regime, is susceptible to summertime convection, but there are two effects that tend to lessen the number of storms that pass over the airport itself. First, there is a preference for convection to be initiated over the higher and warmer terrain on either side of the valley, where there also tends to be abundant moisture from small lakes and evapotranspiration from vegetation. However, once the cells start to move over the river valley, they are often weakened, or dissipated, by the downslope flow and the relatively cooler air that is pooled in the valley. Second, the waters of Cold Lake also act as a dampening force on local convection. The cooling effect of the water on the lowest level of the atmosphere almost completely inhibits convective processes on warm summer days and a clear hole can be seen over, and downwind, of the lake. The Mostoos Hills, just northeast of the lake, form another preferred region of convective development due to their elevation and many small moisture sources. However, the dampening effects of Cold Lake stand as a barrier between this convection and the town, proving to be particularly beneficial for the town and airport. Note that this effect is reversed in the cooler fall months when the open lake acts to heat the air above it.

There are a couple of man-made weather influences that can affect Cold Lake and its surroundings under the right conditions. A large oil refinery is situated 13 miles to the north-northwest of the airport and injects a great quantity of heated water vapour into the air. In the winter months, this is favourable for the formation of stratus and ice fog. However, this phenomena does not often reach the airport as a northeasterly flow is rare. More common at the airport on extremely cold winter days is the formation of ice fog, due to water vapour emissions that result from frequent jet activity, and a steam plant situated on the Canadian Forces Base.

Edmonton to Lloydminster



Map 4-13 - Edmonton to Lloydminster

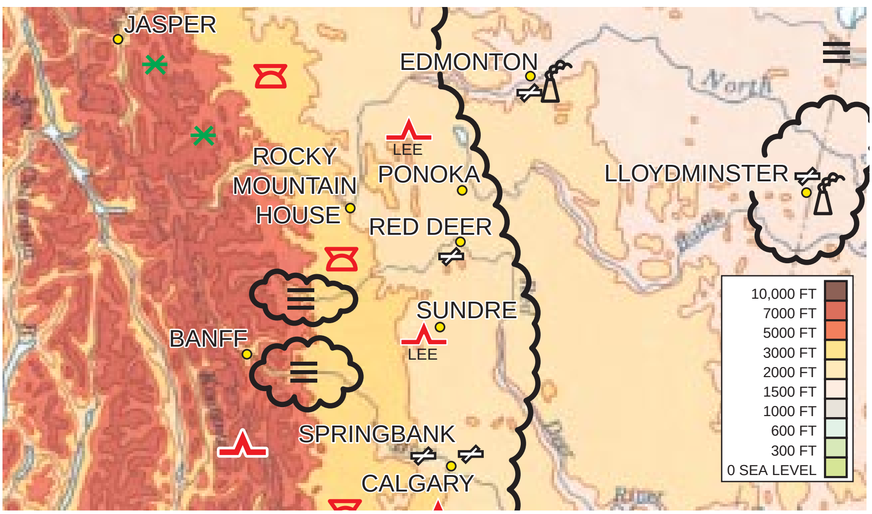
The terrain from Edmonton to Lloydminster slopes gradually downwards which means that, as with many areas in Alberta, the lowest flying conditions are often produced with a persistent upslope easterly flow. This will occur when a low passes though the southern portion of the province, or when there is a well developed and stationary ridge over the eastern Prairies. These conditions can occur at any time of the year but are most frequent in the fall, with the greatest amount of fog occurring in October, November and early December, when lakes are generally open. When the prevailing winds are west to northwesterly, which is the most frequently occurring wind direction for this area, flying conditions are generally good.

The town and airport of Lloydminster are situated on relatively high ground between the North Saskatchewan River, to the north, and the Battle River, to the south. These rivers can supply sufficient moisture for fog and stratus to form in their valleys, especially in the spring and fall, but this tends to stay confined within the valleys and does not often reach as far as Lloydminster. Most of the lakes in the vicinity are too small to have an effect but the Big Gully Lakes, 10 miles east of Loydminster, provide an extra boost of moisture to stratus that is heading towards the airport in an already upslope easterly flow. Some purification ponds are situated two to three miles to the northeast of the airport, and these can create fog and stratus over the runway in a northeasterly flow.

There is a north-south ridgeline through Kitscoty, about 16 miles west of Lloydminster. In a westerly flow, fog and stratus will stay to the west of this ridge allowing Lloydminster to be clear while Vermilion, 35 miles west of Lloydminster, is immersed in fog. The reverse is true in an easterly flow where Lloydminster will be in fog, while Vermillion is clear. This effect is most apparent during the fall.

There are three industrial plants in and around Lloydminster: an oil refinery, a heavy oil upgrader and a canola oil refinery. All three of these contribute condensation nuclei to the atmosphere and enhance the development of low cloud, especially in the fall and winter.

Edmonton to Calgary via Red Deer



Map 4-14 - Edmonton to Calgary via Red Deer

Flying southward from Edmonton to Calgary, there is a continual increase in elevation from 2,300 feet ASL in Edmonton to 3,700 feet ASL in Calgary. There is also higher land on the west side of this flight path as the elevation increases towards the foothills, so any flow from the north through to the east has an uslope component. Synoptic features such as cold lows or lee troughs, which usually produce an easterly surface flow across this route, can result in poor conditions at any time of the year, particularly during the fall and winter. Also, a flow from the north to northeast produces a band of stratus that will typically extend from the foothills to the Ponoka area and southeastward. November is the worst month for flying between Edmonton and Calgary, as there is a high frequency of events of fog, snow flurries and icing from freezing rain. The output from automatic weather stations at Rocky Mountain House and Sundre can be used to fill in extra information for conditions along this route, but since Rocky Mountain House is situated up against the foothills, it is not always a good indicatpr of what is happening further east. The observation from Sundre, however, can be quite indicative of the weather conditions along the southern portion of this route.

The city of Red Deer and the Penhold Airport are in the valley formed by the Red Deer River and are further situated in a bowl-like depression within this valley. Because of this, the airport is sheltered from most wind directions and often reports much lighter winds than would otherwise be expected. It also means that low cloud will tend to linger at the airport, sitting in the sheltered depression, long after the rest of the area has cleared. The Red Deer River flows from south to north, just to the west of the airport. Both the river and the small Dickson Reservoir to the southwest are open (at least partially) throughout the year. Cool weather in the fall and early spring, combined with moisture from these two sources, can produce fog which then drifts across the field to the runways. This phenomena is often associated with a northwesterly flow which gains an extra dose of moisture from Sylvan Lake. The fog starts overnight and generally persist till mid-morning.

If conditions are poor in Red Deer, then they generally worsen southwards towards the Olds-Didsbury area due to the increase in elevation. This area is also quite open and prone to drifting and blowing snow in the winter. Because of Red Deer's sheltered position in a valley, it is advisable to use all other sources of information, such as the Sundre auto weather station, when flying southward to Calgary.

Chinooks are common in the Red Deer/Calgary region. Thorough discussions of this phenomenon can be found in Chapter 3 and at the beginning of this chapter.

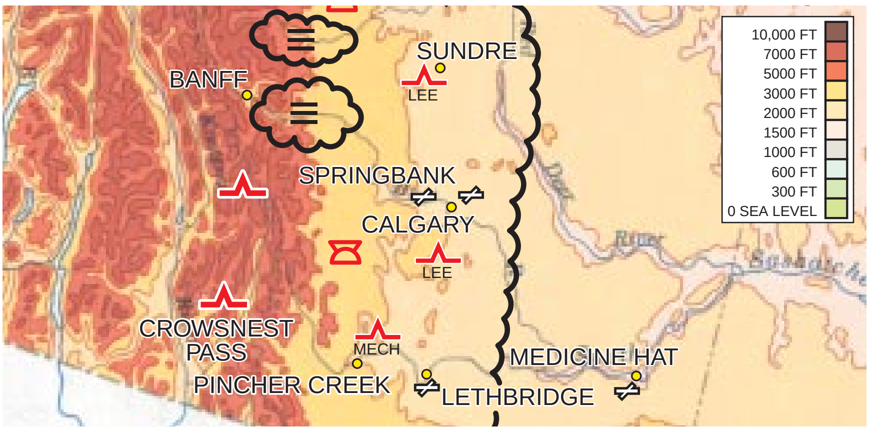
The foothills, stretching along the west side of the flight path between Edmonton and Calgary, are a favoured region for convective initiation on summer mornings. These cells move away from the foothills during the afternoon and affect points along the flight path. The region between Red Deer and Edmonton generates a great deal of activity, particularly in the Lacombe/Ponoka area and the Innisfail/Crossfield area. Because of its closer proximity to the foothills, Red Deer is more likely to experience thunderstorms than Edmonton. In a northwesterly flow, the cells moving towards Red Deer will often stick to the higher ground to the west and head south towards Innisfail. However, the cells that do track across Red Deer eventually move over the higher terrain of the Wild Rose Ridge, southeast of the town, which provides a further impetus for their development. Sometimes in a northwesterly flow, thunderstorms that move into the Alder Flats/Rimbey area, to the northwest of Red Deer, are slow to leave and produce low ceilings and heavy rainfalls over the area.

Foothills thunderstorms are frequent producers of hail, squall lines and, occasionally, tornadoes. Altocumulus Castellanus (ACC) observed early in the morning is a good indication that convection will develop later in the day. Two weather radars, one at Strathmore and the other at Carvel, are used to monitor this development. Red Deer is situated at the halfway point between the two installations but, unfortunately, near the limit of coverage of both. Because of this, the information over the Red Deer area is less detailed.

Lee wave turbulence is frequent in this region up to 8,000 to 10,000 feet when a moderate or stronger westerly flow exists across the mountains. Occasionally, this turbulence can be identified by the presence of lenticular clouds, but this is not a necessary condition for its existence.

From Didsbury southward, the climate becomes drier and the amount of agricultural land increases. Dust storms are possible, especially in the spring and fall when the winds are stronger and crops do not protect the land. These storms can begin anywhere beyond 30 miles east of the mountains.

Calgary, Springbank Area and Westward



Map 4-15 - Calgary, Springbank and westward

This is yet another area in Alberta where any flow with an easterly component has the potential to produce fog, stratus, and drizzle, especially in the spring and fall. This easterly flow, common when there is a low pressure area sitting near the US/Alberta border, will create a region of stratus extending 50 to 110 miles east of the Continental Divide, sometimes as far east as Beiseker, 30 miles east of Calgary. A few occasions have been noted when the stratus edge will sit between Calgary and Springbank but, as a rule of thumb, whenever there are low ceilings in Calgary, even lower conditions will exist in Springbank, due to the rise in elevation to the west. The higher terrain of Scottlake Hill, located about 10 miles west of Calgary, opens up first in these stratus situations.

Sometimes the Calgary Airport will report stratus when Springbank and other surrounding areas have none. This is most likely due to the moisture and large quantities of particulate matter released into the atmosphere by the industry in and around the city. Conversely, unexpected stratus sometimes occurs at Springbank when there is a northerly flow coming off Cochrane Hill.

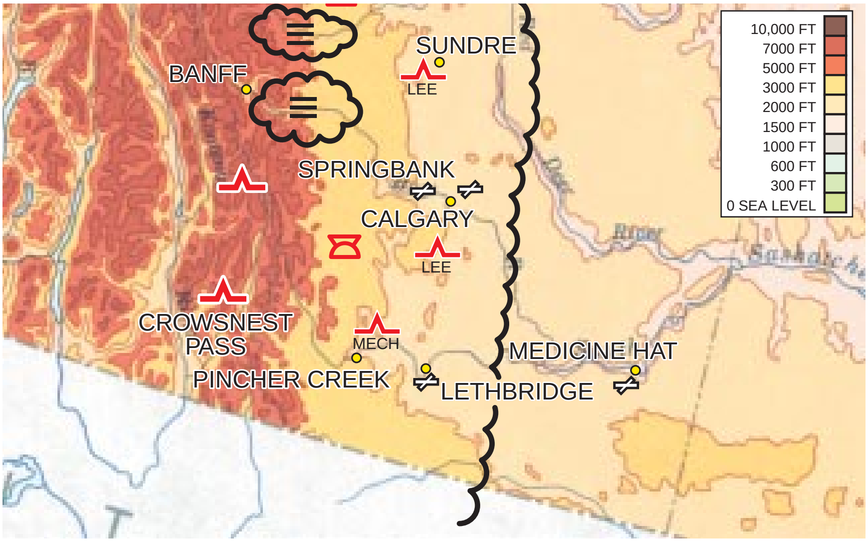
The "Okotoks Hole", an anomalous and puzzling area of clearing within 10 to 15 miles of the town of Okotoks, just south of Calgary, is often observed when Calgary and Springbank are both immersed in stratus. Since this normally happens with an easterly flow, there may be a local subsidence circulation off a small range of hills that is responsible for this phenomenon.

In the summertime, convection can be initiated anywhere in the foothills to the west of Calgary. One common source region is the Cochrane/Ghost Lake/Water Valley area. Cells that form here move southeastward in the Bow River Valley and from there will move either along the Cochrane Ridge into northwest Calgary, or along the Elbow River into southwest Calgary. Other source areas can be the Lake Minnewanka Valley or the Banff/Canmore region, and thunderstorm cells that form as far south as the Livingstone Range can still move northeastward towards Calgary. Convection that forms in the foothills 50 to 60 miles to the southwest of Calgary will frequently dissipate before reaching the city unless some upper support is present and, even in this case, it will generally remain south of Calgary, moving into the Bow River valley and following it eastward.

A strong west or southwesterly flow aloft brings the likelihood of lee or mountain waves over this region. Downdrafts of up to 3,000 feet /minute through Kootenay, Jasper, Bow Valley and Banff park areas are common, producing moderate or severe turbulence up to 14,000 feet in a zone which can extend 60 to 110 miles east of the Continental Divide. This flow is also associated with strong wind shears at the Calgary and Springbank airports. Mountain waves can often be identified by the presence of Altocumulus Standing Lenticular clouds (ACSL), cap clouds, rotor clouds or the "arch" phenomena generated by the common Chinook winds. The strong winds associated with the Chinook first appear in the Bow Valley and then generally take two to three hours to reach Springbank. About an hour later, they reach Calgary. Although the Chinook will improve ceilings and visibilities, severe wind shear and turbulence are always a hazard.

Flying westward into the Bow Valley, Mount Yamnoska is the first mountain encountered where moderate to severe turbulence is frequently reported. Significant turbulence reports are also common flying at 9,500 feet near Rundle Mountain. At low levels, the ride can be equally dramatic with strong surface winds giving low-level turbulence that is often moderate or greater. This turbulence tends to begin just to the east of Canmore between Morley and Exshaw.

South of Calgary



Map 4-16 - South of Calgary

The weather along the flight path from Calgary to Lethbridge is susceptible to many of the same influences as Calgary and areas north. Again, any prolonged easterly flow will eventually blanket the entire area in stratus due to the westward increase in elevation. This flow is most frequently created by a low over the northwestern US. It can happen at any time of the year but is less common in the summer. In the winter, this pattern will often bring snow which appears first in an east to west line over the Milk River Ridge and then progresses northward into Lethbridge.

The airport in Lethbridge is located south of the city to the southeast of the Oldman River, which is fed by a number of tributaries in the area. By far, the most frequent wind directions at this location are west and southwest. These are downslope winds and, when they are blowing, Lethbridge generally enjoys fine weather with clear skies. However, mechanical turbulence is a genuine concern for pilots flying in this area. The predominantly westerly flow is usually quite brisk and, if it attains speeds of 25 to 30 knots, moderate to severe mechanical turbulence can occur up to 4,000 feet above ground level. Even with a westerly flow of less than 20 knots, moderate turbulence can also be experienced directly at the edge of the Oldman River Valley and over the coulees to the west, although these effects will only be felt in the lowest levels.

Chinooks are very common between Lethbridge and Calgary. The weather at any location will change abruptly as the Chinook passes eastward, going from cold temperatures and low overcast skies to warm, sunny and windy conditions. As always, severe turbulence is cause for concern with a Chinook.

In the summer, most convective cells in the Lethbridge area form in the foothills to the west or southwest and move northeastward during the day. Because this region is generally very dry, thunderstorms will often generate microbursts which produce strong surface gusts. Indeed, the entire southern section of Alberta is a favoured region for microburst activity.

Strong northerly winds will usually only occur in Lethbridge in association with a cold frontal passage. In these cases, there is little to no weather, and the passage is mostly marked by a few hours of very gusty north to northwest winds.

Ice fog occurs several times during the winter in Lethbridge. It requires light winds or calm conditions, a stable atmosphere and temperatures colder than -25° C. Events have been known to last for two to three days. During these episodes, diurnal improvements are minimal and a pronounced reduction in visibility is usually experienced during the evening hours.

Although Pincher Creek is known for its high frequency of good flying weather, wind is often a big concern. As with Lethbridge, the most frequent wind direction is from the west, and this direction also brings the highest wind speeds. Pincher Creek is situated at the east end of the Crowsnest Pass, which is famous for strong flows that channel through it. For a pilot looking to fly this route, there are a few observations that can help determine the strength of the flow at any time. Pincher Creek, at the east end of the pass, can be quite indicative of the pass winds, as well as the Crowsnest auto station half way through, and Sparwood, British Columbia at the west end of the pass. Winds are frequently very strong all the way through the Crowsnest Pass and into Pincher Creek, weakening somewhat by the time they reach Claresholm, Fort McLeod and Lethbridge. With these strong west winds, turbulence is often experienced in the pass up to 10,000 feet.

The severity of turbulence at Pincher Creek is not always directly correlated to the wind speed. Because the terrain is so irregular, there have been occasions of little turbulence with very high wind speeds and excessive turbulence with relatively weak winds. One phenomena that Pincher Creek is susceptible to, and one that increases the likelihood of turbulence, is the formation of a "rotor" circulation at the base of the hills. This type of flow occurs when the wind coming down off the mountains is strong enough that a portion of it bounces off the land and returns back up the lower part of the hill. This intense rotation of air is occasionally made evident by the existence of a rotor cloud at the base of the hill but, since the air in the Pincher Creek area is often extremely dry, it is rare that such a cloud will form.

Thunderstorms tend to form from enhanced heating along the slopes of the ridges to the west of Pincher Creek, but they frequently dissipate as they move eastward. Because of this, Pincher Creek and Lethbridge have a relatively low number of thunderstorm occurrences annually when compared to many other Alberta stations. Due to the dryness of the region, whenever thunderstorms do occur, they are typically high-based and precipitation often evaporates before it reaches the ground (virga). This is the primary mechanism that produces dry microbursts and their associated strong winds.

There have been occasions where the stations at Sparwood and Pincher Creek, on either side of the Crowsnest Pass, are reporting clear skies whereas, in the pass itself, severe thunderstorms will force pilots to turn back.

The area from Lethbridge to Medicine Hat does not differ much from the rest of southern Alberta. The land slopes upwards to the west, so any feature producing an easterly flow has the potential to generate low ceilings over the upward sloping terrain. Such a flow usually comes from low pressure systems moving northeastward over the northwestern US or stay just to the south of the US/Alberta border. The resulting stratus band will often begin just to the east of Medicine Hat. Here, the nature of the flow changes from downslope (off the Cypress Hills) to upslope. The climate in this area, much like the rest of southern Alberta, is extremely dry, so it is only during the fall or spring that such a flow can create widespread low ceilings.

All of southern Alberta is susceptible to the effects of the Chinook, but its potency diminishes as the winds spread further east. Usually, the lee trough that forms in advance of the Chinook will be somewhere near Lethbridge, leaving areas to the east in a cool, moist, southeasterly flow. The Chinook and lee trough almost always progress eastward but only rarely reach Medicine Hat, and even then they are generally quite weak, having been displaced that far from the mountains.

The Medicine Hat Airport is situated southwest of the town, just south of the valley formed by the South Saskatchewan River. The predominant wind direction for this site is from the southwest with many flows deflected around the Cypress Hills and down the valley formed by Seven Persons Creek. The area is relatively sheltered and winds are rarely as strong as at Lethbridge. Often, though, when winds are reported from the southwest at about 10 knots at the airport, they can quickly increase to westerly 25 knots, or more, just a short distance above the surface. It is also possible to have lee wave turbulence as far eastward as Medicine Hat.

When a migratory low passes eastward through the Medicine Hat area, the winds will shift to northwest as the associated cold front sweeps southward in its wake. A northwesterly wind is a cross wind at the airport, and any northwest flow 30 knots or greater makes it difficult to use the main runway.

The South Saskatchewan River, as well as Murray and Rattlesnake Lakes, are local sources of moisture for the formation of stratus and fog. In general, however, it is just too dry in this part of Alberta to see these conditions at any time other than during the fall season and occasionally in the spring. There are also two local industrial concerns, a rubber plant and a fertilizer plant, that produce particulate matter and heat which affect conditions in the winter. They can, under a cold winter inversion, produce ceilings of 500 to 1,000 feet, but the visibility is generally good. This cloud is highly localized and may only cover one to two square miles and be 200 to 300 feet thick. When ceilings are below 2,500 feet, the Cypress Hills to the southeast are not visible.

Medicine Hat does not have a great frequency of thunderstorms, but some can be generated on the flat terrain to the west on hot unstable days. Sometimes thunderstorms will cross the border from Montana, and these are usually quite intense. Large and slow moving thunderstorm cells are one of the few phenomena that will generate conditions with low ceilings and poor visibility in the area around Lethbridge and Medicine Hat during the summer, and even this situation tends to be short lived. The typical summertime air mass is just so dry that copious amounts of moisture are necessary to saturate the lower levels.

Weather of Saskatchewan

Map 4-17 - Topographical overview of Saskatchewan

Saskatchewan's distinction as the sunniest and driest of all the Canadian provinces makes it the most truly continental as well. There are no mountains, large bodies of water or climatic irregularities to moderate the extremes allowing for hot summers, cold winters and large diurnal temperature differentials. The land is one vast, glacially carved plain sloping gently to higher elevations in the west. The most southern third of the province is classified as true prairies with open grassy plains, rolling hills and broad river valleys. It is a highly agriculturalized region owing its productivity to the deep layer of glacially deposited fertile soil. This gives way to the mixed forest of the boreal plain of central Saskatchewan, where substantial deposits of sandy soil over top of the Precambrian Shield support vigorous forest growth. The forest becomes mainly coniferous further north, as the soil cover becomes progressively thinner and coarser and barely covers the rock below. Eventually the boreal plain transforms to boreal forest, which is characterized by sparser and more stunted coniferous growth, muskeg, frequent bare rock outcroppings and numerous shallow lakes and streams.

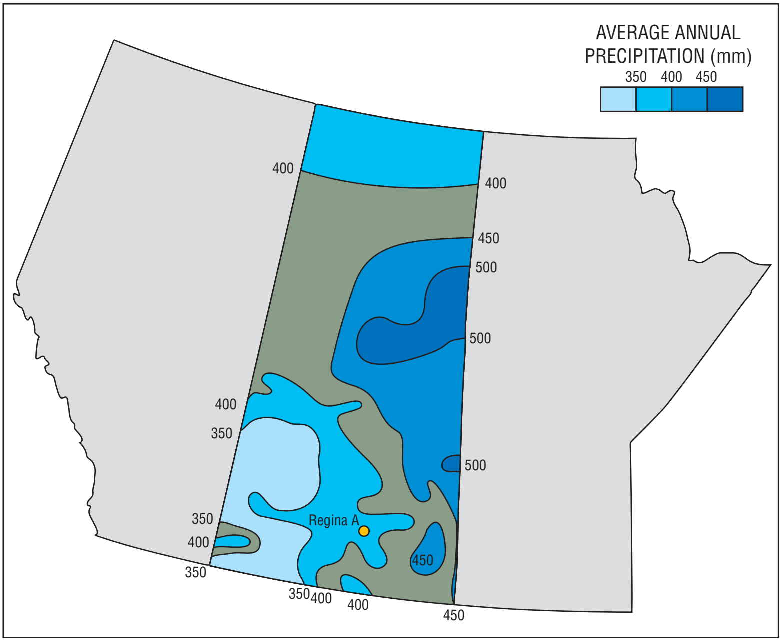


Fig. 4-4 - Annual Precipitation (mm)

The climate across Saskatchewan does not vary greatly. The south is classified as cold temperate meaning it has cold winters and short warm summers, while the northern section is sub-arctic, with the main difference being slightly longer winters and even shorter summers. Annual precipitation is not great in any area and varies from a low of just over 300 mm in the southwest to a high of just over 500 mm in the east/central portion. Most remaining locations receive around 400 to 450 mm per year. Again, this unvaried moisture regime is explained by Saskatchewan's land locked position in the middle of the continent and its relatively uniform topography.

It is the Cypress Hills in the extreme southwest that boast the highest elevations in Saskatchewan at near 4,600 feet, but this is just a rather modest 2,000 feet above the surrounding terrain.

Saskatchewan, as with the rest of the prairies, lies under the zone of mean westerly winds, and weather disturbances generally move from west to east. However, because it is physically open in all directions, it can be the recipient of any number of air masses; cold dry Arctic air from the north, cool and modified Pacific air from the west and southwest, and warm, somewhat moist air from the American south. These air masses will meet and clash over the province frequently generating storms along their frontal boundaries, especially in the spring. This provides a benefit to Saskatchewan agriculture as the maximum precipitation generally falls in the month of June giving a boost to crops during the early part of the growing season. But these storms are not frequent enough to rescue Saskatchewan from being the driest of all the provinces, and even when a moister flow makes its way eastward from the Pacific it has dried considerably by the time it arrives in Saskatchewan.

The heart of the dry country is found over the southwest in the South Saskatchewan River basin, an area sometimes referred to as "Palliser's Triangle" after the man who first settled and explored the region. A climatological study of the area reveals that its dryness can be explained by a combination of characteristics of the mean upper atmospheric and surface circulations that all work together to limit the available moisture. This region is frequented by fewer low pressure systems and more highs than areas to the north and south. In the summer, a time when the rest of Saskatchewan reliably receives the bulk of its annual precipitation, the mean upper flow over the dry belt of Palliser's Triangle acts to deflect the pacific storms well to the north.

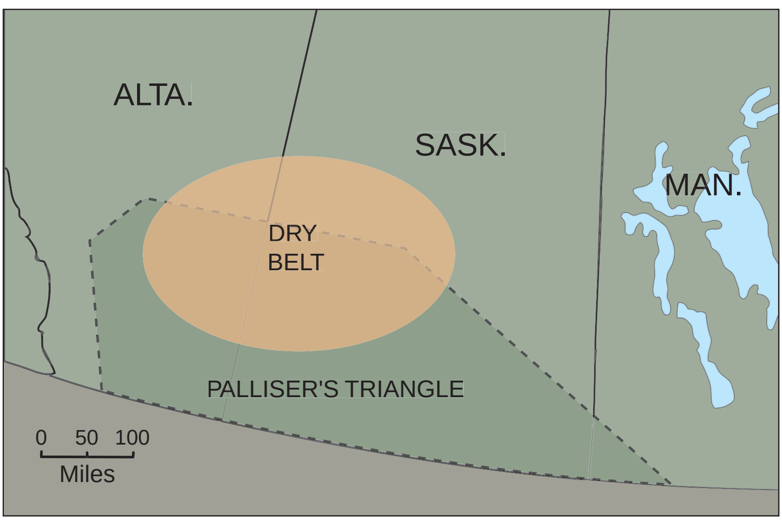


Fig. 4-5 - Palliser's Triangle

(a) Summer

Saskatchewan summers have several characteristics to distinguish them from those of the other Canadian provinces; they are the sunniest; they are the hottest and driest; and they have the greatest diurnal temperature variation, averaging 14 degrees a day. The records for the highest temperature, 45°C, and the most hours of bright sunshine, 2,537 annually, both belong to southern Saskatchewan. Although there is on average little precipitation, the bulk of it is received during the period from May to August, with the wettest month generally being June. This is useful for southern agricultural areas, especially since the harvest months of September and October are noticeably drier.

The generally sunny conditions are occasionally disrupted by the presence of a cold low, the only significant pattern producing large scale, long lived poor flying weather in the summer months. The frequency of these cold lows peaks during the summer, contributing to the monthly precipitation maximum in June. Also, as with Alberta, the worst flying conditions are found over the north quadrant of the low where north to northeasterly winds are forced upslope, producing lower ceilings and visibilities.

Saskatchewan is also noted for violent summer thunderstorms, with the month of July being the most convectively active of the season. There is seldom a summer day without a thundershower somewhere over the province, especially in the southeast where there is an average of 25 thunderstorm days a year. The rain accompanying these storms is usually intense and brief. One particularly violent storm dumped 250 mm of rain in one hour over Buffalo Gap in southern Saskatchewan setting a new Canadian record. Small hail is frequent, and each summer there are about 10 to 15 severe hailstorms that inflict considerable damage. They can occur anywhere but are most frequent over the southwestern dry belt.

Convection in Saskatchewan is most frequently of the airmass variety which is initiated by daytime heating. In this wide-open area, visibility is excellent and convective buildups can be seen at great distances. It is possible to get nocturnal thunderstorms throughout the province, but they generally require some large-scale upper atmospheric support to keep them alive. Sometimes, the early morning period can produce a "surprise storm" over areas that were convectively active the previous day. This happens when residual mid level moisture from a previous thunderstorm lingers overnight and becomes destabilized by morning by radiation cooling at the cloud top. The presence of Altocumulus Castellanus (ACC) cloud is a definite indication of this process.

Convective currents provide an environment for significant turbulence, up to 9 to 10 thousand feet on warm sunny summer days, even when the air is clear. These currents are accentuated along the preferentially heated slopes of hills and valleys and over freshly tilled and summer-fallow fields.

Evapotranspiration from crops is a significant source of low level moisture to feed cell development during the convective season. It peaks during the growing season of June and July and then diminishes as the crops mature in August. The amount and severity of convective activity correlates well with this trend.

Aside from the obvious risks of lightning and hail, violent and damaging winds are a constant concern for aviation interests during the convective season. Tornadoes are, of course, the most violent of these wind events with an average of seven confirmed sightings in the province each year, but these episodes are usually localized and generally last less than an hour. Full-fledged tornadoes are associated with large violent thunderstorms, or supercells, and because of their many hazards are completely avoided by pilots. However, a much more common occurrence, and one that is harder to avoid, is the "cold core funnel" which comes with its own set of dangers. These funnels are usually associated with the cold lows when the cold air moves over the warm land. These funnels rarely touch ground, and are certainly less dangerous than a full tornado, but they do indicate the existence of considerable turbulence. They are often associated with large areas of broken to overcast cumulus and stratocumulus clouds with ragged bases and producing scattered showers. Within this area, a particularly strong updraft can produce a small vortex that appears as a funnel. Cold core funnels are most common in spring and fall.

It must be noted that strong gusty winds and severe turbulence can be associated with any convective cell, even the seemingly innocuous. Downdrafts from cells supporting precipitation also produce a great deal of surface gustiness as they spread out upon impact with the ground and, if cells are large enough or organized into an area, gusts fronts can result. Microbursts are of special concern in Saskatchewan because of the unusual dryness of the atmosphere. In a dry environment, cell bases are invariably quite high. Precipitation from these cells usually evaporates before it reaches the surface but still entrains air, drawing it downwards. Evaporative cooling accelerates this downward motion until the air impacts with the earth, forcing it to spread out horizontally.

Although the Canadian coastlines are certainly windier than Saskatchewan, this province is still famous for its "Prairie Blows." The lack of any topographic features to impede the flow and create sheltered areas in part explains this reputation. In the winter, the mean flow is northwesterly, but this changes to southeasterly in the spring with April and May usually recorded as the windiest months. During the spring and summer period, it is not uncommon to get a very hot and dry southerly flow from the American southwest. These winds dry up the surface moisture over southern agricultural lands and produce reduced visibility in blowing sand and dust an average of 15 hours a year, but these events diminish after May when the planted crops act to stabilize the soil.

(b) Winter

Winter in Saskatchewan is bitterly cold and long with less than half of the year being free from freezing temperatures. Snowfall amounts are not great, varying from an annual average of 100 cm in the south to 175 cm in the north, but it is an important moisture source for groundwater reserves. Good flying conditions are the standard with periods of clear, cold and very dry weather often lasting for days on end. The prevalent wind direction, both at the surface and aloft, is from the northwest and is associated with frigid continental arctic air that supports little moisture making low ceilings and visibility unlikely. These northwesterlies are, however, generally stronger in the south than the north, and this coupled with the wide-open terrain can produce locally reduced visibility in blowing snow.

The transition period when cold arctic air moves in from the north to replace a more temperate airmass over the Prairies is known as an "arctic outbreak." Generally, along the leading edge of this cold air, flurries will occur and flying conditions will be marginal for a short time. Of equal concern to aviation are the gusty northwest winds on the cold side of the outbreak which will likely produce significant mechanical turbulence in the low levels, as well as giving blowing snow, especially in areas where there has been recent snowfall.

Blizzards are the most perilous of all winter storms in Saskatchewan. Snowfall is not necessarily great, but visibility is reduced to near zero due to a combination of snow and blowing snow. To qualify as a Saskatchewan blizzard, the visibility must be reduced to less than 5/8 of a mile for at least four hours. January is the most likely month for these storms to occur, and they occur most frequently over the southwest where there is an average of two full-fledged blizzards a year.

(c) Transition Periods

Early springtime brings an increase in the frequency of poor flying conditions to many areas of Saskatchewan. This is a period when the mean surface flow starts to turn towards the southeast, and any flow with an easterly component is upslope over large parts of the province. Stratus formation is aided by abundant low level moisture supplied by melting snow and lakes that are just starting to open. Once the long warm days of summer set in, poor flying conditions are quite rare as all levels of the atmosphere become progressively drier. The main exception to this is the occasional passage of a cold low which can give low flying weather in the easterly flow to the north of its centre.

Spring is quite a windy season and mechanical turbulence is usually present in the lower two to three hundred feet of the atmosphere if winds attain speeds of more than 15 knots. This turbulence is seldom severe but is often enough to make flight rough for smaller aircraft.

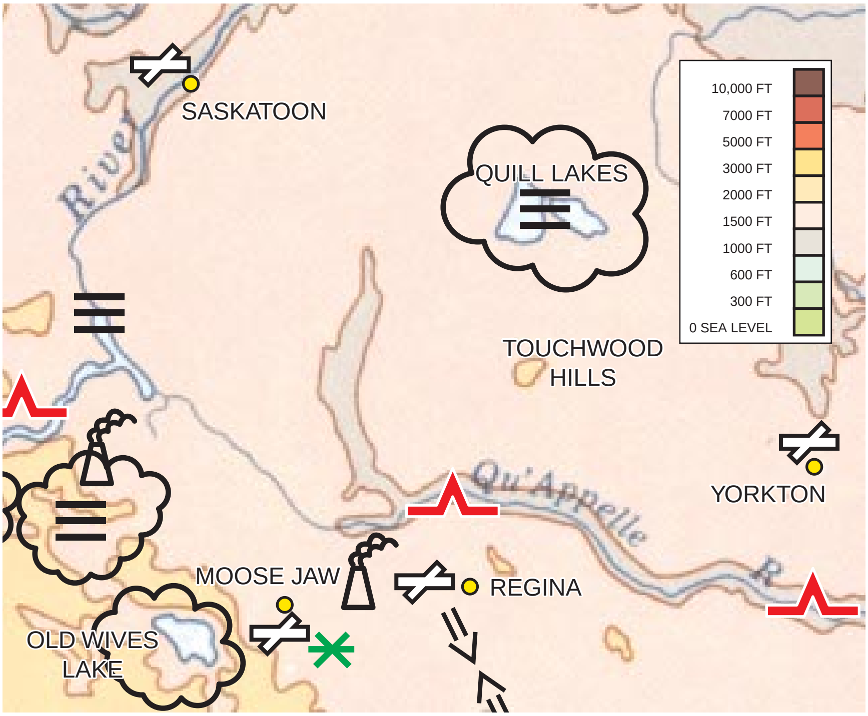
Fall, at least in the southern part of the province, is quite dry and pleasant especially in the first half. In the north, there is an increased likelihood of stratus as there are numerous glacially formed lakes to provide low level moisture. A few of the larger lakes in the northern half of Saskatchewan have enough surface area to generate snow streamers if the air flowing across their open waters is cold enough. This usually requires winds from the north or northwest.

Local Effects for Southern Saskatchewan

This area of the province is, for the most part, a large expanse of gently rolling agricultural land interrupted by a few ranges of larger hills, and by sharp river valleys, sometimes falling several hundred feet below the surrounding terrain, such as with the Qu'Appelle Valley. The main exception to this is the more rugged terrain over the southwestern corner of the province, south of the Trans-Canada Highway. This area's principal features includes the Missouri Coteau south of the South Saskatchewan River, the Wood Mountain Hills shared with the U.S., and the eastern Cypress Hills. However, it must be noted that Saskatchewan's topographic features, that at first seem insignificant, can be quite influential when considering weather in the very low levels. They induce small changes in the surface airflow that can create areas of turbulence and wind shear or create regions of frequent inversions, such as with the Souris Basin. Most ranges are high enough to give local very low flying conditions when ceiling heights in the area are marginal. They are also favoured sites for early day convective initiation as updrafts can be induced or enhanced by differential heating, orographic lift, and surface convergence.

The motion of synoptic scale systems, such as cold fronts, tend to be fairly predictable as they approach and cross the area, as there are no large topographical features acting on them. Simple airmass convection can also be fairly predictable. A visual assessment of the strength of early morning cumulus and towering cumulus development will often speak for the rest of the day.

Regina to Saskatoon



Map 4-18 - Regina to Saskatoon

A broad, level basin formed by the Souris and Moose Jaw Rivers and Wascana Creek, is the primary topographic feature influencing the weather in Regina; more accurately for the entire corridor from Minot through Estevan, Weyburn, Regina, Lumsden and, at times, areas further northwest. Southeasterly flows channelling through this valley frequently advect areas of stratus and fog, which have developed upstream, into the Regina area. Although this phenomena can occur at any time of the year, it is most common from late fall to early spring. It is normally associated with the eastward advance of a low pressure system over Montana and the Dakotas or southern or central Saskatchewan, or with a building ridge of high pressure over Manitoba. Either of these synoptic set-ups provides the persistent upslope southeasterly flow needed to generate stratus.

Weather in Regina is estimated to be good about 90 to 95 percent of the time. The most common time of year for extended periods of poor flying conditions is during the late fall transition period (mid October to early November) when lakes are still open. During this time, cold air advancing from the north or northwest picks up moisture as it crosses open lakes. Much of the area can be covered with low cloud. Even if the flow changes to the southeast, the Souris/Wascana effect mentioned above can prolong the problem.

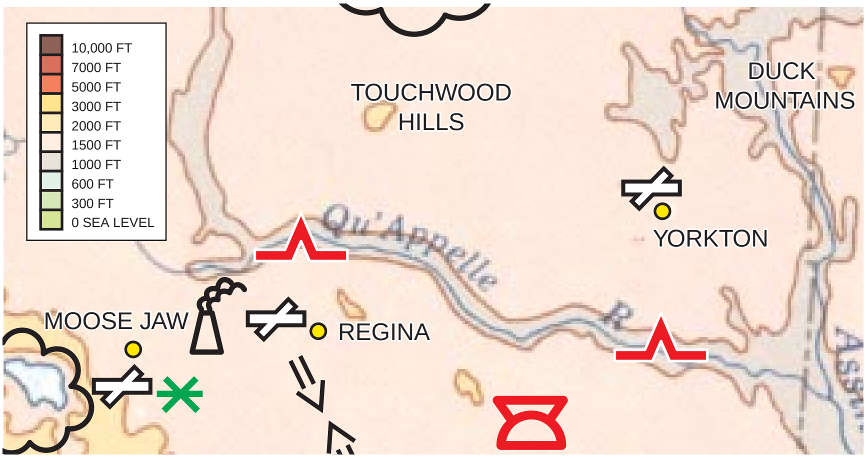
Thunderstorms are common in the area, but those moving toward Regina from the west or southwest have a tendency to split upstream from the city, "following" or developing along the Qu'Appelle Valley to the north and along the western side of the basin southeast of Moose Jaw.

Regina is considered a very windy place by local pilots and is viewed by many to have the most problematic weather, particularly in summer. There are seldom days when winds are calm and most days have gusty winds predominantly from the southeast or northwest. Mechanical turbulence is common up to about 5,000 feet ASL but is seldom severe.

When cold fronts advance from the northwest, Saskatoon and Elbow are good upstream sites to look for signals (changes in pressure, temperature and wind) of a frontal passage. These two sites can be used to anticipate the arrival and severity of the front in Regina.

The path between Regina and Saskatoon covers the open flat agricultural territory of the Souris Basin and the West Central Plains, with Regina situated a mere 240 feet higher in elevation than Saskatoon. Between the two, and closer to Saskatoon than Regina, are the Allan Hills. They are gently sloped and average only 300 to 500 feet above the surrounding terrain, but with an east to northeasterly upslope flow and sufficient low level moisture, stratus can blanket the area with ceilings being lower over the hills than at either the Regina or Saskatoon airport. The fall and early winter months are the periods when this most frequently occurs. When flying between the two points, if conditions are good in Saskatoon but poor in Regina, then the beginning of the stratus is often in the region of the Allan Hills. In fact, weather systems that are passing over the southern prairies will often spread low cloud to the north as far as a line running from around Rosetown to Hanley at the edge of the Allan Hills. Beyond this line, the upslope component of the terrain becomes barely perceptible.

Regina to Yorkton and Eastward



Map 4-19 - Regina to Yorkton

Overall, the terrain is fairly smooth along this route, with a rise in elevation between the Souris/Wascana Basin and the Qu'Appelle River Valley. Once north of the Qu'Appelle, there are regions of higher terrain both to the northwest (the Beaver Hills) and to the southeast (the Pheasant Hills). Ceilings over these hills can be very low when marginal conditions are reported at either Regina or Yorkton, but it is easy to avoid the higher terrain by sticking close to Highway 10, situated in a slight valley between the two ranges. The Qu'Appelle River provides the only distinct relief along the flight path, as it flows in a sharp trench that is roughly 400 feet below the surrounding land surface. Like those formed by most rivers and creeks in the area, the Qu'Appelle Valley trench is contained within a broader drainage system, and turbulence can be present in the low levels when not a problem elsewhere. Winds can shift direction across the valley, forcing pilots to adjust aircraft attitude to stay on course. Convective cloud can be accentuated along the valley as well, and cells tend to follow the lower terrain eastward south of Yorkton.

Yorkton lies in an area of flat land between the Beaver Hills to the west and the Duck and Riding Mountains to the east, near the Manitoba border. Pilots consider the locale to be one of few surprises, topographically and meteorologically.

Yorkton is less windy than Regina, and mechanical turbulence is seldom a significant problem in the area. The flow is predominantly from either the northwest or south-southeast. Flows from the northeast quadrant are quite rare. In the fall months, north to northwesterly winds frequently bring low cloud and fog which is accentuated by the moisture input from Good Spirit Lake to the northwest of the town. Precipitation amounts are also higher on average over southeastern Saskatchewan, as this area is closer to the path of moisture laden synoptic systems moving northeastward from the central and southern U.S. As a consequence, the period when large amounts of low-level moisture are made available due to snowmelt is extended in the spring.

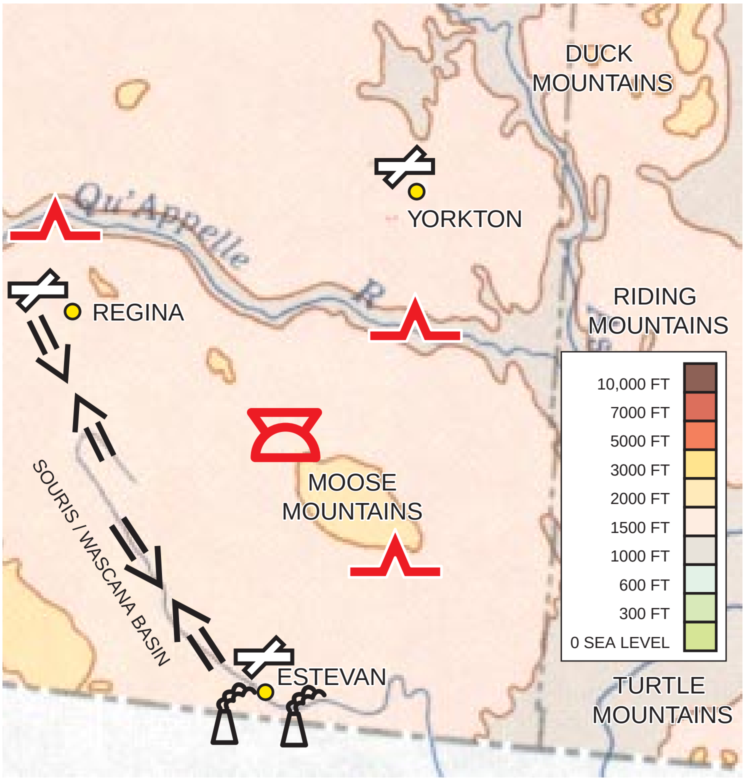
Convective currents are present in clear air on sunny days in the spring, summer and fall, especially over tilled fields, and this causes rough flying conditions in the low levels. In the spring, the snow melts off plowed fields first and the differences in surface heating, due to abrupt variations of albedo, accentuate the updrafts and downdrafts.

Yorkton Eastward

The roughly north-south valley of the Assiniboine River lies just east of Yorkton. Low cloud can pool in the valley especially around the Lake of the Prairies, a long man-made lake that extends north of a dam near Shellmouth. This area is also a common site for enhanced convection in summer.

East of the Assiniboine River, the terrain rises over a series of hills and ranges. Well north of Yorkton, straddling the Manitoba/Saskatchewan border, are the Porcupine Hills, and further south and mostly contained within Manitoba, are the Duck and Riding Mountains. There are several lakes in the area and the surface tends to be moist. Flows from the west are pushed upslope so there can be some deterioration in ceiling and visibility, even if conditions at Yorkton are good. The higher terrain is often shrouded in cloud if marginal values are reported at Yorkton or Dauphin, Manitoba.

Yorkton to Estevan



Map 4-20 - Yorkton to Estevan

As with the path between Yorkton and Regina, the Qu'Appelle River Valley is the main topographical feature enroute. The valley trench is still quite deep at this point, as is that of Pipestone Creek, which joins with the Qu'Appelle north of Broadview. The terrain in this area is fairly complex and susceptible to low level turbulent eddies in gusty wind situations. About 40 miles south of Broadview, the land rises abruptly, about 700 feet, over Moose Mountain and then falls off again into the Souris Basin on the other side. The tops of Moose Mountain are often obscured when low cloud is in the area and there are plenty of small lakes in the region to support and maintain its longevity. Mechanical turbulence is often encountered below 5,000 feet ASL over this higher terrain in strong wind situations, especially those from the northeast.

Annual precipitation amounts are higher over this region than any other area of southern Saskatchewan, the bulk of which arrives in summer when low pressure systems move up from the south carrying warm moist air from the Gulf of Mexico. Higher levels of low level moisture lead to a greater chance of severe convective weather and, indeed, the highest number of thunderstorm days, occur over this corner of the province.

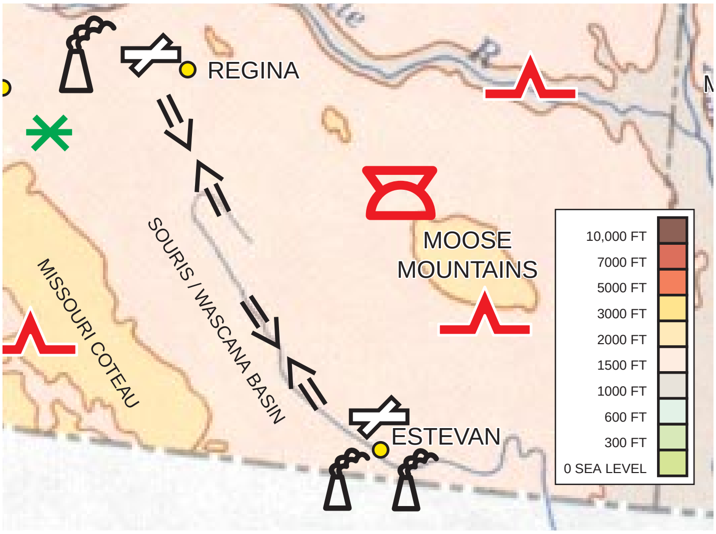
The Estevan Airport is situated about 4 miles north of the town of Estevan which, in turn, lies in an active coal mining area. The provincial electrical utility uses the coal to fuel two large power generating plants in the area. The more modern "Shand" plant lies approximately 8 miles southeast of the airport. The older, larger "Boundary" plant lies about the same distance to the southwest. Both plants are fitted with precipitators which reduce the amount of pollution resulting from coal combustion. However, a huge quantity of water vapour is injected into the atmosphere by these installations each day.

Depending on local atmospheric conditions, this added moisture can cause marked changes in weather conditions across the area surrounding the town and airport. Inversions at any time of the year, but particularly in winter, can trap the moisture near the surface causing local marginal or even lower flying conditions. Reduced visibility in ice crystals is common downwind from the plants on cold winter days and nights, but can also occur when temperatures are higher than those normally associated with the phenomena (usually below -16°C). Southeasterly flows, often already laden with moisture and associated with the poorest weather in the area, are further saturated by the plant discharge, accentuating low cloud and fog conditions.

The most common wind direction is from the northwest, and cross winds often occur over the main runway which is oriented west to east. These flows are also known to bring low cloud and fog to Estevan, particularly in the spring and fall, with a ridge of high pressure building from the north or northwest.

Otherwise, Estevan enjoys a high percentage of good flying days. Winds are the most prevalent concern to aviators, and mechanical turbulence, rarely severe, is common up to about 4,000 feet ASL. Standing lenticular cloud is often present, sometimes at fairly low levels, with strong southwesterly flows aloft over the Missouri Coteau. Convective cloud tends to form upstream in unstable southwesterly flows. Large cells are visible at great distances so severe weather "surprises" are unusual. Convective currents are also responsible for bumpy low level flying conditions in summer, especially over tilled fields.

Estevan - Regina (Souris/Wascana Basin)



Map 4-21 - Estevan - Regina (Souris/Wascana Basin)

The Souris/Wascana Basin is one of the more subtle surface features in southern Saskatchewan but, no doubt because of its overall size, is one of the most important topographical influences on weather conditions in the area. As mentioned earlier, the basin extends from the southeast through Estevan to the Lumsden/Elbow area. It is wider in the south than it is to the north, so southeasterly flows are channelled and accelerated.

The basin is quite shallow, with depths averaging 300 feet below the terrain to the southwest (Missouri Coteau) and northeast (Touchwood Hills - Indian Head - Moose Mountain areas). However, persistent inversions, up to 800 feet deep, are common over the area, especially from late fall to early spring. When an inversion is present, the cold layer is usually moist and stagnant or is being fed by a moist southeasterly low level flow. This causes, sustains, or advects stratus and fog into the area. As a general rule, locations on the southwestern side of the basin enjoy better weather conditions than those sites in central and northeastern areas. When this is the case, winds above the inversion are usually stronger, warmer, drier and from the southwest or west. The inversion is eroded or broken down earlier and rather easily along the southwestern side of the basin by the warm winds subsiding off the Missouri Coteau, thus improving conditions there. However, the shallow cold layer, with its inherent poorer weather, can be quite stubborn over central and eastern sections. Significant directional wind shear is possible near the top of the inversion in this situation, especially when there are reasonably strong southeasterly winds in the cold layer.

With the passage of a synoptic scale low pressure system, there can be locally enhanced precipitation along the "sides" of the basin where winds have an upslope trajectory. This is especially true when systems pass to the south, producing an easterly flow across the basin that is forced to rise up the eastern slopes of the Missouri Coteau. In winter, this can lead to significant snowfalls that, when combined with gusty winds, can produce local blizzard conditions with visibility near zero in snow and blowing snow.

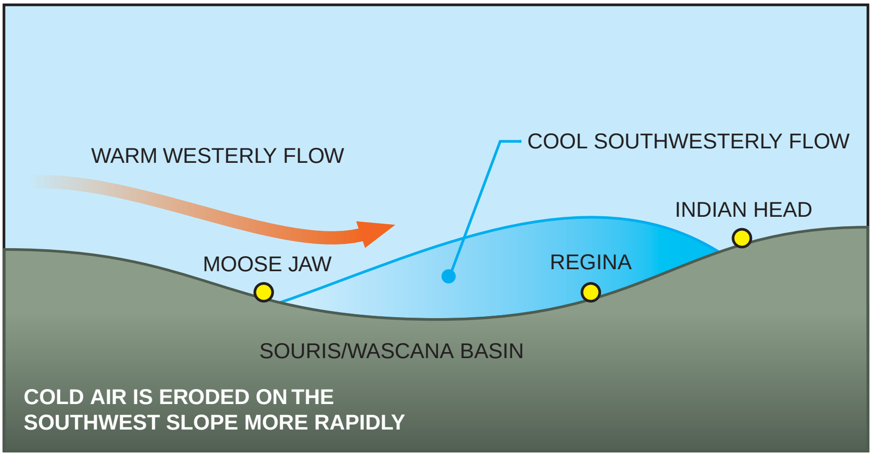
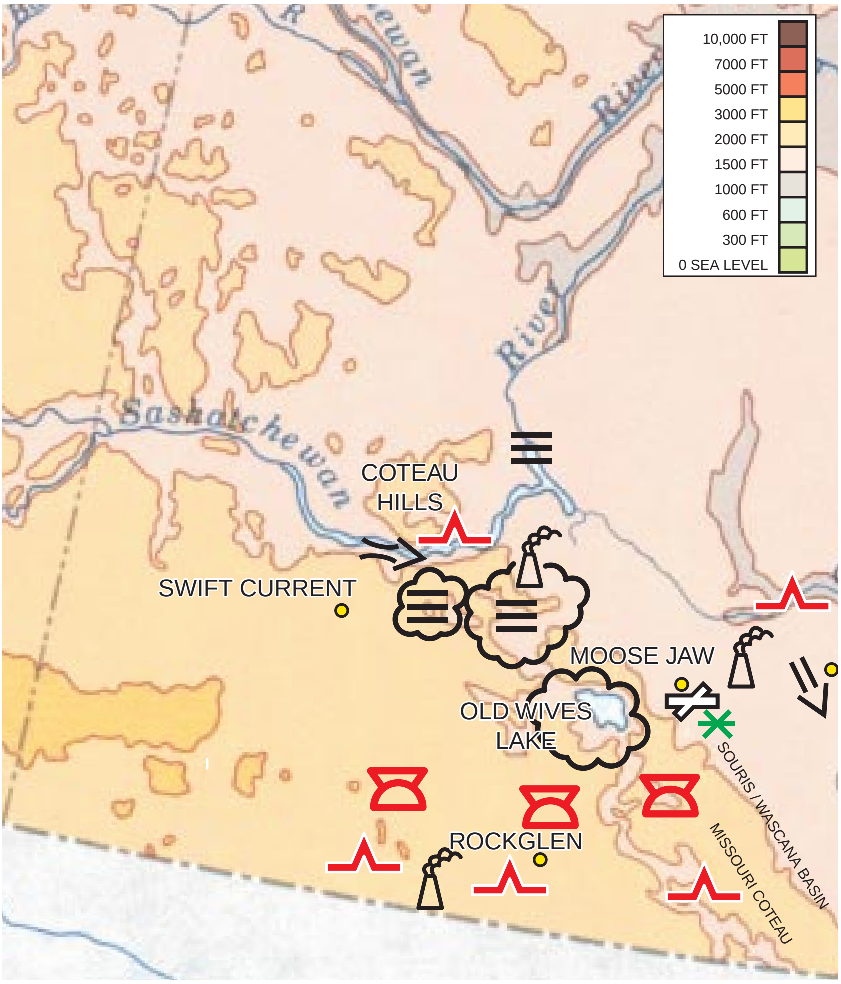


Fig. 4-6 - Pooling cold air in Souris/Wascana Basin

The Missouri Coteau



Map 4-22 - The Missouri Coteau

The Missouri Coteau is a large region of relatively rugged terrain made up of several ridges of hills, criss-crossed by deep valleys and coulees. Geologically, it extends west from the Souris/Wascana Basin to the Cypress Hills and northwestward into Alberta east of Edmonton, but is most prominent south of Lake Diefenbaker. The myriad of landforms are a result of glacial movements during several ice ages and the subsequent melt and runoff. This is especially evident over extreme southern sections (Big Muddy Lake, Rockglen and Wood Mountain areas) and the Cactus Hills south of Moose Jaw.

Convective activity in the area tends to initiate earliest along ridges of the Missouri Coteau and drift eastward across the Souris/Wascana basin as it continues to develop.

The Coteau itself is typically an area of enhanced convection when the airmass is unstable. Severe weather is most likely in June and July when daytime heating is most intense, and low level moisture is at its peak. Because of the complex nature of the terrain of the Coteau, winds can be funnelled in an almost random way. Mechanical turbulence below 6,000 feet ASL is common over the area.

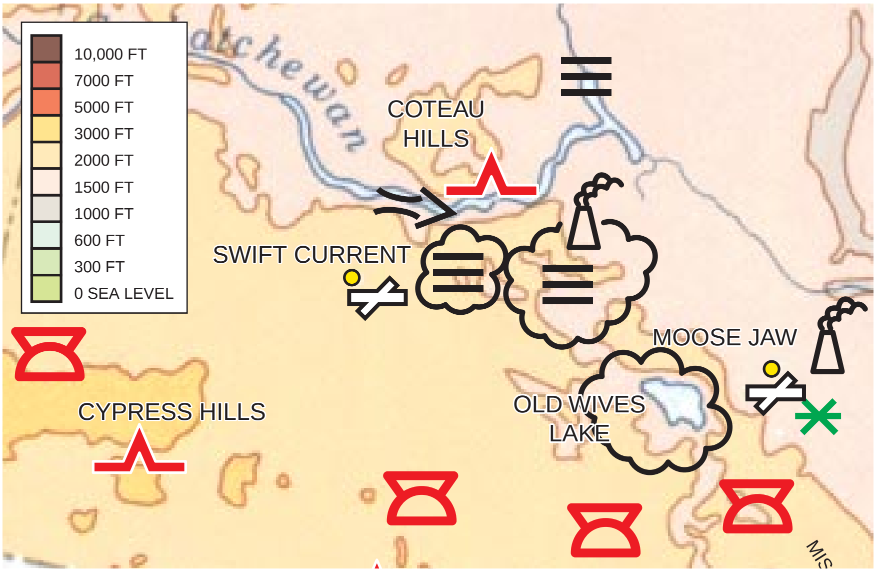
Strong southwesterly flows can produce widespread standing wave activity and mechanical turbulence over and to the lee of the Coteau. Lenticular cloud is often present at low and mid levels and indicates the presence of lee waves.

The land can be described as semi-arid so widespread radiation fog in summer is not very common. It can happen where cool air pools in the lower valleys and near lakes. There is a coal-fired power plant, similar to the Shand Plant near Estevan, located on the Poplar River east of Rockglen. This generator can be responsible for locally poor conditions, as its emissions also include a large amount of water vapour.

The Cypress Hills rise, on average, about 1,400 feet above the surrounding territory and include one of the few forested areas in southern Saskatchewan. The highest elevations in the province are here, exceeding 4,500 feet ASL near the Alberta border. As one would expect, the area is susceptible to mechanical turbulence up to several thousand feet above the terrain in windy conditions, and in enhanced convective weather when the airmass is sufficiently unstable. Small-scale upslope and downslope effects can produce varying deterioration and improvement in weather conditions over short distances, depending on the amount of low level moisture and wind direction. The northern slopes of the Cypress Hills are particularly vulnerable to upslope stratus when cool moist air is invading from a northwest, north or northeasterly direction. When surrounding stations are reporting marginal ceilings, the higher terrain is likely enshrouded or, at least, the ceilings are considerably lower there.

Precipitation amounts tend to be greater over the Cypress Hills than the surrounding area and snowfall accumulation can be significant over the higher elevations in winter. In fall, when freezing levels are dropping, precipitation phase can often change from liquid to solid, and back again, as one traverses the Cypress Hills. This phase transition can result in serious icing conditions when temperatures are sufficiently cold.

Swift Current to Moose Jaw



Map 4-23 - Swift Current - Moose Jaw

Swift Current is situated north of the more rugged sections of the Missouri Coteau and Cypress Hills, but much of the local weather is still caused by the influence of that terrain. Southwest to westerly flows are forced over and around the Cypress Hills resulting in occasional “Chinook-like” conditions in the winter, as well as some acceleration in winds from those directions at any time of the year. Lee wave and/or mechanical turbulence up to 6,000 feet ASL can be expected with these winds. The local land surface is somewhat smoother, but there are several ranges of hills in the area, as well as rivers that have carved deep trenches. The South Saskatchewan River and Lake Diefenbaker, just north of Swift Current, twist through a trench that falls as much as 500 feet below the surrounding area. Terrain around these features is ideal for enhanced mechanical turbulence and erratic wind shifts.

Low cloud events at Swift Current are usually the result of one of two situations. During the fall months, cool, moist northwest or northerly flows are forced up the slope out of the South Saskatchewan River Valley and encounter the rising terrain to the south of the town. Sometimes stratus invades from the west, but this is usually cloud that has been formed in the northerly upslope flow and deflected eastward by the Cypress Hills. In the second case, low cloud can also advect from the southeast with a flow from that direction. This is common in the fall but can happen in the winter and spring as well, especially during or after a period of snow melt.

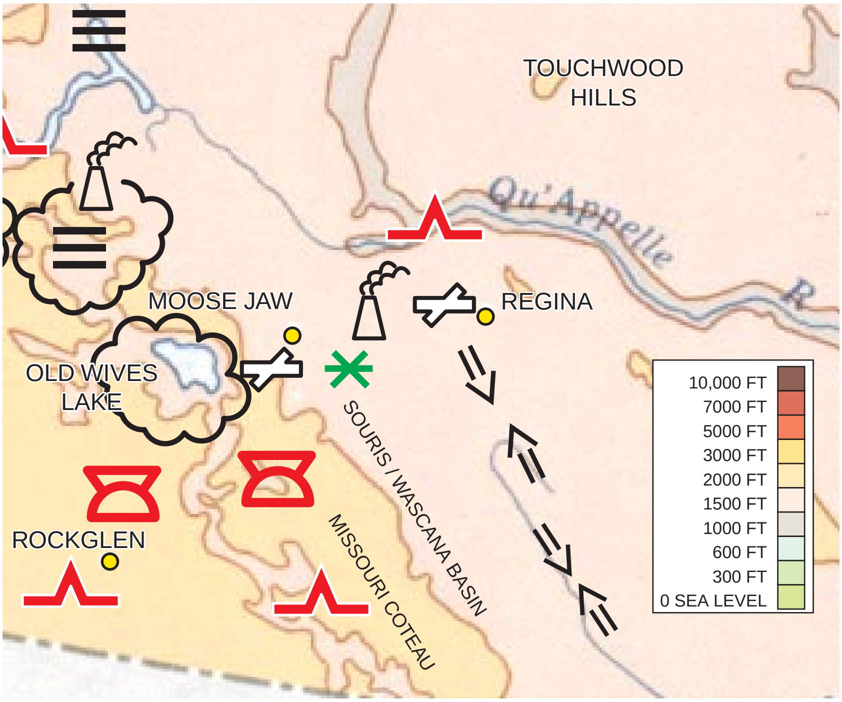
Several sewage lagoons lie just to the northwest of the Swift Current airport. In an effort to reduce the water volume in the lagoons in winter, local authorities use what is best described as a type of snow making machine. When temperatures are below -10°C, the machines are turned on and inject the fluid into the air, with the hope that it will be evaporated or sublimated and carried away by the wind. This process has a tendency to create local stratus and fog that can directly affect the airport when the winds are northwesterly.

The route from Swift Current to Moose Jaw follows the Trans-Canada highway, which crosses several shallow valleys separated by ridges or lines of hills, most of which are aligned roughly northwest to southeast. Although these features are not as prominent as those further south, they can produce some mechanical turbulence in the low levels when winds blow across them.

There are several shallow alkaline lakes in the area. The largest of them are Reed Lake and Chaplin Lake, near the highway, and Old Wives Lake, southwest of Moose Jaw. The size of these lakes can vary greatly depending on the amount of precipitation or evaporation that takes place in a given year. These lakes can be responsible for several local effects: local fog on cool, clear summer nights; enhanced convection due to the extra availability of low level moisture; fog and stratus with cold west to northwesterly flows in the fall; and, occasionally, some enhanced early winter snowfalls. Also, like other alkaline lakes, these do not always freeze completely and can continue to inject a small amount of heat and moisture into the lower atmosphere throughout the winter and early spring.

There is a sodium sulphate processing plant near the highway at the north end of Chaplin Lake. When the plant is operating, its discharge can enhance (or locally cause) low flying conditions in fog and low cloud. The combined effects of the sodium sulphate plant and the lake could be the reason for a local rule of thumb: when ceilings are poor or marginal in Swift Current and Moose Jaw, they can be as much as 400 feet lower near Chaplin Lake.

Moose Jaw to Regina



Map 4-24 - Moose Jaw and area

Moose Jaw lies on the western side of the Souris/Wascana Basin on the eastern slopes of some high terrain that is part of the Missouri Coteau. This location is beneficial, especially in winter, because subsiding westerly winds (Moose Jaw "Chinooks") erode the shallow inversions that frequently form in the basin, much earlier here than at points further east. Since the winds at Moose Jaw are predominantly westerly, temperatures are usually several degrees warmer and the weather is typically better, or at least, isn't poor for as long, in Moose Jaw than in Regina.

Easterly flows are upslope here and are responsible for the majority of cases of poor weather, especially from fall to spring. The synoptic pattern is usually that of a high pressure area to the north and lower pressure to the south. In the winter, strong east to southeasterly upslope winds will accentuate snowfalls and in turn combine with the fresh precipitation to produce poor conditions in blowing snow. Westerly winds will also bring blowing snow to Moose Jaw. However, this condition gradually makes its way into the aerodrome area only after it has already obscured the higher terrain to the west, so there is some advance notice of impending deterioration.

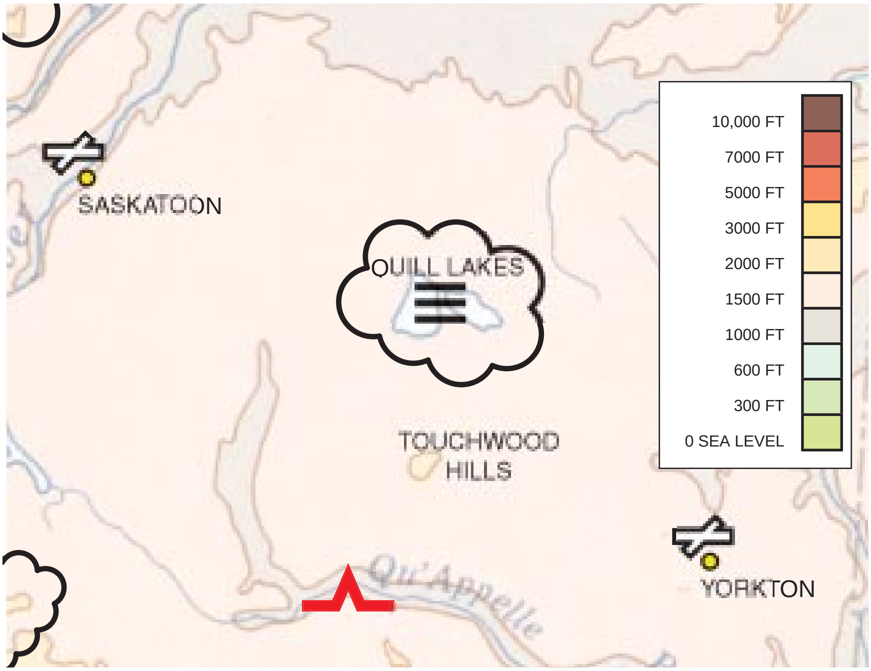
As mentioned, the Missouri Coteau is noted for enhanced convection during the summer. Old Wives Lake, southwest of Moose Jaw, is another feature in the area that can intensify convective activity by providing extra low level moisture. As a result, thunderstorms are common at Moose Jaw during the summer season.

Strong southwesterly winds traversing the Coteau can cause significant mechanical and/or low-level lee wave turbulence over Moose Jaw.

Railway lines run through the area and there are several sidings west of Moose Jaw where locomotives will sit and idle. In the winter, when winds are light and temperatures cold, the exhaust from these engines can promote the formation of ice fog that tends to pool in the Thunder Creek valley, which joins the Moose Jaw River in the town.

There is a noticeable "transition zone" in weather conditions between Regina and Moose Jaw, which tend to be quite different between the two places. This is particularly evident in winter when an inversion is present in the Souris/Wascana Basin (Regina) and drier, warmer westerly winds have scoured out the cold air to the west (Moose Jaw). Belle Plaine, a town on the highway between the two cities and site of a large potash plant, commonly marks the boundary between good conditions to the west and poor conditions to the east. The potash plant probably has something to do with the predictability of the boundary. If this boundary is farther west, there can be marked differences from the weather reporting site at the military base south of Moose Jaw and the Moose Jaw Municipal Airport, 6 to 7 miles northeast of the town.

Yorkton to Saskatoon



Map 4-25 - Yorkton to Saskatoon

This path also takes a pilot along fairly flat terrain; there is less that a 20-foot difference in elevation between the two airports. Major topographic features include the Beaver and Touchwood Hills to the south on the first half of the route, and the Allan Hills just southeast of the Blackstrap Reservoir, near Saskatoon. These hills can be dangerous obstructions when marginal flying conditions exist at reporting sites, and they are often locations of enhanced convective activity in the summer.

The Quill Lakes are large, shallow alkaline bodies of water located roughly halfway between Saskatoon and Yorkton, just north of the Touchwood Hills. In fact, Big Quill Lake is the largest saline lake in Canada. These lakes are responsible for several marked changes in the weather along the route. If the airmass is sufficiently unstable, the lakes can provide enough low level moisture to initiate and accentuate convective activity in the area. In the summer, stratus and fog commonly forms on cool, clear nights over and around the lakes and is then advected downwind, creating a problem for flight operations until late in the morning. In the fall and early winter, cold west to northwesterly flows passing over the warmer water generate large areas of low cloud that can extend downwind as far as Yorkton. This low cloud is usually embedded with streamers of convective cells that produce locally enhanced precipitation. When air temperatures are low enough, poor visibilities in snow showers can be expected. Since the lakes are high in mineral content, they typically do not freeze readily and can have “soft spots” in the ice cover. These spots continue to inject heat and moisture into the lower atmosphere throughout the winter and early spring, although on a much smaller scale. Finally, the lakes are a breeding area for vast numbers of shore birds during warm months and bird populations swell further during migratory season. Pilots should be concerned with bird impacts in the region.

When this area is under the influence of flows with a westerly component, pilots in Yorkton prefer to use Saskatoon, rather than Regina, as the best upstream indicator of weather they can expect. The limited information provided by the automatic reporting site at Wynyard can give some indication of the weather around the Quill Lakes, but it may not be representative of the general conditions along the route.

Saskatoon is situated in a broad area of open and flat terrain, in central Saskatchewan. The airport is on the north side of the city and has a relatively uncomplicated climatology, with close to the lowest frequency of low flying conditions in Saskatchewan. The months of November through February bring the greatest likelihood of poor weather. The South Saskatchewan River flows through the center of town in a south-southwest to north-northeast, but the valley is quite wide and has gently sloped sides. There is some higher terrain, the Allan Hills, about 25 miles to the south-southeast of the town, but they rise only 400 to 500 feet above the surrounding area. Because of the openness of the land, there is no strongly preferred wind direction in Saskatoon, although there is a slight partiality for winds from the northwest or the southwest. The strongest winds are almost always from the northwest.

Saskatoon is frequently cold and clear in the winter, as dry continental arctic air enters from the north. This allows for frequent low level inversions which does lead to the occasional period of ice fog fed by condensation nuclei from local industry. A power plant on the south side of town will sometimes spread smoke as far as the airport under inversion conditions if there is a light southerly flow, but it will not usually significantly reduce the visibility.

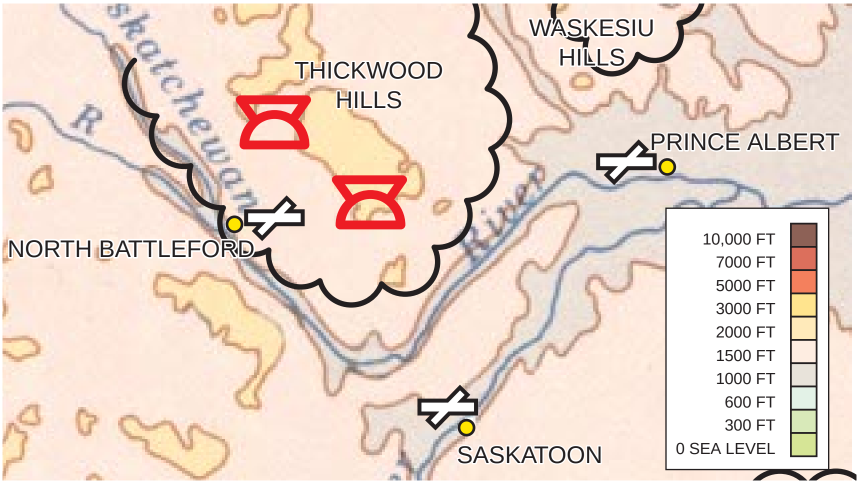
Local Effects for Northern Saskatchewan

For the purposes of describing aviation weather, northern Saskatchewan will be defined as Prince Albert and all areas to the north. At this point, the land makes a transition from being mainly agricultural to the much more sparsely populated areas of the boreal plains and forest of the north. The land between the Saskatchewan River and the Churchill River (between Prince Albert and La Ronge) is characterized by small rolling hills, several larger lakes and the vigorous mixed forest. The most significant topographical feature is the Mostoos Hills, to the north of Meadow Lake.

North of the Churchill River, the land becomes flatter with the lakes becoming much more numerous and smaller in size. The rock of the Precambrian Shield is very near the surface in this region and only a scrubby coniferous growth is supported. Lake Athabasca and its drainage system dominate the farthest northern reach of the province. Here, outcroppings of bare rock are not infrequent.

In general, convective activity decreases as one progresses northward due to the mitigating influences of forest cover and numerous lakes. Compared to the south, thunderstorms are less frequent in northern Saskatchewan, and more importantly, less severe, with large hail and tornadoes being extremely rare. The north is prone to more stratus, especially in the transition seasons, as there is abundant low level moisture supplied by the lakes. As well, the larger lakes in the central region, and Lake Athabasca in the north, can be prone to streamers in the early spring and the late fall, especially in a cold north to northwest flow.

Saskatoon - Prince Albert - North Battleford



Map 4-26 - Saskatoon to Prince Albert

The path between Saskatoon and Prince Albert mainly follows the broad valley of the South Saskatchewan River. The terrain around Saskatoon is flat prairie but heading towards Prince Albert, land cover shifts to predominantly boreal forest. Prince Albert issituated on the North Saskatchewan River, just west of the junction where the two branches of the River meet to form the Saskatchewan River. At this point, the valley is very wide and gently sloped. Along this route, the terrain slopes gradually downwards to the northeast, with Prince Albert 250 feet lower than Saskatoon. Stratus tends to form along this route in the fall and early winter whenever there is a moist flow coming from the northeast quadrant.

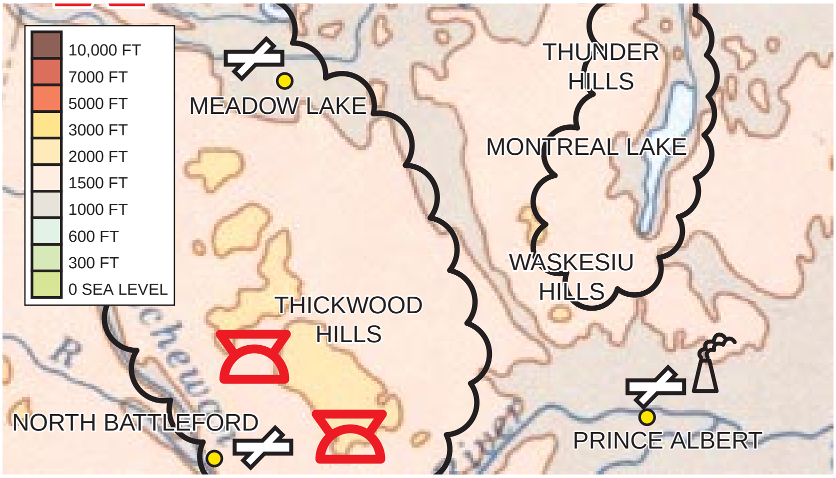
The main topographical feature between Prince Albert and North Battleford is the southern end of the Thickwood Hills, which are encountered about half way to North Battleford and rise about 1,000 feet above the surrounding area. If conditions are marginal at either North Battleford or Prince Albert, then they will certainly be lower over the Thickwood hills where ceilings are often down to the ground. A moist east to southeasterly flow will give the lowest conditions over the hills with the stratus piling up on the east side. Although a westerly flow will still be upslope on the western half of the hills, it is usually too dry to induce any cloud formation.

North Battleford Airport is situated on the east side of the town. Both are just north of the North Saskatchewan River. Because of the influence of the northwest to southeast valley, the winds are almost always oriented along this axis with winds from any other sector being infrequent and generally light. With the prominent hills situated on either side of the valley, the Thickwood Hills to the northeast and the Eagle Hills to the southwest, the only upslope flow comes from the southeast up the river valley. If a moist southeast flow blankets southern Saskatchewan in stratus, then there is almost always a progressive deterioration in ceilings with the highest values occurring in Moose Jaw and Saskatoon, and lower values in North Battleford. Ceiling heights then continue to deteriorate towards Lloydminster.

In spring and summer, if there is little spread between the temperature and dew point in the overnight period, a broad band of fog and stratus will often form over the North Saskatchewan River Valley and spread into the North Battleford Airport. It will usually start to break up by 8:00 AM local time.

The path between Saskatoon and North Battleford stretches over the much flatter terrain of the North Saskatchewan River Valley, with the Thickwood Hills on the north side and the Eagle Hills on the south. If the region is blanketed in stratus due to an easterly flow, then ceilings will often gradually lower towards North Battleford due to the slight increase in elevation, but with no significantly lower ceilings enroute. The southern slopes of the Thickwood Hills are known to generate convective buildup in the summertime. Cells formed in this area will generally track southeastward along the North Saskatchewan River Valley.

Prince Albert to Meadow Lake



Map 4-27 - Prince Albert and area

Prince Albert airport is located in the east to west valley of the North Saskatchewan river, nestled into a U-shaped deviation of the river so that it is surrounded on three sides by water. This means that flows from every direction, except the north, could potentially advect stratus and fog into the airport from the river valley. However, an easterly flow is the most likely to do this as it is pushed upslope. As well, it can acquire significant moisture in the low levels from its long trajectory within the confines of the east-west valley of the South Saskatchewan and North Saskatchewan Rivers.

There are two local anomalies in the topography that need to be considered when low cloud is in the area. About 15 miles southwest of the airport, Red Deer Hill rises nearly 300 feet above the surrounding terrain, and 16 miles to the north-northwest, Handson's Hill rises slightly over 300 feet.

Prince Albert is a prime location for morning radiation fog due to its proximity to the river. These events are most frequent from April through October, with the peak being in August and September, when the night becomes longer and radiational cooling is greater. Radiation fog tapers off greatly in the winter months when the river freezes over, but there are still some occurrences of ice fog due to rapids on the river just to the north of the airport that are slow to freeze. Occasionally, there is ice fog or thin stratus coming from the emissions of the local pulp mill if the flow is light northeasterly, and there is a low level inversion. Another wintertime consideration for the Prince Albert Airport is the making of snow at a ski hill situated one mile to the west. If the flow is light westerly, then this will advect some of the low level moisture and subsequent ice fog over the airport, usually creating low ceiling and low visibility.

The orientation of the river valley in Prince Albert is from east to west and this strongly influences the wind, which predominantly blows within the confines of the valley. However, the strongest winds are generally northwesterlies which develop in the wake of the passage of a low over the area.

Heading northwestward from Prince Albert towards Meadow Lake, one follows a path that is in a natural depression in the land with ranges of hills on either side. The Thickwood Hills stretch most of the distance along the southwestern side, and the much smaller Waskesiu Hills are on the northeast side on the first part of the flight. Closer to Meadow Lake the prominent Mostoos Hills rise to the north, but they are not encountered on either a path from Prince Albert or La Ronge. This course also tends to delineate agricultural lands to the south from the forests of the boreal plain to the north. Not surprisingly, flows from the east to southeast are upslope over this area and are most likely to bring the lowest conditions. However, Meadow Lake is only 170 feet higher in elevation than Prince Albert, so there is generally not a notable difference in weather reported at either of the two sites. There are usually no significantly lower conditions between the two airports if the hills on either side are avoided.

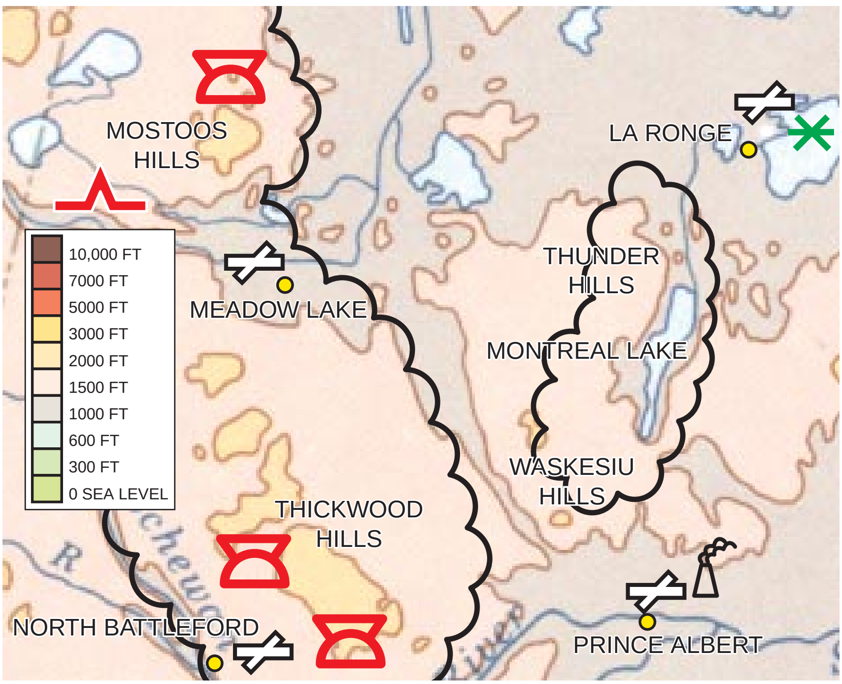
Meadow Lake, both the airport and the town, are situated in an east-west valley created by the Beaver River flowing eastward from Cold Lake. The river itself is more than 10 miles north of the airport so it does not have a great influence on conditions there, but it does mean that a north wind is upslope for the airport as it makes its way up the side of the valley. However, winds from either the north or the south are uncommon in Meadow Lake, and are usually quite light. Meadow Lake is sheltered from strong wind flows from most directions; southwesterlies are the most common direction, but it is rare that speeds attain more than 10 knots.

Meadow Lake does not have a high incidence of reduced visibility in fog, but there is a peak season for morning radiation fog that runs from June through September. August is the month most likely for this to occur with about 8 percent of the days seeing some period of fog in the morning hours. The lake that the town is named after is about 4 miles to the west and no doubt plays a role in supplying low level moisture for fog formation.

Flying the lower terrain between Cold Lake, Meadow Lake, Prince Albert, and even northeastward to La Ronge, provides fairly safe and reliable weather conditions. The most hazardous regions are directly to the north or south of Meadow Lake. Heading south towards North Battleford takes a pilot directly over the Thickwood Hills that rise 1,000 feet between the two airports. When conditions are even close to marginal at either of these two airports, there is likely to be very low conditions, even down to the treetops, somewhere over these hills. It is often necessary to divert around the the eastern side of the Thickwood Hills. Almost every wind direction will provide upslope conditions at some point over the hills, but winds from the northwest through to southwest are generally the safest as they are typically dry in the low levels, due to the predominantly downslope conditions to the west in Alberta.

To the north, the Mostoos Hills rise quite sharply, more than 1,500 feet above the valley of the Beaver River, and are the most prominent geographical feature in the northern half of Saskatchewan. They are infamous for very low to obscured conditions especially in a moist south to southeasterly flow. The northeastern portion of the Mostoos Hills is situated inside the boundaries of the Primrose Lake Weapons Range, which is restricted airspace under the control of the Cold Lake military base. For this reason, as well as the likelihood of weather hazards over the hills, pilots heading north from Meadow Lake towards Buffalo Narrows will often stick to the lower ground on the eastern side of the hills. In the summer, the southern slopes of the Mostoos Hills are also an area of frequent convective buildups and thunderstorm generation.

Prince Albert to La Ronge



Map 4-28 - Prince Albert to La Ronge

Flying directly between Prince Albert and La Ronge, the territory is quite flat and swampy with small ranges of hills on either side. Montreal Lake, a long thin body of water stretching on the west side of the flight path about half way between the two sites, is notorious for producing a great deal of stratus, especially in a moist flow from the east. On the west side of the path there are also two ranges of hills, the Waskesiu

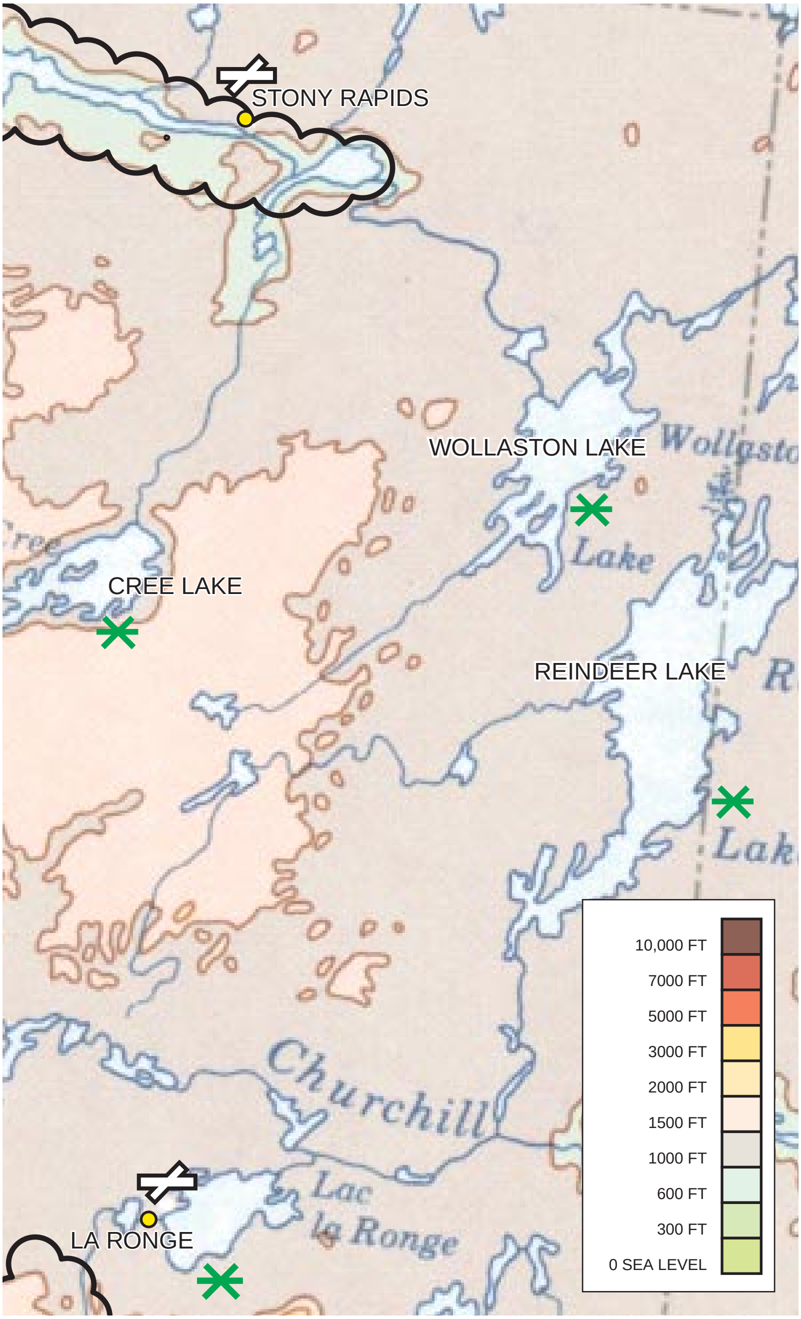
Hills, just southwest of Montreal Lake and the Thunder Hills, just west of the lake at its northern end. Naturally, these two areas of higher land, 600 to 800 feet above the terrain to the east, experience very low ceilings in east to southeasterly flows. The Thunder Hills can be particularly treacherous, as any flows from the eastern quadrant will receive an extra injection of low level moisture from Montreal Lake before ascending to higher elevations. Staying on the east side of Montreal Lake will generally ensure the best ceilings and visibilities as this keeps a pilot to the lowest elevations in the area. There is also the additional benefit of a slight downslope off the small ranges of the Cub and Wapawekka Hills to the east. In general, any flow from the west is quite favourable in this region. However, in the fall and the spring, a cold northwesterly flow can become unstable as it crosses the warmer waters of Montreal Lake. This can produce an area of cumulus and stratocumulus with the potential for embedded snow streamers.

La Ronge sits on a small peninsula of land, at the border of the Precambrian Shield, which is surrounded by lakes on most sides. The largest of these is Lac La Ronge, to the east of the airport, which is quite shallow and dotted with numerous islands. Any prolonged east to northerly flow can advect quite low conditions into the airport area due to the long fetch over the lake, but this is most prevalent in the spring and fall; the late fall shows the greatest likelihood of poor flying conditions. Lac La Ronge tends to freeze and thaw somewhat later than other lakes in the area, and this does affect the periods of maximum stratus formation.

La Ronge has the reputation of being a windy airport. It is exposed to winds from most directions with west to northwesterly flows being the most frequent, followed closely by east to northeasterlies. Flows with a northerly component must be regarded with caution when flying in areas to the south of La Ronge, as the Thunder and Wapawekka Hills do provide enough upslope terrain to generate stratus.

The winds at La Ronge Airport can be influenced by lake breezes during the summer months causing changes that are completely opposite to the expected flow. One way of anticipating the onset of the lake breeze is to watch for the signature of these lake effect winds; ripples in the water close to the shore while the center of the lake remains mirror-like and smooth.

La Ronge and points north

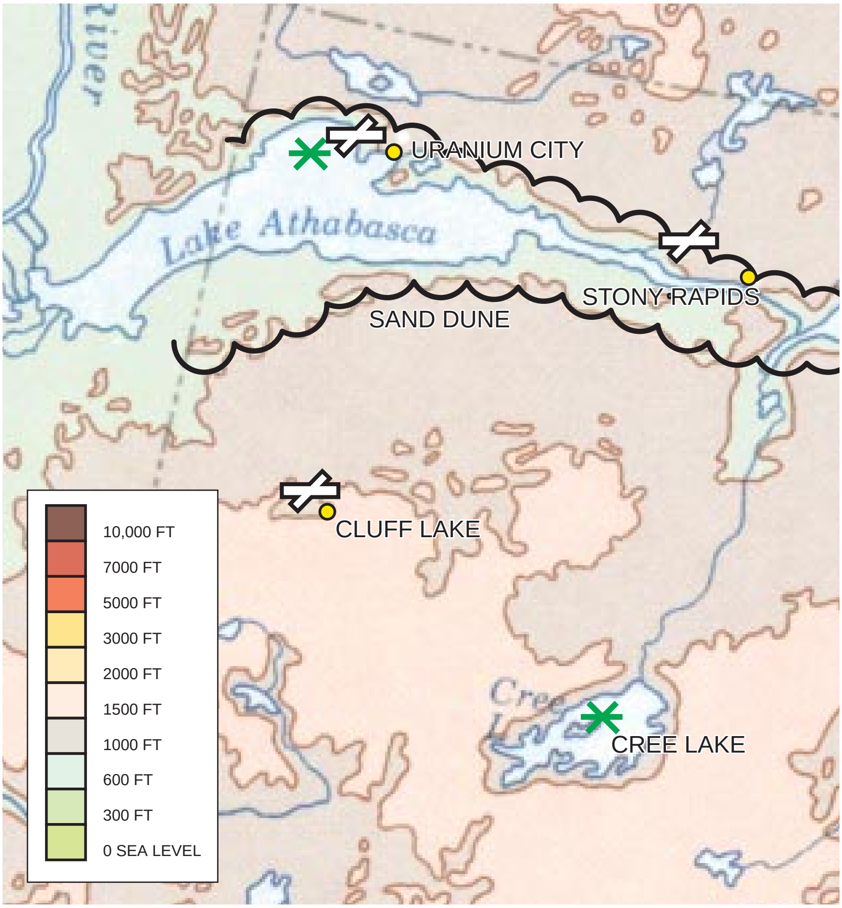


Map 4-29 - La Ronge and points north

Regions to the north of La Ronge are within the Precambrian Shield and this greatly effects the topography as well as human activity; settlements are infrequent and landing strips are widely spaced. At this point, the lakes and rivers become countless and most of the land cover is scrubby forest growth and muskeg. The lakes are generally small and shallow with the exceptions of Cree Lake, Wollaston Lake, and Reindeer Lake. The hills in this area are few and very small, so upslope conditions are present only for flows from the northeast to east. Obviously, with these wind directions, there is copious low level moisture available, outside of the winter season, so stratus can blanket the entire region if the flow persists long enough. In the fall, before the lakes freeze, cold northwest or northerly flows are quickly saturated and destabilized in the low levels as well, causing widespread low cloud and precipitation. Regardless of the situation, the worst conditions tend to exist to the lee of the larger lakes mentioned above.

The Churchill River runs roughly west to east, about 40 miles to the north of La Ronge, joining numerous lakes through the north-central section of the province. It is frequently observed that the river itself forms a natural weather divide over northern Saskatchewan, with low cloud staying confined to one side or the other. Differences in land elevation and topography no doubt play a role in this, but it is not impossible for well-developed areas of low stratus or stratocumulus to cross the river and fill the valley completely.

Stony Rapids and the Lake Athabasca Drainage Area



Map 4-30 - Stony Rapids and the Lake Athabasca drainage area

The Lake Athabasca drainage area comprises the extreme northern part of the province and shapes the local weather conditions in a number of ways. Lake Athabasca is situated in a broad east-west basin with numerous small lakes and rivers and with elevations a mere 600 to 800 feet above sea level. The southern shore of the quite large Lake Athabasca is a long stretch of sand dunes, and the northern side is a sharp escarpment rising 1,200 feet above the level of the lake. The eastern end of the lake constricts into a long channel, the Pine Channel, that joins Fond Du Lac and Stony Rapids. The Western end of the lake extends southwestwards into Alberta ending at Fort Chipewyan.

Stratus frequently invades from the north into this area, and often has its southern edge within the confines of the basin lowlands. Ceilings can be very low, or down to the surface, over the escarpment on the north shore of the lake. This is a consideration when flying to, or near, Uranium City which is on the southern edge of this escarpment.

The weather conditions at Stony Rapids are strongly influenced by the Pine channel. Winds are frequently funnelled through this passage and show a strong preference for either east or west directions. Winds coming from the west have a long fetch over open water and can advect stratus down the Pine Channel and into Stony Rapids. Winds coming from the north or south quadrants occur less than ten percent of the time and are invariably quite weak.

Lake Athabasca produces snow streamers in the spring and fall when cold flows develop from the west to northwest. Often these will reach as far as Stony Rapids, plaguing the airport with low visibilities in flurries. Lake Athabasca is quite shallow and will usually freeze over by late November or early December, with the spring thaw happening in late May or the first week of June. However, the Pine Channel has some relatively fast flowing waters and often stays open most of the winter between Fond Du Lac and Stony Rapids. This leads to frequent occurrences of ice fog at the Stony Rapids airport.

Morning radiation fog becomes a problem at Stony Rapids after the spring thaw, peaking during the months of July, August and September. In fact, Stony Rapids has the greatest frequency of summer radiation fog in Saskatchewan, with occurrences on 16 percent of the days during the month of August.

Adding all of these factors together, Stony Rapids, as with many sites in the Athabasca Basin, has a rather high likelihood of poor weather compared with other spots in Saskatchewan. Low flying conditions peak in the late fall and early winter when the area is prone to snow streamers, morning fog events, and frequent invasions of stratus from the north. Around January, conditions start to improve as very cold and dry arctic air masses frequent the area.

Weather of Manitoba

Map 4-31 - Topographical overview of Manitoba

Manitoba's climate is purely continental; its location in the centre of Canada puts it a vast distance from any truly moderating coastal influence. It is certainly not a surprise that it possesses the distinction of being the province with the greatest range between summer and winter temperature averages. Winters are long and hard, while summers are warm and short. The transition seasons are short and unreliable; there is a greater than 50 percent chance of having a frost after May 25, and before September 20, in any given year. A persistent snow cover can usually be expected after mid November but with sporadic events occurring much earlier.

Manitoba is quite dry as would be expected of a continental climate, but it does receive a bit more precipitation that the other two Prairie provinces. Totals range from a low of 400 mm annually in the north, to near 600 mm in the southeast. The foothills of Alberta are the only other location on the Prairies to exceed 600 mm in a year. The reason for Manitoba's higher, and somewhat more reliable, precipitation amounts has to do with its greater exposure to southerly flows of warm moist air from the central United States and the Gulf of Mexico. Fortunately, 60 percent of the annual precipitation falls during the growing season from May to August, with June being the wettest month.

Even though one sixth of Manitoba's surface is water, the lakes and rivers do not exert a major influence on the province's climate. In actuality, the much more distant Pacific Ocean and Gulf of Mexico have a much stronger influence than the local bodies of water. The only exception is the Interlake region, between Lake Winnipeg to the east and Lakes Winnipegosis and Manitoba in the west. Even the influence of Hudson Bay is minimal and usually confined within a short distance of its coast. Churchill's temperatures are somewhat cooler in the summer, but by mid winter the bay is completely frozen and becomes almost indistinguishable from the frozen tundra around it.

Manitoba is at the eastern edge of the vast sloping plain that comprises all of the Prairie provinces, and it has the lowest and most uniform elevations of the three. For this reason, terrain does not exert a significant control on the province's climate, with the local exception of the Manitoba Escarpment. This topographic feature, shared along the southwestern boundary with Saskatchewan and the U.S., is the most recognizable in the province, and is made up of at least four separate sets of hills or mountains: the Porcupine Hills, Duck Mountain, Riding Mountain and Turtle Mountain. The Escarpment extends from west central Manitoba, south-southeastward, to the international border and beyond. Together, these hills present a fairly uniform north-south barrier and have a significant influence on the local climate.

Manitoba, as with the rest of the Prairies, lies under the zone of mean westerly, with weather disturbances generally moving from west to east. There are, however, a great variety of synoptic situations that have the potential to affect this province.

Colorado Lows are more likely to bring moisture to southern parts of Manitoba than elsewhere in the Prairies. When they reach Manitoba, they have generally developed into full-fledged frontal systems with a plentiful supply of moisture. The Colorado Low can occur at any time of the year, but peaks during the spring. Cold lows formed over Alberta also frequent the province, but by the time they make it to Manitoba they have usually lost their closed circulation in the upper levels, and this gives them a faster more predictable movement. As is typical with all lows in the Prairies, the worst flying conditions are found in the moist upslope easterly flow on the north side of the low's centre.

In summer, southern portions of Manitoba can be the recipient of sweeps of warm humid air from the Gulf of Mexico. There is usually a great deal of thunderstorm activity embedded in these air masses which gives this part of Manitoba an extra dose of rainfall, making the local agriculture less dependent on irrigation. In the northern reaches of the province, there are often prolonged periods of low cloud and poor weather. This is due to the tendency for lows to move into the region of Hudson Bay, or northwestern Ontario, and then remain nearly stationary for some time, flooding the region with cool, moist air from the north.

Another synoptic situation that is worthy of mention, although not associated with precipitation, is the winter phenomenon known as the "Arctic Outbreak". Strong high pressure cells, that have developed in extremely cold air masses over the western Arctic, invade the Prairie provinces, usually in the wake of a migratory low pressure system. These domes of frigid air spread southeastward, almost unimpeded, and typically herald long periods of clear, dry, and bitterly cold weather.

(a) Summer

Summers in Manitoba are short and hot by Canadian standards; they begin in late April or early May and last until the beginning of September. While Saskatchewan holds the record for the hottest recorded temperature, Manitoba has slightly warmer summers on average. Both are known for the large summer diurnal temperature range, averaging 14° Celsius degrees per day. Summers are fairly dry, but 60 percent of the annual precipitation falls within the growing season of May to August.

During the summer, the typical storm track is pushed northward. Cold lows formed in Alberta often end up near Hudson Bay and affect northern parts of the province, whereas Colorado Lows typically follow a path close to the Manitoba/U.S. border, influencing the weather over southern regions. Regardless of where the low originates, the lowest flying conditions are generally found within 60 to 100 miles north of its center where a persistent east to northeast flow, forced to rise up the sloping terrain, becomes increasingly saturated. However, by the time these storms have reached Manitoba, they have usually gained some momentum and move through this province at a faster pace than those to the west. Thunderstorms are common over Manitoba throughout the summer and most prevalent over the south. Typically, Brandon and Winnipeg report thunder 25 to 30 days a year. Air mass thunderstorms are the most common, although they do not have a strongly favoured region of development, due to Manitoba's flat terrain. Two slightly preferred areas are the slopes of the Manitoba Escarpment and the Interlake region, but often storms are initiated elsewhere and enter the province freely from any direction. Manitoba is the Prairie province that is most susceptible to nocturnal thunderstorms, mainly because it is the most eastern of the three. Thunderstorms that are formed far to the west and southwest begin tracking in an easterly direction once they have reached a certain stage. Most of these will weaken and die after moving away from their source region, but if they are strong and there are sufficient dynamics to support them, they can travel a considerable distance. The storms that are able to reach as far as Manitoba will generally arrive late in the day or overnight. They often seem to dissipate during the evening hours, but then have a period of regeneration during the overnight hours when cloud top cooling gives them an extra dose of instability. It is this modified life cycle that accounts for the higher frequency of overnight and early morning thunderstorms.

When discussing thunderstorms in Manitoba, it is necessary to consider those that sometimes invade from the south, embedded in very warm, humid and unstable streams of air that originate over the Gulf of Mexico. This is a pattern usually only seen in the summer, as it requires a southerly upper circulation to transport air from the Gulf all the way to Canada. When such a pattern occurs, southern Manitoba often receives a significant infusion of rainfall. These air masses can support thunderstorm complexes that are large and long-lived. The typical path they follow often just clips southeastern Manitoba as it turns into Ontario.

Low-level turbulence is a frequent concern during summer, most notably on warm sunny days. Thermal updrafts are common over the land due to surface heating, and their effects can be particularly turbulent along boundaries where they are juxtaposed with downdrafts generated over large bodies of cool water. These paired updrafts and downdrafts can be strong enough to initiate lake-breeze circulations which are common in the Interlake region.

(b) Winter

Winter in Manitoba is generally considered to be from mid-November through to early April. During this period, good flying weather is common, but the migratory lows that affect the other Prairie provinces also plague Manitoba. These can originate in Colorado, the western Prairies or Northern Canada, and often bring prolonged periods of very low flying conditions and significant snowfalls when they visit.

Lows that form in the Colorado or Wyoming region can be particularly messy for southern Manitoba. The typical trajectory for the center of such a low will keep it south of the province, but there is often a warm front extending from the low that reaches into southern sections. Precipitation can change from snow through freezing rain to rain, depending on one's location with respect to the front. Low ceilings and visibility, as well as significant icing, are common with this pattern. Ceiling heights can vary greatly, especially in the southwest where the terrain is irregular. Once the system has passed, a strong northwesterly flow invariably develops in its wake. The resulting cold winds cause blowing snow over regions of fresh snow cover and can quickly freeze warmer surfaces where rain has fallen.

Lake effect snowfalls, such as the "Elie Blizzard" scenario (see Winnipeg to Portage La Prairie to Brandon section), are most common over southern Manitoba during the late fall, but can still develop in mid winter. This is usually a small-scale phenomenon that happens when a northwesterly flow over the large lakes is strong enough to create large openings (leads) in the ice cover. The resultant injection of heat and moisture produces snow streamers downwind. Because of the large amount of snow generated along a narrow swath, localized blizzard conditions are easily achieved when the wind further lowers the visibility with blowing snow.

Arctic outbreaks plague Manitoba throughout the winter. Generally, along the cold front which normally marks the leading edge of this cold air, flurries will occur and flying conditions will be, at best, marginal for a short time. Of equal concern to aviation are the gusty northwest winds that develop north of the front which often produce significant mechanical turbulence in the low levels and cause blowing snow, especially in areas where there is fresh snow cover.

Transitional Seasons

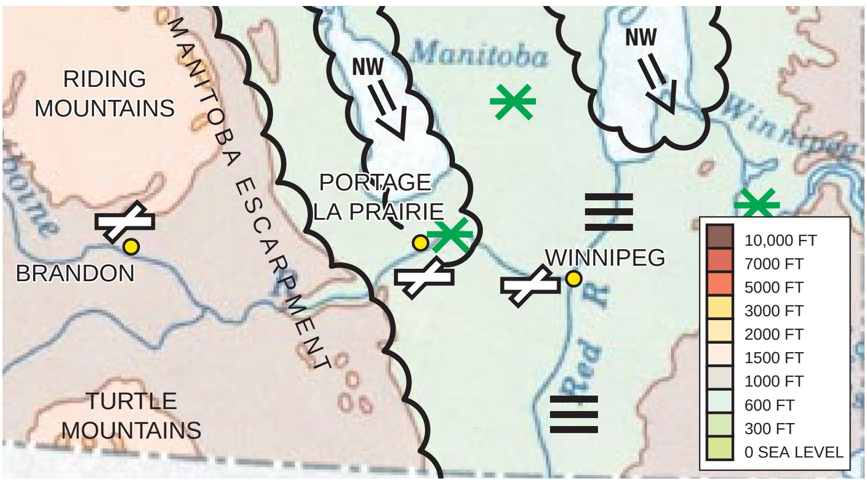
Spring and fall are both short and provide unreliable flying weather in Manitoba. Often the south is beset by late spring snow storms, and the Red River Valley occasionally floods. Both seasons bring an increased occurrence of fog and stratus, especially in the north where the abundance of trees and lakes can trap and hold the low-level moisture for extended periods. In general, there is a more plentiful supply of low level moisture in the transitional seasons. In the spring, evaporation from snow melt and a greater frequency of upslope northeasterly winds provides the moisture. In the fall, it is supplied by Manitoba's numerous lakes.

Manitoba is a windy province, and spring and fall are its windiest seasons. The strongest winds are unvaryingly northwesterly, but this is not the most prevalent direction. In the spring, it is north to northeasterly, and in the fall, westerly winds are most common. Mechanical turbulence is usually present in the lower two to three thousand feet of the atmosphere on windy days but is seldom severe. However, it is often enough to shake smaller aircraft, particularly in the southwest where rough terrain enhances and deepens the turbulent layer.

The "Land of 100,000 Lakes" is, of course, susceptible to the development of snow streamers in the fall. This is mitigated somewhat in the north as most of the lakes are quite small and stretched in a southwest to northeast direction. This orientation limits the distance, or "fetch", that cold northwesterly winds span over the water surface. However, there are several larger lakes in the north and, of course, Lakes Winnipeg, Manitoba, and Winnipegosis in the south, that are particularly well known for streamer development.

Local Area Weather

Winnipeg and Area



Map 4-32 - Winnipeg and area

Winnipeg is located in the middle of the wide, shallow, north to south valley of the Red River. The smaller Assiniboine River also flows into the city from the west, meeting the Red River in the centre of the downtown area. The combined flow of the two rivers then heads north-northeastward to Lake Winnipeg. The city of Winnipeg is about 45 miles southeast of Lake Manitoba and 40 miles south-southwest of Lake Winnipeg. The area has a decided preference for southerly winds; not surprising, as any winds from the south tend to be channeled along the Red River Valley. The valley carved by the Assiniboine River is slight and does not influence the local flow. Northwest is the second most frequently occurring wind direction for Winnipeg, most notably in the winter. North to northeasterly winds are also common as some channeling will occur in the valley north of the city. Winds from other directions are quite rare and usually light.

Radiation fog is extremely rare in Winnipeg and its few appearances are usually in the spring, when the snow is melting and there is plentiful low level moisture. There are more occurrences of ice fog in winter because of the prolonged periods of very cold temperatures, not to mention the usual particulate matter common in large urban centres. Winnipeg frequently sees large deposits of hoarfrost during these ice fog events. If this is the case, the fog can be slow to lift as the sublimation of the hoarfrost feeds moisture back into the atmosphere. Cold air entrenched in the Red River Valley is difficult to remove. Warmer flows from any direction tend to overrun the cold pool, and the process of eroding the inversion can be markedly slow.

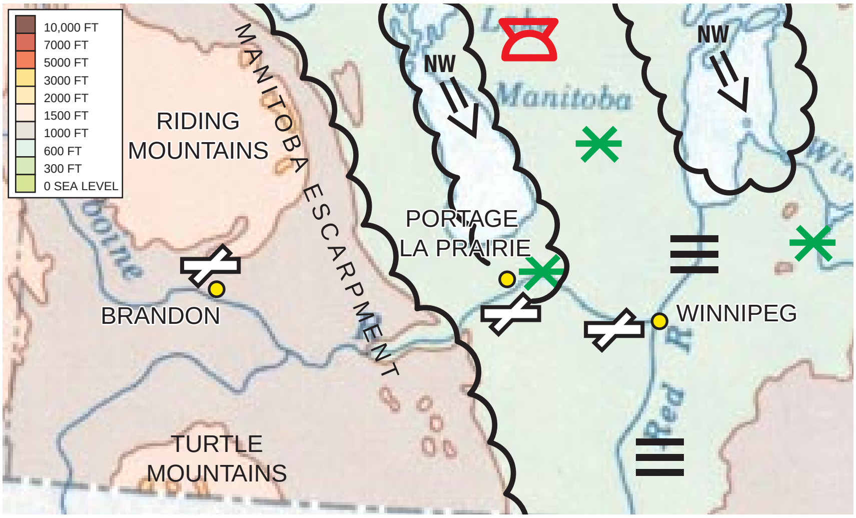
While radiation fog is uncommon, advection fog is not. It is usually associated with low stratus and almost invariably invades from the south, travelling within the confines of the Red River Valley. Its passage down the valley can happen quite quickly, but it is possible to get advance warning by watching for the development of low conditions at Grand Forks and Emerson. If the southerly flow is strong enough, it will diminish the likelihood of fog, but may still advect in a deck of low stratus. Less frequently, fog can also move into Winnipeg with a northeasterly flow off Lake Winnipeg.

Even though the Red River Valley is very shallow, it does have a marked effect on the weather. Winds with a north or south component are channelled and strengthened within the confines of the valley. This increases both mechanical turbulence in the low levels and the frequency of reduced visibility in blowing snow in the winter months. Southerly flows are likely to be much stronger than the synoptic situation would indicate, especially if the flow in the lower portions of the atmosphere is also brisk and aligned from the south. Also, because of the valley sides, winds from the west and the east are downslope and are less likely to produce low flying conditions. Westerly winds give the best flying weather over the Winnipeg area. Easterly flows are trickier for two reasons; both because they are often associated with the moist flow on the north side of a low pressure system, and because they are generally upslope over southern Manitoba. If a moist east to northeast flow does bring stratus into Winnipeg, then it can be expected to persist until there is a change in the wind direction.

A large portion of the precipitation that falls in Winnipeg is attributable to the passage of Colorado Lows that are described in the climate portion. Rainfall from thunderstorms is also a major contributor in the summer, and Winnipeg is especially known for the nocturnal variety. Snow squalls from Lake Manitoba and Lake Winnipeg can dump copious quantities of snow over areas around Winnipeg, but they usually miss the airport and city itself. The required condition for their initiation is a cold north to northwesterly flow, and this will give the streamers a trajectory that will take them east of Winnipeg if they form off Lake Winnipeg, and west of the city if they form off Lake Manitoba.

In the fall months, a pilot flying around Winnipeg must be on the lookout for areas of reduced visibility due to smoke from stubble burning. This is a frequent practice of local farmers that usually starts in late August and continues to the end of October. If there is low level moisture in the vicinity of the burning, particulate matter provided by the smoke can aid or initiate the formation of stratus.

Winnipeg to Portage La Prairie to Brandon



Map 4-33 - Winnipeg to Portage La Prairie to Brandon

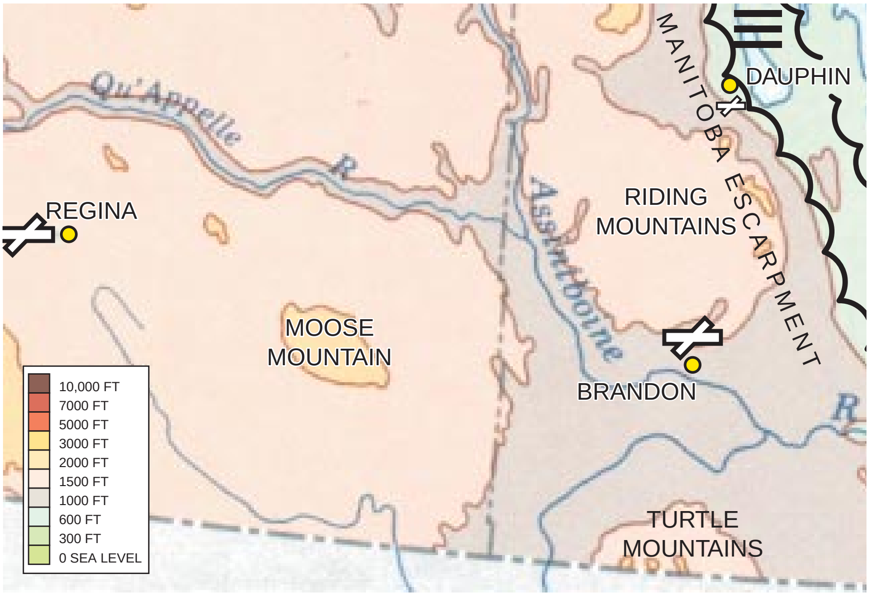
The land between Winnipeg and Brandon slopes gradually upwards towards the west with a gain in elevation of over 560 feet by the time Brandon is reached. Naturally, an east to northeast flow is the most likely to give prolonged stratus due to the upslope component. It is quite normal to see deterioration in ceiling heights from east to west under such conditions. To the west of Portage La Prairie, ceilings and visibilities tend to deteriorate markedly near Austin because of terrain height increases and can become quite low further west over the Carberry Hills. These hills are quite distinctive as they are comprised of sand and gravel, and their gently rolling slopes can trap stratus in an easterly flow and hold it in the area. Flying further west towards Brandon, terrain rises become quite significant on the north and south sides, but a safe and reliable route is found along the lower terrain of the Assiniboine Valley.

Encountering snow streamers or snowsqualls, on a flight from Winnipeg to Brandon, is a distinct possibility, from fall to spring, when the flow is northwesterly. The locally heavy snowfalls are the result of cumulus and towering cumulous embedded within a larger area of stratocumulus cloud, so the hazards to aviation are threefold; pockets of very low visibility in snow flurries, significant turbulence, and mixed icing throughout the entire region of cloud.

Streamers off the Lakes Winnipeg and Manitoba follow a fairly predictable path. Those from Lake Manitoba tend to give the highest snowfalls to the area between

Winnipeg and Portage La Prairie, and those from Lake Winnipeg to areas east of the city of Winnipeg. It is rare that the cells will persist beyond about 20 miles south of the Trans Canada highway. In either case, Winnipeg is generally safe from this effect. The worst hit area is often centered around the tiny town of Elie, located halfway between Portage La Prairie and Winnipeg. This small area not only receives the greatest amount of lake effect snowfall, it is also a very open region where winds can blow unimpeded. Visibilities near zero in blowing snow are common, even after the snow has ceased to fall. Pilots should watch for the presence of this phenomenon, known locally as the "Elie Blizzard", particularly when the wind direction is anywhere between 320 and 350 degrees true and the temperatures are cold.

Brandon and Westward



Map 4-34 - Brandon and westward

The city of Brandon is nestled in the west to east valley of the Assiniboine River on the river's south side, and the airport is about 3 miles north of it. From the Assiniboine River valley northward, the terrain slopes gradually upward, reaching the tops of the Riding Mountains at 2,200 to 2,300 feet, some 50 miles north of Brandon. The Minnedosa River Valley interrupts this rise in the terrain, about 20 miles north of the airport. From the Assiniboine River valley southward, the land is fairly flat for about 10 miles and then rises into the Brandon Hills about 20 miles south of the airport. Farther south, near the American border, is the much more significant rise of Turtle Mountain.

A northwest flow is very favourable for Brandon as any weather associated with it is weakened by subsidence off of the Riding Mountains. The second most favoured wind direction in Brandon is northeasterly, important because it is an upslope flow that is quite capable of producing stratus. The majority of stratus events for Brandon are confined to the fall and are associated with this northeast to east flow. If the airport is reporting marginal to good ceilings in stratocumulus, it must be kept in mind that conditions could be much lower over the higher terrain on virtually all sides.

Because the city of Brandon is in a river valley, it does get radiation fog, but it is not overly common at the airport. In the spring-time, with an east or southeasterly flow, melting snow in North Dakota can supply enough low level moisture to give wide-spread stratus across North Dakota and southern Manitoba. This low cloud can last 5 to 6 days and be the cause of significant accumulations of rime ice.

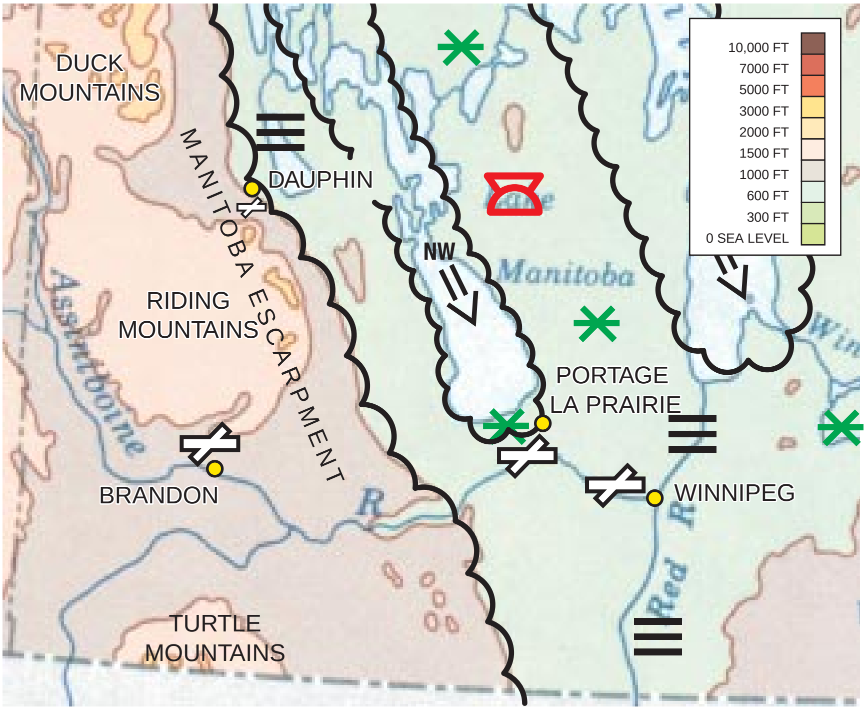
The summertime brings frequent convective activity in the region around Brandon. The convective cells have a tendency to form in areas to the south and southwest but, due to the prevailing west to northwesterly flow, they will frequently miss the airport and stay south of Highway 2.

While there is not much pollution or industry in the area, Manitoba Hydro and a fertilizer plant have smoke stacks on the southeast side of the city. The condensation nuclei from these can contribute to stratus development and lower ceilings if the flow is from the southeast.

Flying west from Brandon, it is usually advisable to stick to the lower terrain of the Assiniboine River Valley which takes a turn to the northwest about 50 miles west of the city. Right at the Manitoba/Saskatchewan border, the Qu'Appelle River joins the Assiniboine River, making the valley of the Qu'Appelle an easy visual landmark to follow on a westbound route.

South of the valley of the Assiniboine and Qu'Appelle Rivers, and about 60 miles to the west of Brandon, the Moose Mountains rise some 400 to 500 feet above the surrounding terrain. These mountains start near Virden and carry on as far west as Fort Qu'Appelle. If the Brandon, Yorkton, Estevan and Regina observations are showing a lower deck of stratocumulus in the region, then conditions can be very low over the Moose Mountains. If the flow is from the east or northeast, ceilings could even be close to the ground over the highest points of land.

Brandon to Dauphin

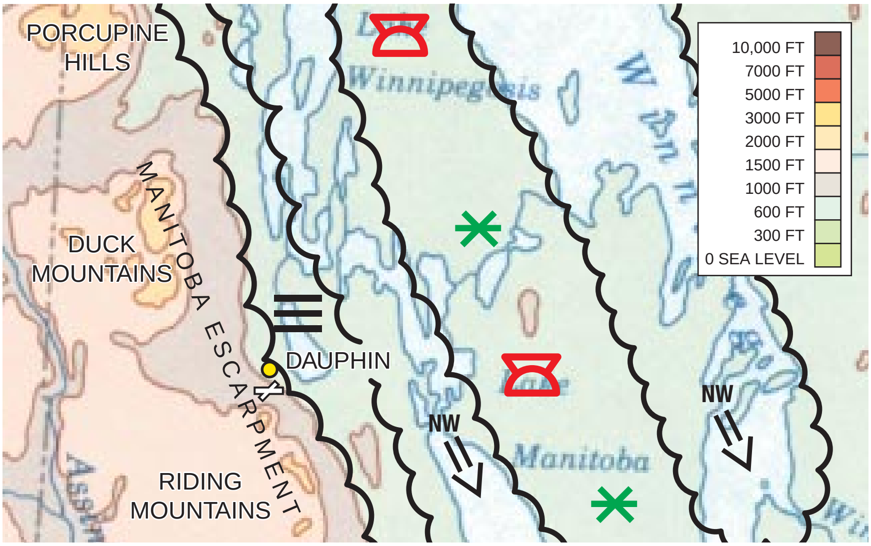


Map 4-35 - Brandon to Dauphin

Brandon's elevation at 1,341 feet above sea level is actually higher than that of Dauphin at 1,000 feet, due to Dauphin's location within the lower terrain of the basin formed by Lake Manitoba. However, the Riding Mountains stand as a barrier between the two and rise a considerable 1,200 feet above the elevation of Brandon. Whatever ceilings are reported in Brandon, it is necessary to subtract at least 1,000 feet to get representative ceilings over the Riding Mountains.

The Minnedosa River runs from the town of Rivers northeastward through Minnedosa, 30 miles north of Brandon. The associated valley has fairly steep sides and tends to trap stratus for extended periods of time. The absence of stratus in Brandon is no guarantee that it won't be encountered in the Minnedosa Valley. The valley can also be an area of frequent low level turbulence, especially with a northwesterly flow and on convectively unstable days.

Dauphin and Vicinity



Map 4-36 - Dauphin and vicinity

The town of Dauphin is in a broad valley between the Duck Mountains, rising 25 miles to the northwest, and the Riding Mountains, stretching across the southern horizon. The northern escarpment of the Riding Mountains is a mere 5 miles south of the airport, which is situated on the south side of the town of Dauphin. To the east of Dauphin, the terrain slopes gently downwards towards the shore of Dauphin Lake, some 8 miles east of town. Dauphin Lake then drains into Lake Winnipegosis, a larger and very shallow lake well to the north. Further east of Dauphin Lake, the terrain continues to lower towards the large basin area of Lake Manitoba. The airport is at 1,000 feet ASL, but elevations rise precipitously over the northern escarpment of the Riding Mountains just to the south. The highest peak within the Riding Mountains is just 9 miles south of the airport, and it has a height of 2,200 feet above sea level. Because of the complicated terrain around Dauphin, the weather reported from the auto station is frequently not indicative of the surrounding area.

To the west of Dauphin, the terrain is wide open and part of the valley between the Duck and Riding Mountains. Winds are channelled through this passage and the strongest are from the west to southwest. Luckily for the Dauphin Airport, southwesterlies also bring the best weather conditions.

Often when light west to northwest winds are indicated for Dauphin by the synoptic pattern, the winds can make an unexpected shift to the east and be surprisingly brisk. There are two factors at play here: heating of the nearby slopes and lake effect breezes. On a sunny day, the east slopes of the Riding Mountains will heat faster than their surroundings causing air to rise locally. To the east over the lakes, the air is being cooled by relatively cold waters causing it to subside. This produces a low level circulation pattern as the denser, cooler lake air will move westward into the region where the warm slope air is rising. This can produce an easterly wind of up to 15 knots.

The worst weather conditions, at least in terms of flying, will generally occur when there is a low pressure system situated over Hudson Bay. This gives a north to northeasterly flow of moist air from Hudson Bay over western parts of Manitoba, which provides a good deal of upslope terrain, especially in the Dauphin area. To add to this, there is a further injection of low level moisture from Lakes Winnipeg, Manitoba, and Winnipegosis, and the marshy terrain that surrounds them. Very low conditions can also occur when a low passes to the south of the area. The moist easterly flow to the north of the low is further saturated by upslope terrain and by moisture from Lake Manitoba.

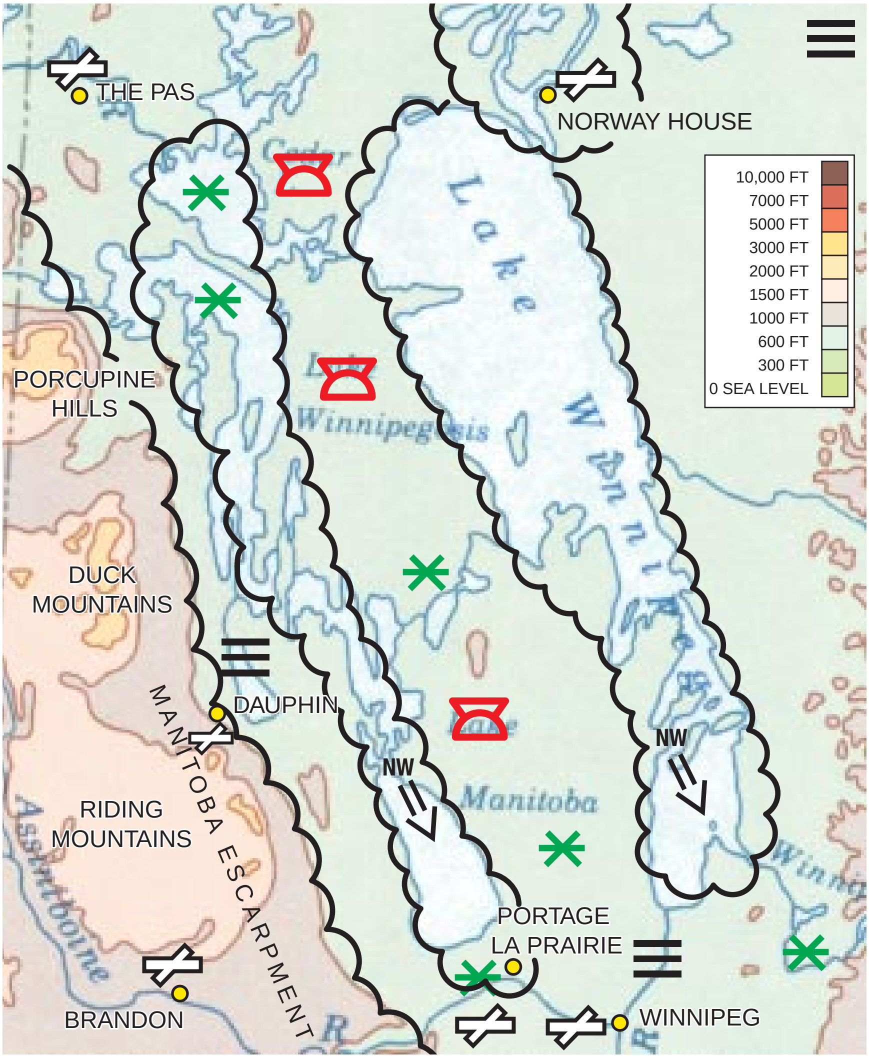
The eastern slope of the Riding Mountains is quite steep, so with a fairly strong west to southwesterly flow it is possible to have Chinook effects. This flow actually produces a small lee trough east of the hills with southeasterly winds on the east side of the trough and westerlies to the west. It is difficult to detect the presence of this phenomenon, as the only observation site in the area is the auto station at Dauphin; too far north to be in the lee trough. Often, however, low level standing lenticular cloud forms about 10 miles east of the mountains, and significant subsidence warming occurs. Both are a sure indications of the presence of the downslope flow. Regardless, a strong west to southwesterly flow should always be regarded with caution as it can generate, or add significantly to, turbulence on the lee side of the hills, up to about 5,000 feet ASL. As one would expect, the same effect can be felt on the eastern slopes of the Duck Mountains. The most common area for the "Dauphin Chinook" to be felt is from Cowan in the north to McCreary in the south.

Radiation fog does not occur very often at Dauphin. On clear nights with light winds, a drainage wind tends to develop off the escarpment to the south that will prevent fog from forming. There is, however, some possibility of fog being advected into the airport area by an upslope northeasterly flow off of Dauphin Lake. This is most likely to occur in the late summer and early fall.

It is possible, with a persistent northeast flow off the lakes to the east of Dauphin, to generate a continuous band of very low stratus that begins near Sifton, about 15 miles north of Dauphin, and extends southward. To the north of Sifton, ceilings are generally much better. This pattern is much more likely in the spring and fall when the lakes are open and the lower atmosphere is not as dry.

Thunderstorms typically form in the regions to the west of Dauphin, under a southwest or northwest flow. They frequently diminish in intensity before reaching the town and airport due to the effects of subsidence.

The Interlakes Region



Map 4-37 - The Interlakes region

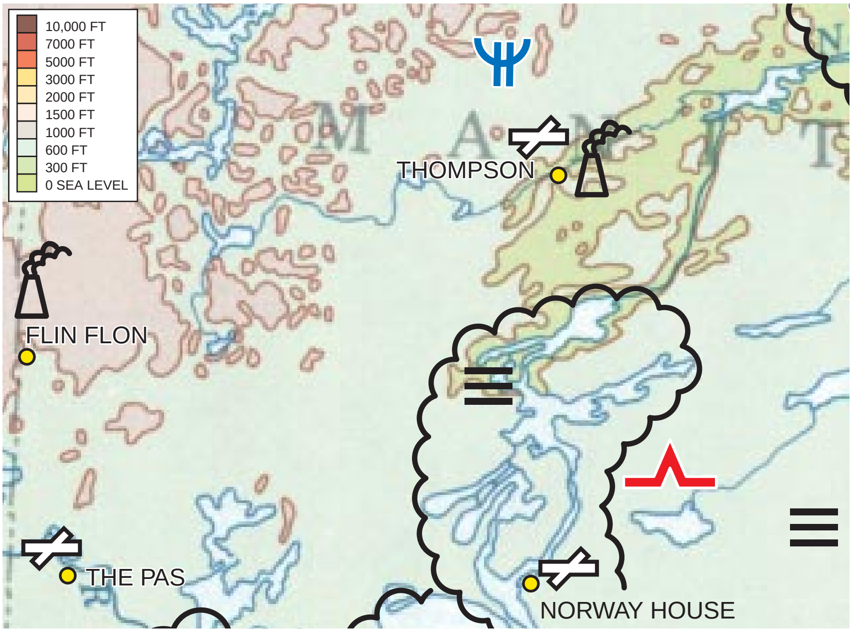
The Interlake refers to the area between Lakes Manitoba and Winnipegosis on the west and Lake Winnipeg to the east. Carved by the last glacial passage over Manitoba, the lakes are long, shallow, and irregularly shaped, stretching from the north-northwest to the south-southeast. The large basin-like depression around the lakes is mostly marsh and bog lands, interspersed with many smaller lakes, and is virtually uninhabited except for the extreme southern end.

The three larger lakes are big enough to set up sea breeze circulations producing quite variable winds throughout the area. This has a significant effect upon convective patterns on warm summer days. The air over the water is cooled in the low levels, producing subsidence that keeps the skies over the lakes completely clear. On the east and west sides of the large lakes, however, there is enhanced development of convective cells where lake breezes have established a line of convergence with the environmental flow. This is especially magnified in the Interlake region as the lake breeze from Lake Winnipeg impacts with the lake breeze from Lake Manitoba. Small cumulus or towering cumuli are the norm, but large thunderstorms are quite possible if there is enough instability. The cells will usually dissipate if they move away from their source area.

In the spring and fall months, snow squalls are also a distinct possibility over and to the lee of the lakes. The ideal synoptic set-up requires a predominantly ice free water surface and a cool north to northwesterly flow, with the air temperature at least 10 degrees Celsius colder than that of the water. If the air is very stable, a widespread area of cumulus and stratocumulus cloud will be formed giving snow flurry activity. However, more often, towering cumulus cells will develop producing localized areas of moderate to heavy snow, or ice pellets and mixed rain and snow. In a few cases, the air will be unstable enough to form small cumulonimbus cells up to about 20,000 feet. Low visibility is not the only concern within a band of snow streamers; this is the perfect environment for convective turbulence and moderate to severe mixed icing.

With any synoptic scale low pressure system passing south of the region, the already moist easterly flow to the north of such a feature can be further saturated by passage over the Interlake area. This is only true as long as the lakes are open, which in general tends to be from early May to the first week of November. Expect ceilings to be considerably lower to the west of the larger bodies of water.

North of the Lakes - The Pas - Flin Flon - Thompson



Map 4-38 - North of the Lakes - The Pas - Flin Flon - Thompson

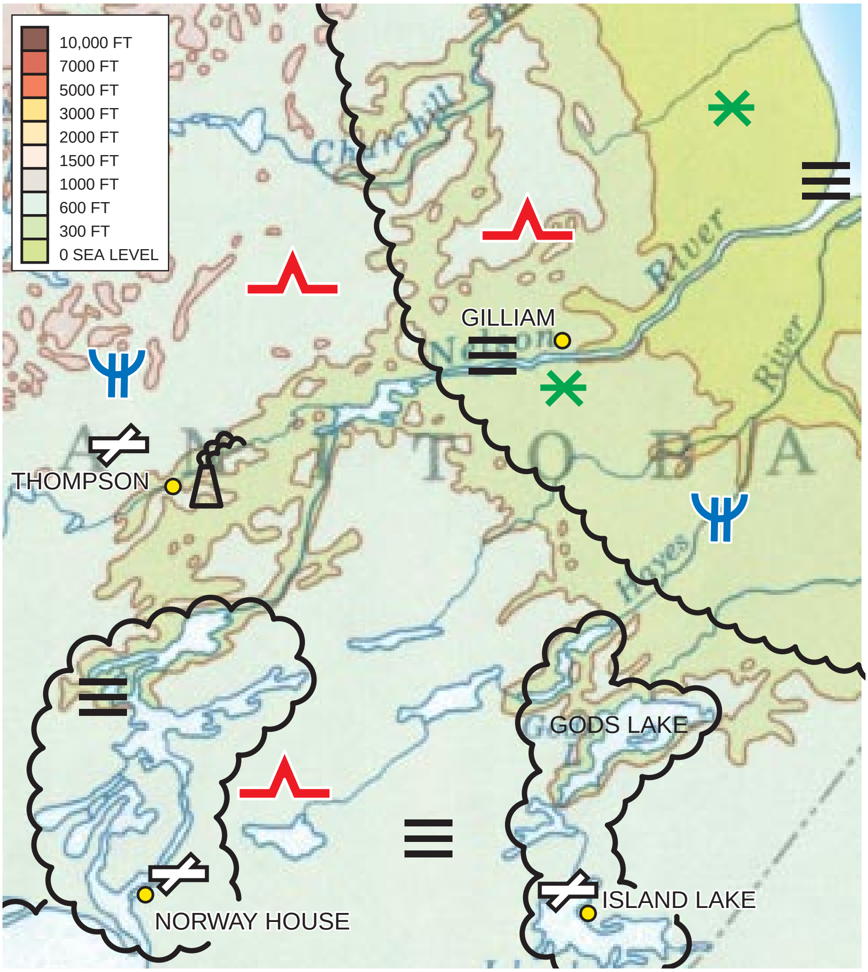
Elevations fluctuate only slightly over this area, averaging about 850 feet ASL, and ranging from about 1,200 feet northeast of Flin Flon to about 600 feet near the lakes south of Thompson. From spring through late fall, moist east to southeasterly upslope flows can cause deteriorating conditions, especially for points northwest of Snow Lake, and moisture picked up off Lake Winnipeg can further aggravate the situation.

Vegetation is predominantly mixed boreal forest that provides some shelter from strong winds. Winter "white-outs" are rare, but low level wind shear and/or mechanical turbulence below 4,000 feet ASL are quite common during strong wind events.

There are several large lakes in the Flin Flon - The Pas area. The largest, including the huge Cedar Lake Reservoir and Lake Winnipegosis, are southeast of The Pas. The Pas Airport is located just south of Clearwater Lake, which is roughly 12 miles across. The area is susceptible to local fog and stratus, especially in the spring and fall. Extensive streamer activity can occur over and southeast of these lakes in the fall, when the winds are cold and from the northwest.

Flin Flon is one of several mining towns in northern Manitoba and is the site of a large copper/zinc smelter, located on the western outskirts. The stack discharge adds particulates to the atmosphere which, at times, can contribute to fog formation, especially when a strong low level inversion exists.

Norway House - Island Lake - Thompson



Map 4-39 - Norway House - Island Lake - Thompson

This region exhibits one of the smoothest topographies in Manitoba, with elevations staying uniformly near 750 feet ASL. There are a few widely scattered hills reaching as much as 200 feet above the surrounding terrain and a few water surfaces dipping 100 feet or so below. The area, covered by mostly coniferous boreal forest that thins only over the northeast, is peppered with lakes and muskeg. The region, much like the rest of northern Manitoba, is plagued by ample surface moisture and poor drainage. Fog and stratus are most common during the transitional seasons, especially when there are moist flows from the northwest through north to southeast. The Norway House and Cross Lake districts are particularly vulnerable, due to large expanses of water and muskeg near the upper reaches of the Nelson River, as are the areas adjacent to the two largest lakes in the area, Gods Lake and Island Lake.

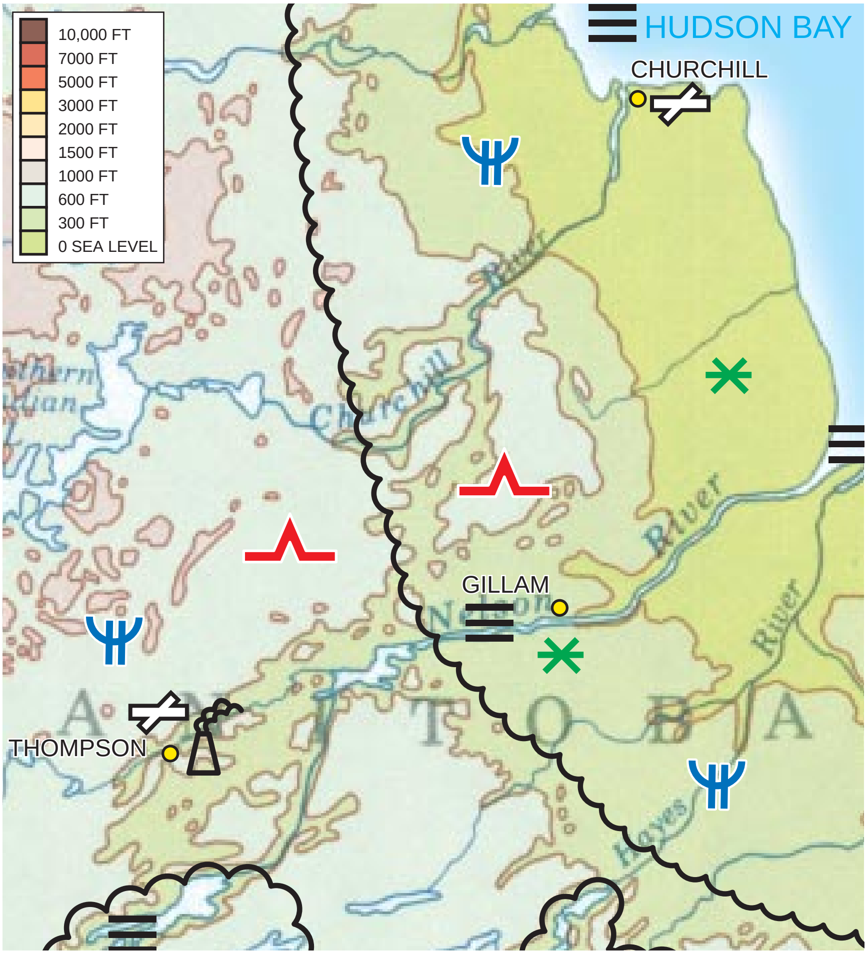
Primary aerodromes in this sector are all very close to (or surrounded by) water, so freeze up (early to mid November for smaller lakes, December for Lake Winnipeg) and break up (mid to late April) are significant controls for the weather.

Even though Hudson Bay is at a considerable distance, it still has an influence on the weather in this region. Thick blankets of stratus and fog can develop over the bay at any time of the year, but most notably from June to December. Northeasterly onshore flows advect this "blanket" inland, usually about 150 miles, affecting the lower Gods River valley and Shamattawa areas. It can, however, under a persistent northeasterly flow, reach Gods Lake and Thompson. Often these regions of stratus present an icing problem; if temperatures within the cloud fall in the range of zero to -15 °C, then moderate mixed icing is common, and severe mixed or clear icing is possible.

There are no preferred areas of summertime convective development. Thunderstorms, usually moving from west to east, tend to live out their life cycle in a reasonably predictable fashion. Fair weather currents of buoyant and subsiding air along forest/lake boundaries can interact with the environmental wind and sometimes cause significant turbulence up to 4,000 feet ASL.

Even though drainage in the region is poor, there is so much water to move that several of the rivers have sections of rapid flow that often do not freeze over in winter. The presence of open water at this time of year can create local pools of evaporative fog or ice fog, especially when temperatures are very cold and winds are light. Two notable places where this phenomenon commonly occurs is around the strip and float plane facilities at Gods Lake Narrows and near the village of Gods River.

Thompson and Area



Map 4-40 - Thompson and area

Thompson is the transportation hub of northern Manitoba. The city's airport is the second busiest in the province with several companies providing scheduled and charter service to and from Winnipeg, and to many other communities in northern Manitoba and southern Nunavut. Thompson also boasts an active float plane and helicopter base on the Burntwood River and is a principal railway depot on the line serving Churchill. A huge nickel mine and smelting operation, located on the southern outskirts of the city, is a major supporting industry.

The Thompson Airport, located about 4 miles north of the city, is built on what is locally described as "a swamp." As with much of the terrain in northern Manitoba, the ground does not drain well naturally, although recent ditching around the runways has improved the situation. Nonetheless, local ponds and muskeg, the northern reaches of Birch Tree Lake just to the west, and a generally high level of soil humidity, give a ready supply of low level moisture outside of the winter months. Frequently, during shallow fog events, the worst conditions tend to occur within the local control zone. In fact, it is often noted that the lowest conditions are encountered on final approach to the main runway from the west. This is most likely due to the proximity of Birch Tree Lake as well as particulate discharge from the nearby gravel pit and asphalt plant. The fog can sometimes extend outward along the Burntwood River valley nearby. However, fairly often, the float plane base on the river near the town is not affected. Another problem attributed to ground moisture is the tendency for the paved surface of the main runway to be somewhat unstable. Freeze and thaw cycles create dips and heaves that require constant repair by maintenance crews.

Seasonal weather conditions are generally fairly predictable. Since much of the system weather affecting Thompson approaches from the west, observations from Lynn Lake and The Pas make good upstream indicators. Lynn Lake is especially useful for timing cold frontal passages behind low pressure systems. Gillam provides advanced notice of weather approaching from the northeast or east, but since a flow from Gillam is upslope, there could be some further deterioration by the time it reaches Thompson.

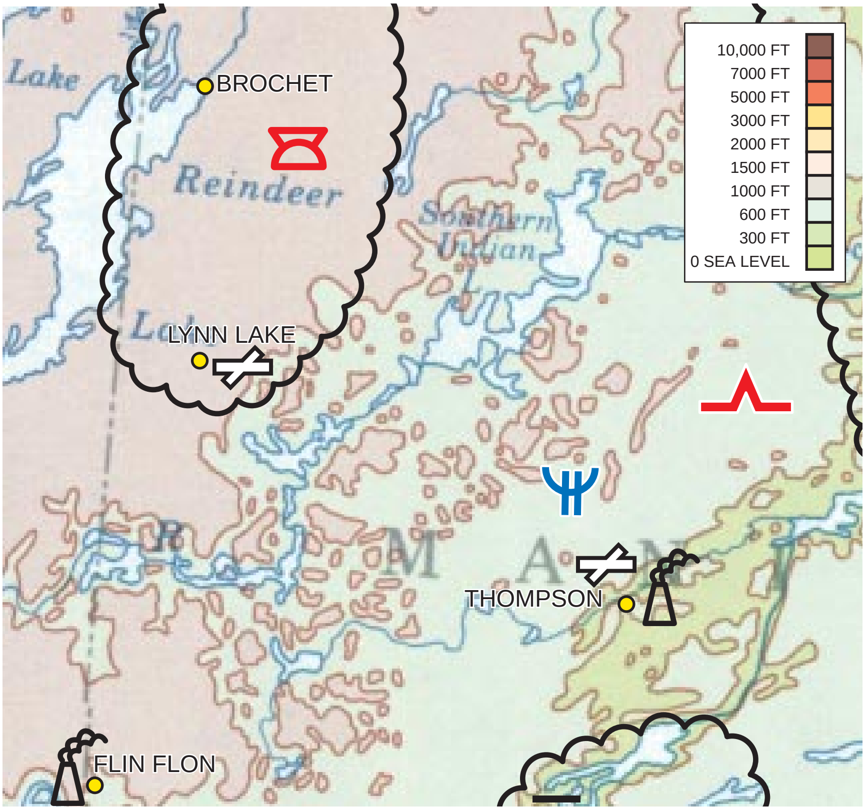
Summer is short, but it tends to be pleasant and possesses the greatest percentage of good flying weather of all the seasons. Cumuliform cloud is very common and convective currents cause some turbulence up to about 4,000 feet ASL. Combined with gusty surface winds, this turbulence can be significant below 1,000 feet above the ground, especially along lake/forest boundaries. Severe convective weather can be expected once or twice each year, especially in June and July when evapotranspiration from the surrounding vegetation is at its peak. Locally, there are no preferred areas for convective development.

Winter is the time when strong, arctic high pressure systems move or build across this area from the north or northwest. They bring gusty west to northwesterly winds, very cold temperatures, and very pronounced surface based inversions. These inversions can act to trap exhaust moisture and particulate matter from aircraft and auto engines, from the local smelter, and from wood burning heaters used in many of the local households, resulting in locally reduced visibilities in ice fog. Ice crystals are usually present and can be large and heavy enough to cause a significant reduction in visibility, as well as accumulate to measurable amounts. To complicate matters, Manitoba's most northern ski resort is located about 4 miles north of the airport. When snow making operations are underway and the winds are from the north, visibility can be reduced by crystals carried downwind.

Typical winter storm tracks tend to carry eastward-moving low pressure systems south of Thompson. This is significant as snowfalls are frequently at their heaviest north of these lows, not to mention the enhancement of low level moisture created by the east to northeasterly flow. The strongest winds will generally occur in the northwesterlies that develop after the centre of the system has passed eastward, but luckily for Thompson, the surrounding forest provides enough shelter to diminish the winds and minimize the occurrences of blowing snow. Freezing precipitation is not uncommon, with an average of roughly two events per month during the winter. These events are not triggered by classic surface warm front situations as these tend to pass well to the south of Thompson. What happens, instead, is an upper warm front develops well north of the surface front, as the warm air in the south overruns the firmly entrenched arctic air at the surface. The rising warm air can generate liquid precipitation that falls through the much colder layer below. The icing created by such an event can be extremely tenacious as there is rarely any subsequent surface warming to cause melting.

As with most communities across the northern Prairie provinces, the trickiest weather occurs during the transitional seasons of spring (late March to mid May) and fall (late September to early November). During these periods, a greater number of storms move across the area. Cold northwesterly flows inevitably develop behind these systems and are quickly saturated in the lowest levels by moisture from melting snow in the spring, and from the warmer water of the many lakes and muskegs in the fall. Poor flying conditions usually persist until the flow pattern changes to a warmer southerly direction. Fog is most common during the transition seasons, and is considered the biggest obstacle to aviation activities in the Thompson area. A local rule of thumb for classic radiation fog (usually occurring with a ridge of high pressure, giving clear skies and light winds) puts the time of dissipation at around 10:00 a.m. The last traces of fog are usually gone by 11:00 a.m. However, if other processes, such as evaporation or advection, formed the fog and stratus, it can be much more persistent and sometimes requires a complete change in air mass to dissipate, showing only marginal diurnal improvement. The addition or removal of local moisture sources is important to consider when assessing the threat of fog. Lakes and muskeg in the area are usually frozen over by mid-November. The snowmelt begins in April, and ice on the lakes starts to break up during the latter half of that month. Large diurnal temperature swings in early fall and late spring are common in the area and can cause additional difficulties; rainfall during the day often falls on ground that has not yet warmed to above freezing temperatures after a cold night. The result is hazardous and widespread ice formation on roads, runways and other surfaces. Finally, the worst airframe icing conditions usually occur during spring and fall, when thick low cloud is present at temperatures in the zero to -15° C range. Mixed and rime icing are common but significant clear icing is relatively rare.

Thompson - Lynn Lake - Northwards



Map 4-41 - Thompson - Lynn Lake - Northwards

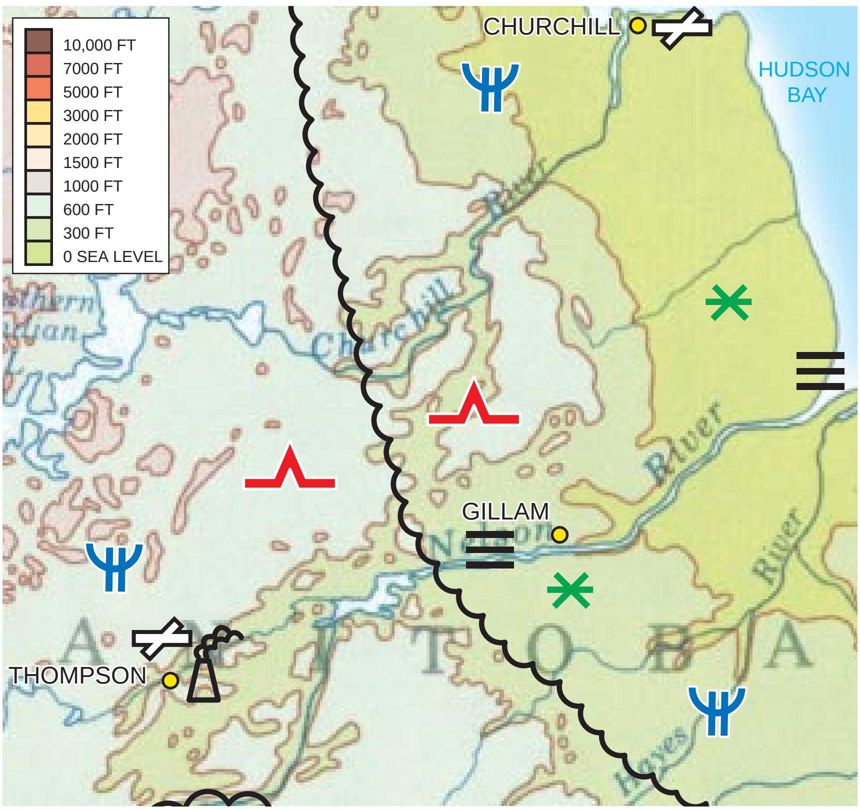
This route follows highway 391 along a gradual incline from the Burntwood and Nelson River Valleys across the Churchill River Valley, to the higher elevations of northwestern Manitoba. Surface characteristics in the area are, for the most part, similar to those around Thompson; a profusion of lakes and muskeg with ample surface moisture. However, there is some ruggedness north of Lynn Lake due to a multitude of eskers and other glacial leavings. Easterly winds are effectively upslope with elevations increasing roughly 600 feet between Thompson and Lynn Lake. Under the influence of such a flow, lower ceilings can be expected in the Lynn Lake area and to the north, but these differences are usually not very great.

Trees become more spotty and stunted as one progresses further north to places like Brochet and Tadoule Lake. Because of this, surface winds tend to be stronger in these areas and there is a greater susceptibility in winter to periods of reduced visibility in blowing snow. Moderate mechanical turbulence below 3,000 feet above ground is a common occurrence, especially if the winds are from the north or northwest.

The high land near the Saskatchewan border, northeast of Reindeer and Wollaston Lakes, tends to be a preferred place for development or intensification of convective cloud when the area is under the influence of a southwesterly flow of unstable air. Topographical effects and added moisture from these large lakes are probably responsible for this phenomenon.

In the fall, northwesterly flows of cold air across the warmer water of Reindeer and Wollaston Lakes can generate "streamers" of convective cloud that bring bands of rain or snow showers to the area around Lynn Lake and southward toward Pukatawagan. Extreme and rapid fluctuations in ceiling and visibility can be expected in such conditions. Other lakes in the area, which are generally elongated in a southwest to northeast direction, do not have a similar potential for streamers when the flow is northwest, as the distance or "fetch" across each lake is relatively short.

Thompson - Gillam



Map 4-42 - Thompson - Gillam

The Thompson to Gillam route follows the Nelson River downstream toward Hudson Bay. Elevation decreases roughly 250 feet between the two communities and there are no surprises topographically. Northeast of Gillam, the land follows a similar, but slightly steeper slope to the Hudson Bay Lowlands, which contain the lower reaches of the Churchill and Seal Rivers. The local features of this area are glacially created and include several eskers and some fairly rough debris deposits (one just north of Stephens Lake near Gillam) but, overall, the terrain is fairly smooth.

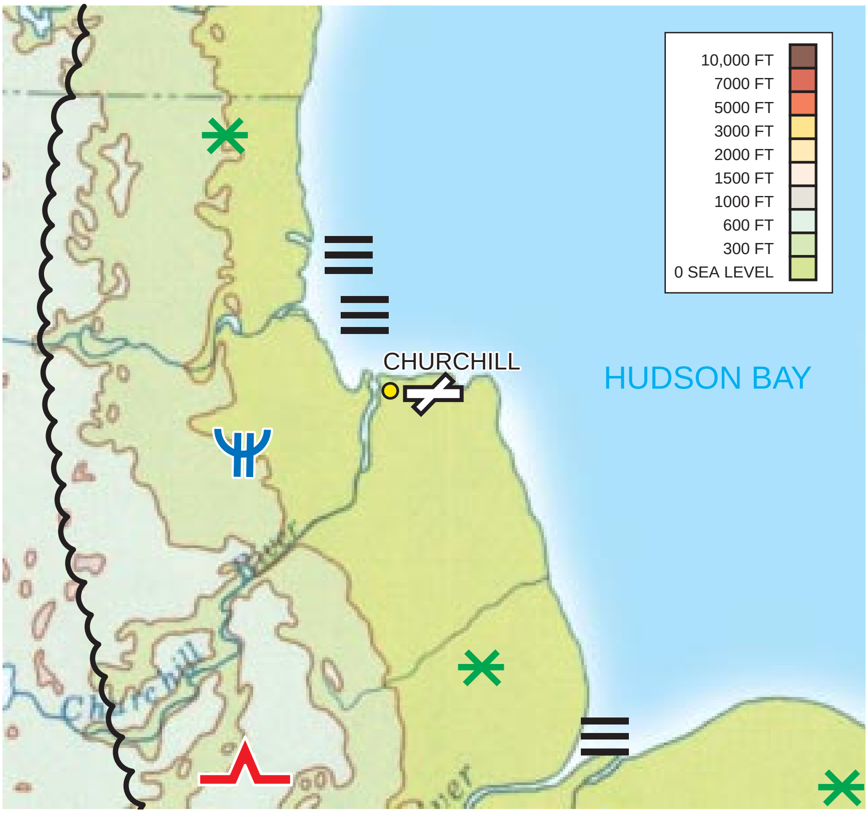
Any winds with an easterly component are upslope over this area, and those from the northeast statistically give the lowest ceilings and visibilities. This is, of course, due to the vast open body of water provided by the Hudson Bay from late spring to early winter.

The Nelson River current is quite strong along this stretch, bolstered by water diverted from the Churchill River system. Hydroelectric installations, two of which are just downstream from Gillam, tap this flow. Many stretches of the river are slow to freeze in the winter and break up early in the spring, especially where rapids exist and in discharges from dams. These stretches, when they are open, are particularly vulnerable to evaporation fog on cold winter days.

Stephens Lake, extending approximately 27 miles west-northwest of Gillam, is a sizable body of water. In the fall, this lake can produce streamers around the Gillam airport during west to northwesterly cold air outbreaks.

Because the forest canopy gradually thins out over the lowlands towards Hudson Bay, that area is more prone to winter blizzard conditions when strong northwest to northerly flows develop behind the deep low pressure systems that frequently traverse the area.

Churchill - Hudson Bay Coast



Map 4-43 - Churchill - Hudson Bay

Churchill has the distinction of being the site of the only major aerodrome in the Prairie provinces that is situated along a coastline. It is also Canada's only arctic seaport. The airport itself sits on a bluff a little over 90 feet above Hudson Bay and is roughly one mile south of the water's edge. The coastline runs about 27 miles due east to Cape Churchill, then south-southeastward toward the mouth of the Nelson River. Just to the west of the airport, the northward flowing Churchill River spills into the bay. It is about 3 miles wide at this point, although it narrows to a channel just over 1/2-mile wide at the mouth itself. A few miles further west is Button Bay, an inlet about 6 miles across. From there, the coastline begins to turn northward toward Arviat.

Topography in the area plays a relatively minor role. The Hudson Bay Lowlands could easily be described as one of the smoothest tracts of land on the Prairies, broken only by the lower valleys of the major rivers that drain into the bay. Muskeg, small lakes, patches of stunted trees and sedge grass cover the landscape. Mechanical turbulence is seldom severe, but can be moderate up to 3,000 feet ASL during episodes of strong winds. Needless to say, the local weather in Churchill (and anywhere else along the coast for that matter) is largely dictated by Hudson Bay itself.

As is the case with any coastal environment, it is critical to have a good idea what constitutes an "onshore" wind and one that flows "offshore". In this region, a general rule of thumb concludes that the weather usually is poorest when winds blow from the water to the land, and is usually better when the opposite transpires. This, of course, depends on many other things, including qualities of the air (moisture content, temperature and stability), temperature of the water, amount and extent of ice cover, but the rule of thumb is a good one. Even though the coastline in the immediate area of Churchill lies roughly west to east, an examination of the larger scale shows it runs, overall, from north-northwest to southeast. Although Cape Churchill protrudes to the east of the town, it is too low and flat to alter the moisture content in east to southeasterly flows. If atmospheric conditions are prone to change, any wind from about 310° through 360° and 90° through 140° traverses enough of Hudson Bay to pick up sufficient additional moisture to cause some deterioration in the weather in Churchill.

Hudson Bay is largely free of ice from the end of July to early November, but open water can be present near the coast at any other time of the year as well. Knowing the location and extent of open water at these "other times of the year" is fundamentally important when trying to understand why certain weather conditions occur under different wind regimes during that time. It is also important to note that water surface temperatures can differ greatly, particularly in summer, between the colder open sea and warmer shallow coastal areas. The surface water is even warmer near the mouths of the major rivers, as it takes some time for the heated, fresh water from the river to mix into that of the bay. As a result, the river outlets are preferred locations for advective and evaporative fog formation when conditions are ripe. This is especially true at the mouth of the Nelson River.

Ice formation and break up cycles on Hudson Bay are quite complex, especially near the outlets of major rivers such as the Churchill River. This is, in part, due to the layering effect of fresh over saline water in these areas. The fresh water is less dense than salt water and freezes sooner. In October, fresh water from the rivers "flooding" the salt water begins to freeze, creating a slushy suspension called "grease ice." Onshore winds cause the grease ice to accumulate along the coast where it freezes into a hard sheet. This event marks the beginning of the formation of stationary "shore-fast" ice that typically extends about 3 to 4 miles out from the coast. Waves, tidal actions and storm surges break this ice up into blocks and slabs, which refreeze into a thicker, rougher surface. Ice does not start to form in earnest over the open sea until the latter half of November. It is hardly a continuous sheet, but rather a jumble of pans or floes that are blown about by the winds and otherwise drift with the counter-clockwise current that is present in the bay. They collide with each other and with the shore fast ice, creating ridges along impact zones that can be 60 feet high. By mid winter, Hudson Bay is basically ice covered, but prolonged winds from a given direction can open up leads that are several miles wide, often along the edge of the shore-fast ice. These leads can persist as long as the winds continue and take many hours, even days, to close or freeze over once the winds abate or change direction. In early June, the break-up of the rivers marks the beginning of the end of the winter's ice over Hudson Bay. The fresh water rushing out floods the ice and eventually cuts a channel through it. Through June and July, the ice gradually recedes, fractures and thaws until it eventually disappears. The area of the bay north of Churchill can be completely cleared of ice fairly early in this period if there is a prolonged southwesterly wind event (4 to 5 days on average) followed by a shift in the winds to the northwest or north. The southwesterly winds push the ice out past Cape Churchill where the current begins to carry it southeastward. If the winds then shift to the northwest or north, the ice is literally driven toward the mouth of the Nelson River and areas to the east, where it tends to remain until it melts.

Summer along the Hudson Bay coast is fairly short. The bay is open and generally covered, at least partially, with low cloud (marine stratum). Northeast to easterly winds will eventually advect this cloud over the lowlands and cause a general deterioration in ceiling. Moderate rime or mixed icing often occurs in this cloud where it extends above the freezing level. On warm sunny days with light winds, a sea breeze circulation can set up and this, too, can cause or advect low cloud several miles inland along the shore. Fog can accompany this low cloud, but normally does not extend too far inland. At the Churchill airport, the northern end of the runway can be completely enshrouded while the visibility at the southern end is unrestricted. Southwesterly to west flows are associated with good flying weather and usually push the marine stratum offshore. Flows that follow the coastline bring variable weather conditions to the area. Summer convection is normally associated with unstable west to southwest upper flows. Cells that affect the area usually form upstream (inland) and move downwind. A few thunderstorms reach the Churchill region each summer. Once the cells move out over the colder surface of Hudson Bay, much of their thermal support is lost and they tend to weaken rapidly if not supported by other dynamic or thermodynamic mechanisms.

During the fall, the local moisture sources are gradually cut off as the rivers freeze over and the shore-fast ice develops. However, easterly winds continue to advect stratus and fog into the area from further out on the bay. Early in the season, strong northwest to northerly flows of cold arctic air (generated by building high pressure areas to the west and/or deep low pressure systems moving across Hudson Bay) become unstable over the warmer water. Widespread low cloud formed in these flows is embedded with bands of convective cells that bring a mixture of precipitation types to the area, resulting in wildly variable ceilings and visibilities at times. Even cool westerly flows can be tricky in Churchill at this time of year, as Button Bay and the Churchill River can provide sufficient fetch for the formation of low cloud and fog around the town. Freezing drizzle is most common at this time of year since the bay is largely open and temperatures are dropping. As the season progresses, substantial snowfalls can occur along the coast, which combine with the strong winds to cause periods of white out conditions. Low level icing associated with the embedded convective cloud or freezing precipitation can be problematic for approaching and departing aircraft. A combination of mechanical and convective turbulence can also cause difficulties. Conditions improve when the winds shift to an offshore direction, cutting off the low-level supply of moisture and heat.

As winter sets in and ice cover extends well out over the bay, the polar bears leave the land to gorge on seals during their annual hunt and overall weather conditions tend to improve. However, winter storms that affect the area usually follow a track that carries them from the south or southeast toward Hudson Bay, where they can remain for several days. These storms are usually accompanied by ridges of high pressure over western Canada. The strong pressure gradient in between the two features generates a long ribbon of strong northwesterly winds along "blizzard alley", which extends from the central High Arctic across northeastern Manitoba into northern Ontario. Since the lowlands are basically devoid of a continuous forest canopy, the area is susceptible to prolonged blizzard conditions. These winds also open huge leads in the pack ice, often just beyond the shore-fast ice, and streamers of low level convection develop downwind. If the winds increase from the east after the northwesterlies subside, these streamers turn with the wind and affect the coastal areas with widespread snowshower activity, especially if the lead is along the edge of the shore-fast ice (i.e. close to shore). If this is the case, a rule of thumb in Churchill states that the lead will close in 8 hours or less if the ice on the other side is visible on the horizon. If it is not, expect the flurries to last until the lead finally closes or the winds shift direction again. Arctic high pressure areas that establish themselves over northeastern Manitoba bring clear skies, very cold temperatures and light winds to the area under a strong inversion. Periods of reduced visibility in arctic sea smoke, ice crystals and ice fog are common during these events. Smoke from refuse burning at Churchill's famous dump, just east of the airport, can aggravate this problem locally.

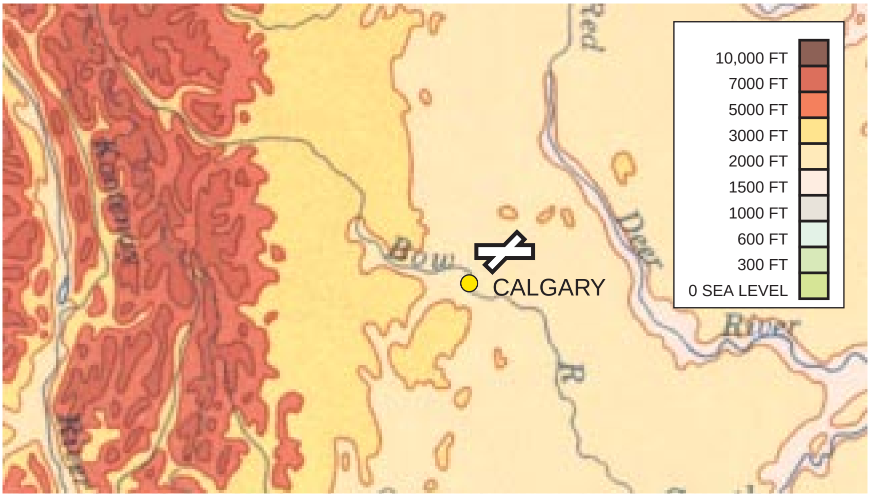
Spring along the coast arrives with snow melt and the opening of the rivers, in late May and early June. There is a rapid increase in local surface moisture sources as the rivers flood the ice on the bay. Fog is common over and downwind from the rivers and over pools of meltwater on the ice. The Churchill airport is often affected by fog off the Churchill River when winds are light westerly, during the spring. As the sea ice retreats, larger and larger expanses of open water gradually return the general weather trend to an oscillating marine stratum scenario, as winds shift from onshore to offshore and back. The polar bears come back, too.

Chapter 5

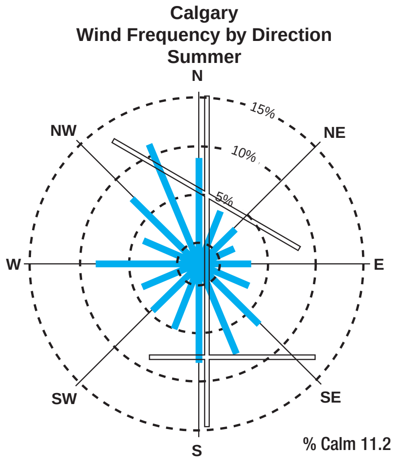
Airport Climatology

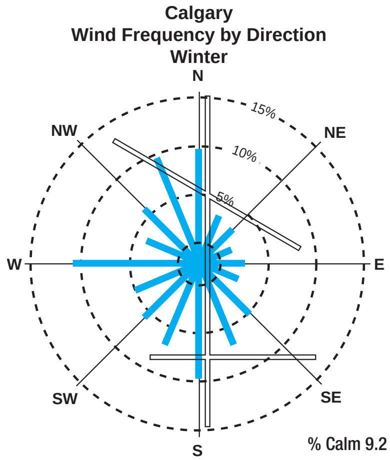
Alberta

(a) Calgary



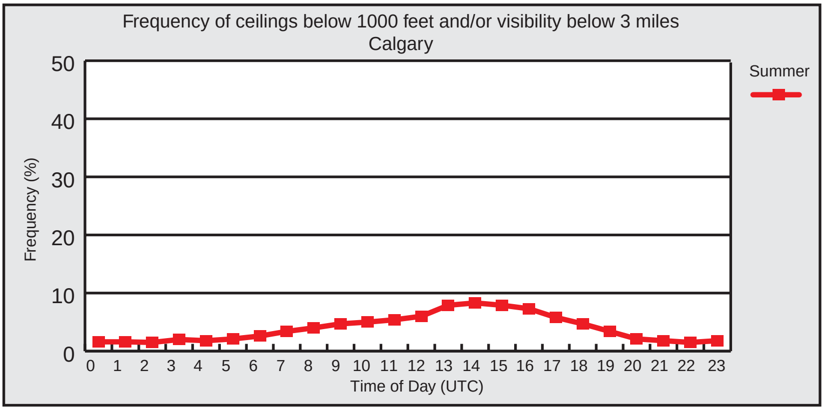
Calgary lies about 40 miles to the east of the Continental Divide, at the union of the Bow and Elbow River Valleys, in southern Alberta. In a large treeless tract of grassland, the river valleys provide the only strong physical relief. The airport is situated on a nearly flat tableland, 3 miles northeast of the centre of the city of Calgary. From the airport the land falls away to the valley of Nose Creek, about one mile to the west and then rises sharply to the crest of Nose Hill, a little over 3 miles west of the airport, which has an elevation 500 feet higher than the airfield. To the west of Calgary, the land rises steeply into the foothills of the Rocky Mountains. To the east, the land slopes away, generally from northwest to southeast. Southward the land slopes gradually to the Bow River, whose easterly flow bisects the city, until a sharp southerly bend, 3 to 4 miles south-southeast of the airport. Despite the fact that the local elevations are around 3,600 feet above sea level, the proximity to the Rocky Mountains allows it to benefit from the moderating effect of mild Chinook winds during the winter.

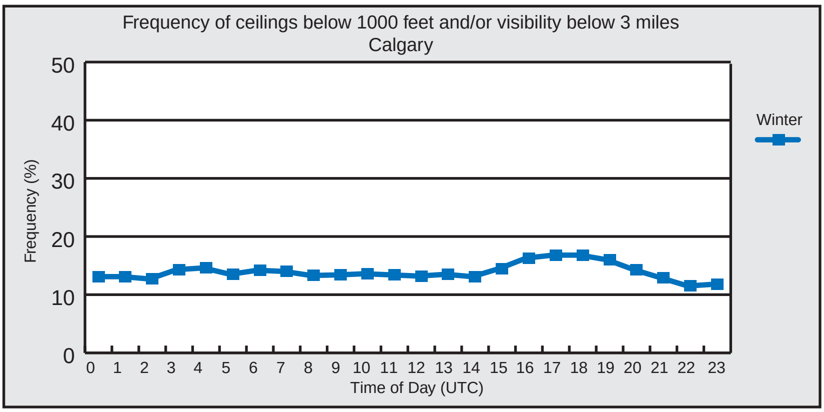




Calgary is in the zone of the upper-level westerlies which produces predominantly northerly or northwesterly winds in the winter and a more westerly or southwesterly flow in the summer. There are slightly more southwest winds in winter than summer, hinting that there may be more intrusions of warm pacific air in the winter than at other times of the year. In extreme summer cases, southerly winds can carry moist tropical air from the Gulf of Mexico into the area.

In the wintertime, the westerly winds can be produced by Chinooks and are frequently quite turbulent. Since the Chinook arch always accompanies this phenomenon, it can be used as a good indicator in timing the associated turbulence. Also, at any time of year, it is possible to set up lee or mountain waves, which will cause low-level wind shear and turbulence. While the lee waves are frequently indicated by lenticular cloud in the area, this is not always present, and in these cases, the lee wave turbulence can be quite hazardous. Of all the major cities in Canada, Calgary is most likely to be affected by this phenomenon.



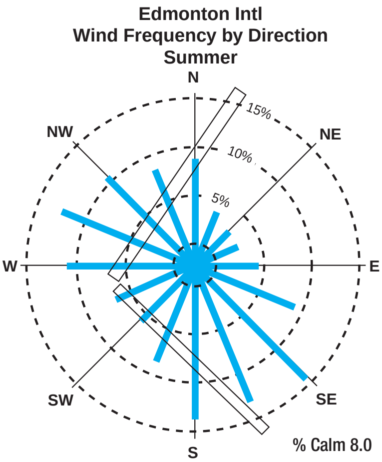


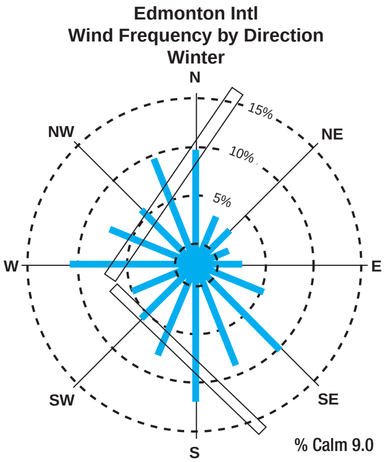
Summer, typically, has very good flying weather. The main concern is on warm days when thunderstorms can develop. Usually, thunderstorms form in the foothills to the west of the city and move eastward. Many of these dissipate before reaching Calgary but for those that don't, strong winds, heavy rain, hail, lightning and even tornadoes are possible. The frequency of low conditions increases after dark in summer, up to a maximum at 1400 UTC, and then improves.

Fog is mostly a wintertime event. The average number of fog days per month peaks at 2 or 3 in November, February, March and April. Poor flying conditions, when they occur in the evening, continue through the night with little change. Then, just after sunrise and probably due to the increases in aircraft movements providing a spike in low level moisture, the frequency reaches a maximum late in the morning after which conditions improve.

(b) Edmonton International

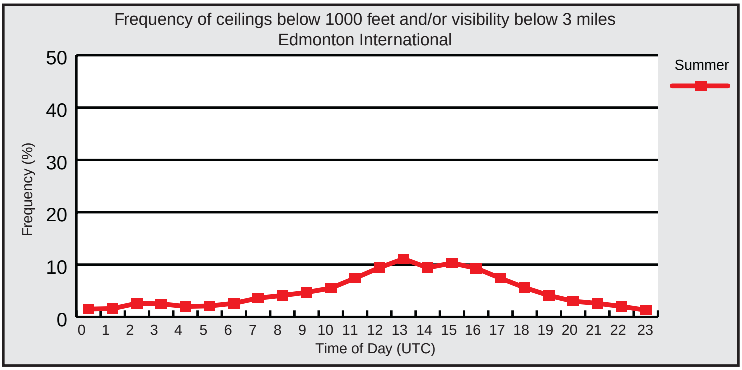
The city of Edmonton is situated along the North Saskatchewan River in central Alberta, and is located in the transition zone between prairie grassland and northern forests. The International airport is located near Leduc, about 9 miles to the south of the Edmonton city limits. The area surrounding the airport consists of generally flat farmland with the occasional wooded area. The North Saskatchewan River flows northeastward approximately 5 miles northwest of the airport.

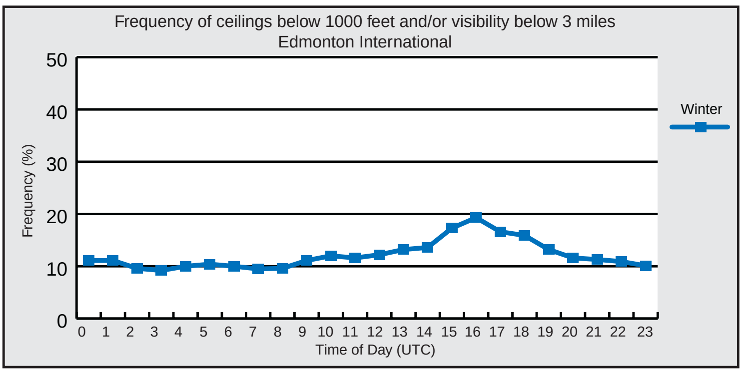




Edmonton is in the zone of the upper level westerlies, a large-scale atmospheric circulation that streams generally in a west to east direction. In the winter, this flow shifts to northwesterly or northerly which allows for frequent invasions of cold Arctic air. In the summer, a more westerly or southwesterly upper flow allows for incursions of moist Pacific air.

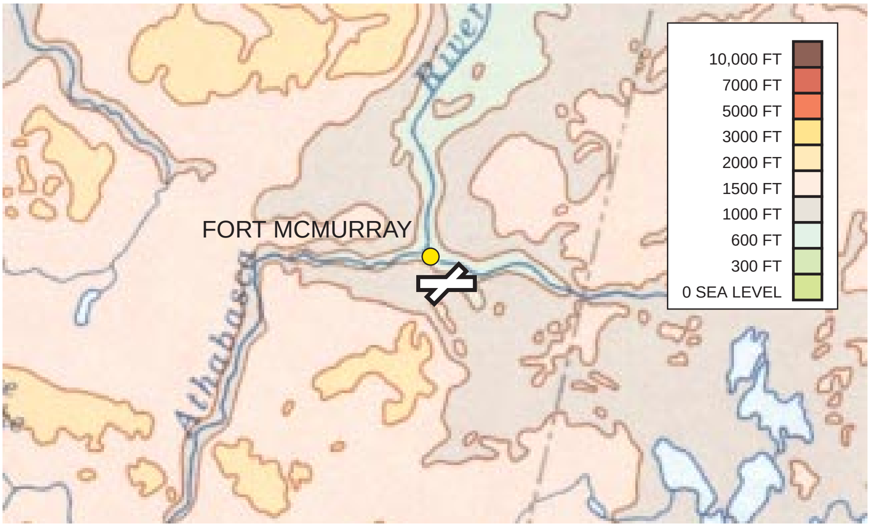
Winds are typically lighter in winter than those during the rest of the year. However, a combination of fresh snow, wind and cold temperatures may result in blizzard conditions, but these events are rare in Edmonton. The winds become somewhat stronger in the spring and summer and favour a west to northwest direction.



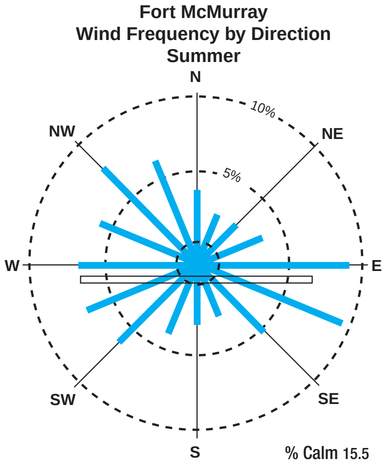


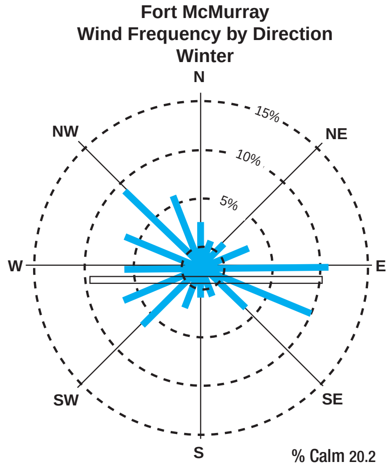
In Edmonton, throughout the year, the predominant west to northwest winds generally are associated with good flying weather. A prolonged easterly (northeast - southeast) flow is normally associated with the development of stratus and fog and the poorest flying conditions.

(b) Fort McMurray

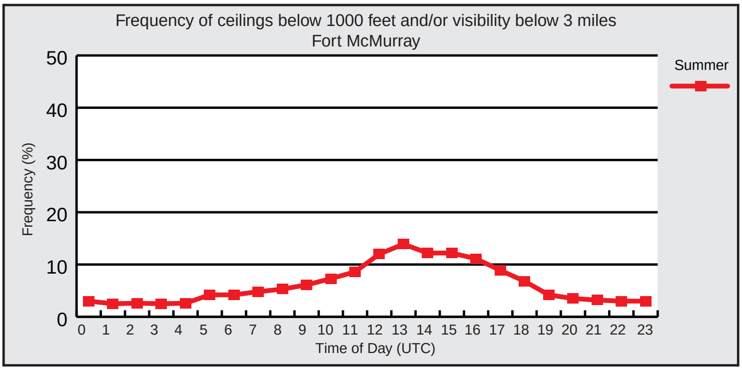


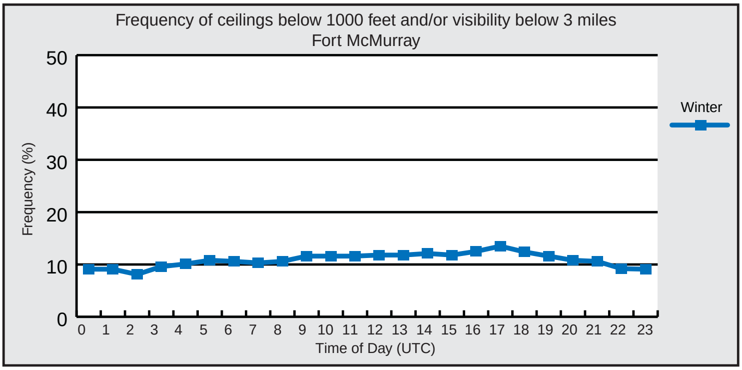
Fort McMurray is located at the confluence of the Athabasca and Clearwater Rivers, and the airport is located 7 miles southeast of the city. The Clearwater River passes within 2 miles north of the airport before joining the Athabasca River in town. The slightly rolling terrain rises moderately to the north and to the south of the Clearwater River valley.





The prevailing winds flow either up or down this river valley with very little difference from summer to winter. There is a secondary wind maximum from the southwest and there is a high percentage of calm winds.

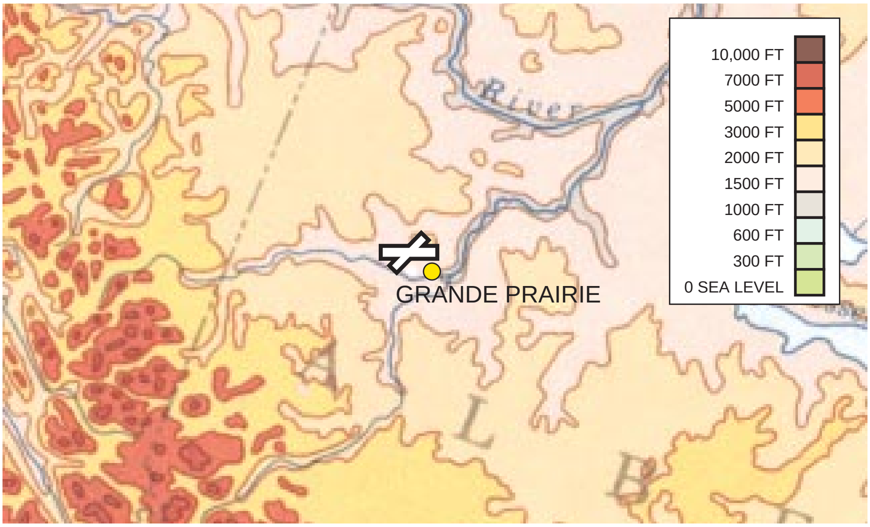




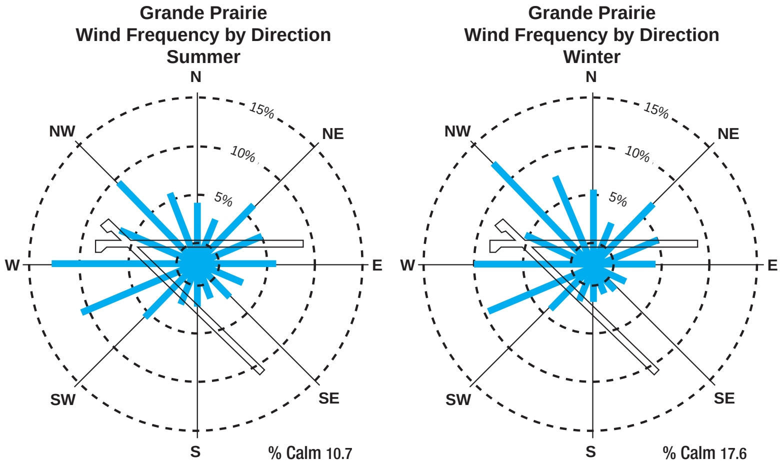
Summer flying conditions in Fort McMurray are generally very good but, after dark, the frequency of low ceiling and poor visibility conditions increases to a maximum near 1300 UTC. After this time conditions improve. There are a lot of small lakes and stretches of muskeg in the area that promote fog formation, even in the middle of summer and especially after a thunderstorm. In a northerly flow, it is possible to get "Syncrude Smog" advected into town and to the airport.

In winter, conditions are best in the late afternoon but deteriorate slightly during the evening and overnight. They get worse just after sunrise, for an hour or two, before starting to improve. This is due to aircraft movements generating significant amounts of low level moisture, and ice fog which is slow to clear in light wind situations.

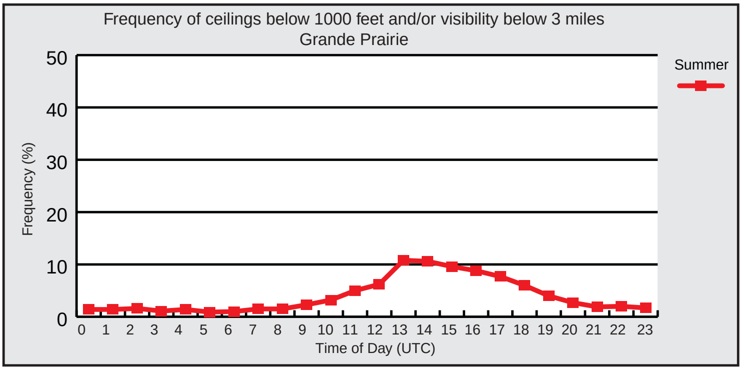
(c) Grande Prairie

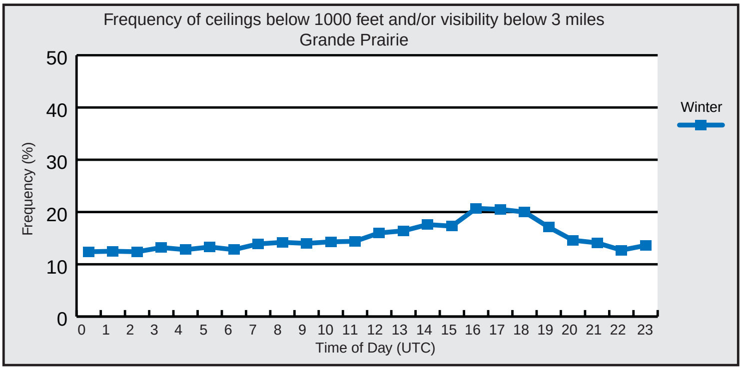


Grande Prairie is located about 43 miles east of the BC border in west central Alberta. The airport is located 2 to 3 miles west of the city of Grande Prairie on comparatively flat farmland which is generally free of trees. The Bear River drains Bear Lake, located about 5 miles northwest of the airport, and passes within about 1 mile east of the airport. The Saddle Hills lie on an east to west line about 19 miles north of Grande Prairie. The highest elevation in the Saddle Hills is White Mountain at 3,400 feet, located 19 miles northwest of the airport.



The winds at Grande Prairie favour the western quadrant, the result of funnelling around the Saddle Hills to the north and the Rocky Mountains to the south. With the approach of a synoptic scale high from the west, westerly winds predominate for some time until the high moves past. The winds then shift to an easterly direction. There can be brief but very strong westerly wind events after cold frontal passages associated with a migratory low, especially if the pressure is rising sharply behind of the front. Southerly and northerly winds are quite rare.



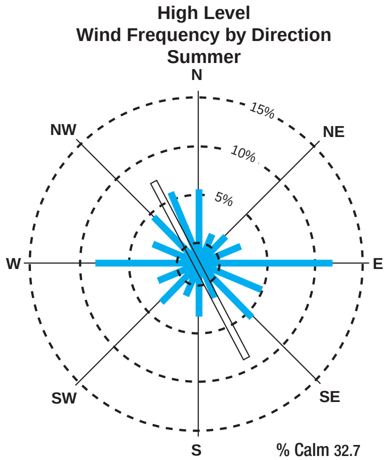


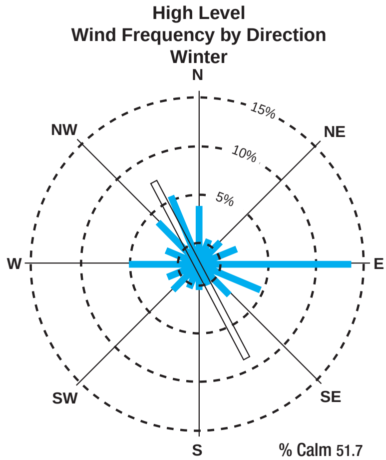
Flying weather in Grande Prairie in the summer is normally very good during daylight hours. After dark, the frequency of below VFR conditions increases up to 1300 UTC and then decreases for the remainder of the day. In winter, this frequency rises fairly steadily all night, peaks just after sunrise for a few hours and then decreases.

Shallow inversions, bolstered by light easterly or calm surface winds, are frequent year round and trap moisture in the low levels. As a result, overnight fog tends to persist here longer than at other sites in the region, especially from late fall to early spring.

(d) High Level

This site is located at an Alberta Forestry Service airport adjacent to the eastern shore of Footner Lake. A level forested area of aspen and spruce surrounds the site. Only enough clearing was done to maintain minimum clearance at the airport and so there are trees within 1/2 mile of the runway. Mount Watt, a ridge oriented in a southwest to northeast line, is located 12 miles west-northwest of the airport. The peak of Mount Watt is 2,500 feet ASL while the airport is 1,150 feet. The Caribou Mountains are located 17 miles northeast and are 3,300 feet high. High Level is situated in the bottom of a basin about 50 miles in radius that opens to the east. On a topographical map of Alberta, the Buffalo Head Hills are to the southeast, Caribou Hills to the northeast, Cameron Hills to the northwest and the Naylor Hills to the southwest.

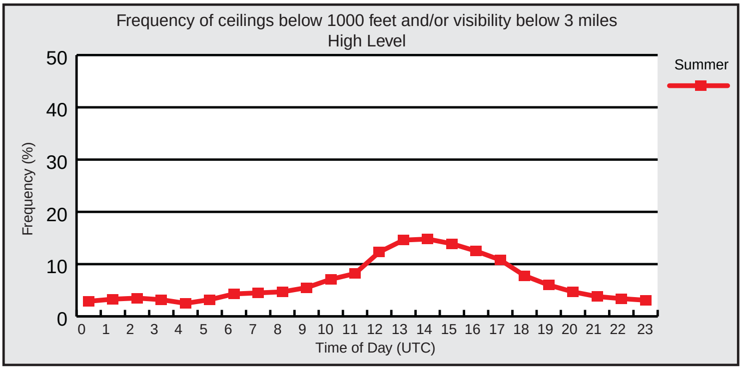


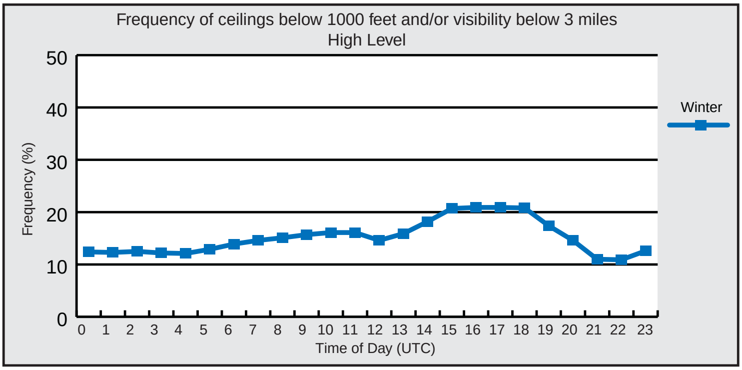


The hills present openings to the east and west and, as one would expect, the prevailing winds blow from these directions. There is also a secondary wind maximum from the north or northwest which would be the most common direction during a cold outbreak in winter.

During the winter, the airport can be enveloped all day in stratus while the town is clear, especially in a light easterly flow. There is a large percentage of calm winds both in the winter and summer here. The basin noted above allows for the formation of persistent inversions all year long.

Wind shear on descent below the treetops is a big concern at the High Level Airport. If the winds are blowing across the runway, an inbound aircraft cannot straighten out until below tree level. The subsequent loss of airspeed, occurring about 50 feet above the ground, is a hazard.

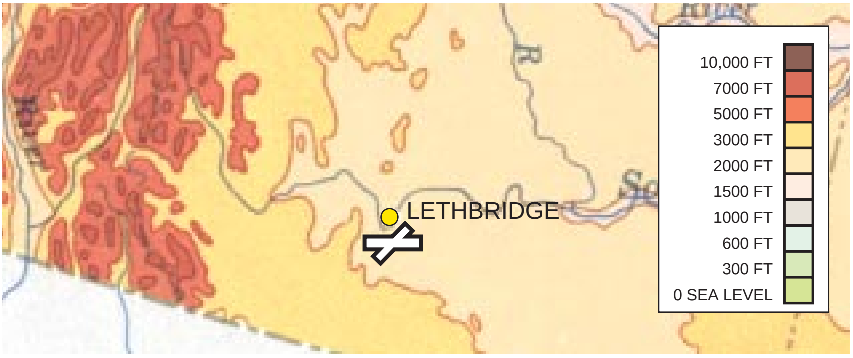




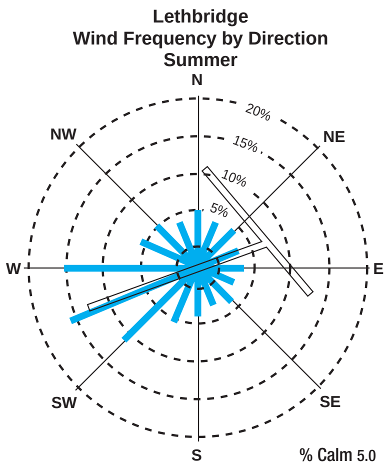
High Level usually has very good daytime flying weather in the summer. The surrounding hills provide some protection from thunderstorms during the season. It is rare to have thunderstorms approaching from the south. Cells that do hit High Level usually come off the Naylor Hills to the southwest and down the Chinchaga river valley. Thunderstorms in a westerly flow are diverted to the north or south by Mt. Watt and often miss High Level. Rarely do they traverse Mt. Watt to the airport area. After dark, conditions are likely to deteriorate. The highest frequency of low ceilings and poor visibility occurs near 1300 UTC after which time there is an improvement.

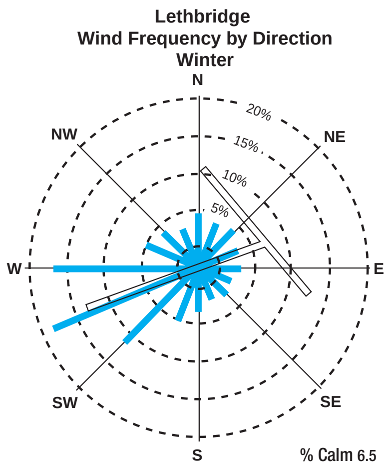
In the winter, the frequency of poor flying conditions is fairly steady from early evening through the overnight period, but near sunrise, conditions deteriorate. The worst weather usually occurs between 1500 and 1900 UTC before improvement early in the afternoon.

(e) Lethbridge



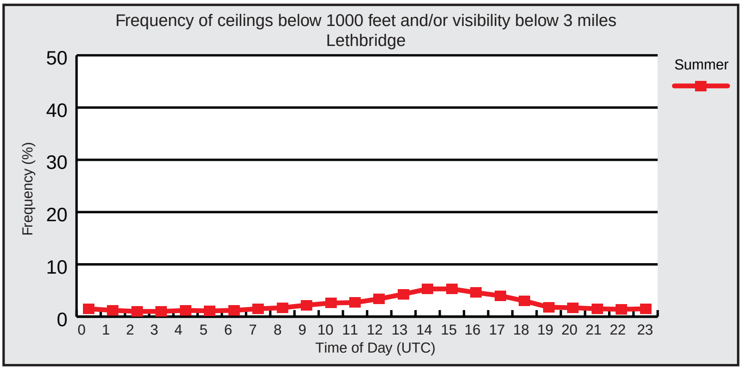
The Lethbridge Airport is located about 3 miles to the south of the city of Lethbridge, and is situated on a huge plain with a modest rise to the west and southwest. The Rocky Mountains are about 43 miles west of the airport. The Oldman River passes within 1 mile northwest of the airport as it meanders off to the east. About 21 miles to the south-southeast lies the Milk River Ridge, which rises about 1,300 feet above the surrounding terrain.

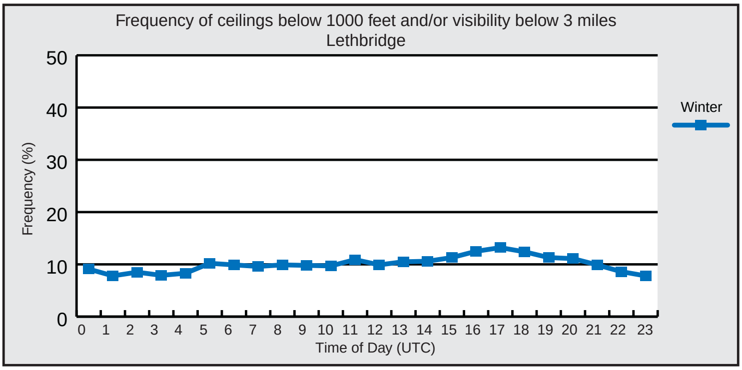




The winds at Lethbridge strongly favour the west and southwest. These are also the preferred directions for strong Chinook winds that frequently occur in Lethbridge during the winter. Marginal flying conditions associated with the southeasterly flow ahead of the Chinook Arch change for the better behind it.

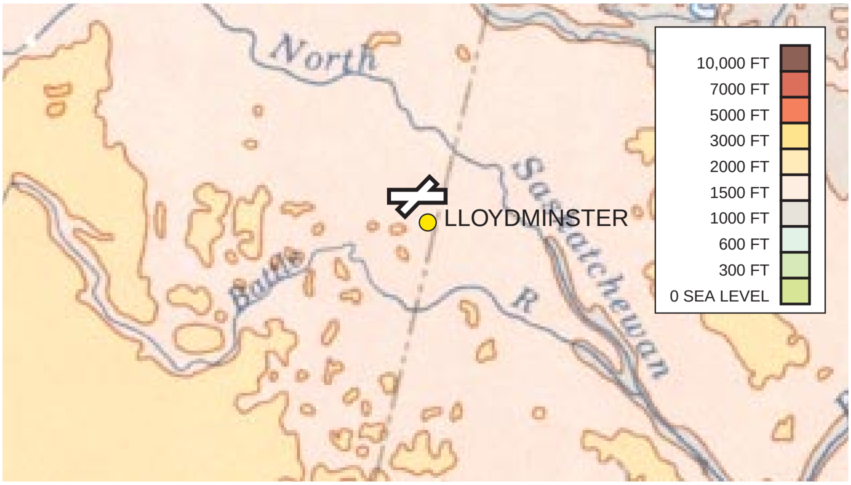
While the flying conditions may be good west of the Arch, the strong westerly flow associated with the Chinook can be quite turbulent. Wind events from other directions are evenly distributed, but not very frequent.



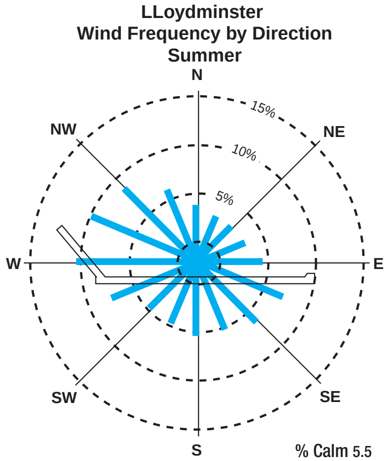


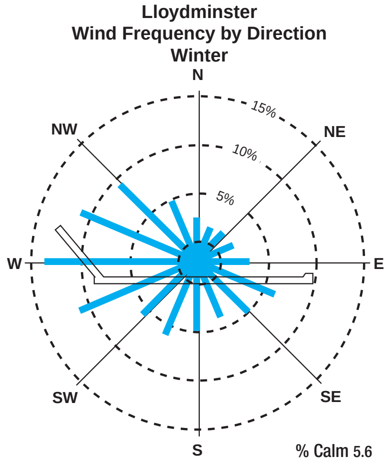
The frequency of good flying conditions in Lethbridge is similar to that of Calgary, but Lethbridge has the best weather of all the major Prairie aerodromes. Only one poor flying day in 20 can be expected in summer and one day in 8 in the winter. After dark in the summer, statistics show a gradual increase in the chance of below VFR conditions, reaching a maximum at 1400 UTC. In winter, the probability of low conditions remains fairly constant all night, spiking at 1700 UTC and then diminishing. Easterly winds are not frequent but when they do occur there is a good chance of low ceilings or poor visibility.

(f) Lloydminster

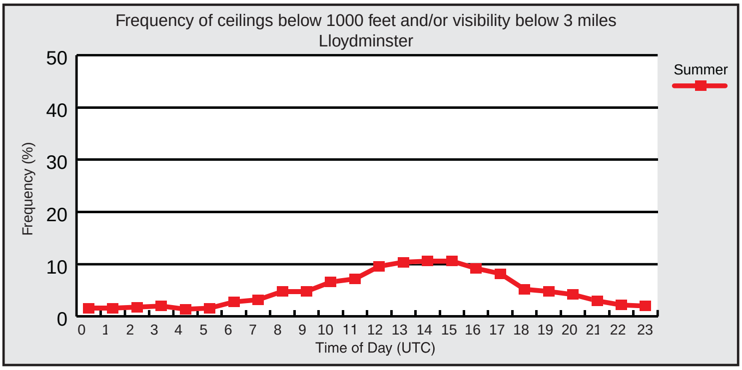


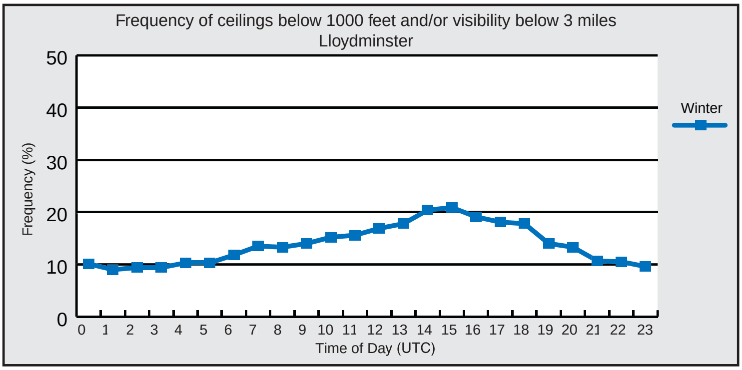
Lloydminster is located on the Alberta - Saskatchewan border between the North Saskatchewan River, to the north, and the Battle River to the south. These two rivers often channel the winds from either the west or northwest or from the southeast. A synoptic scale ridge of high pressure approaching from the west will usually generate westerly winds at Lloydminster. After the high goes by, the winds shift to the southeast.



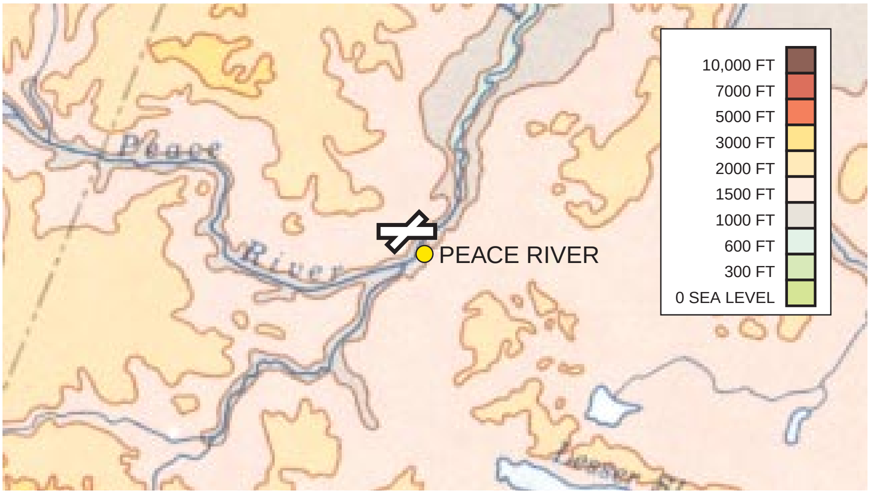


In summer during the day, good flying weather can be anticipated around Lloydminster. During the night, there is a gradual increase in the probability of poor flying conditions, up to a maximum of 10 percent from 1300 to 1700 UTC. Once fog or stratus arrives, the Big Gully Lakes and pollution sources in town are able to provide enough moisture and particulate to maintain or enhance the low flying conditions. In winter, there is a steady increase in below VFR frequency up until about sunrise and then a gradual decrease.

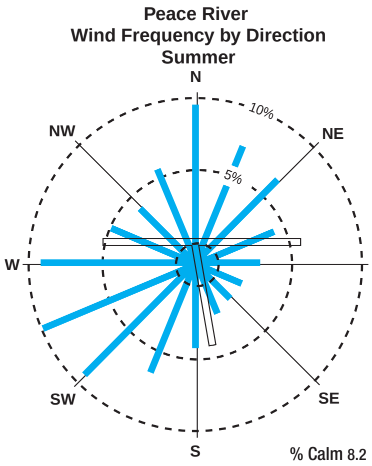


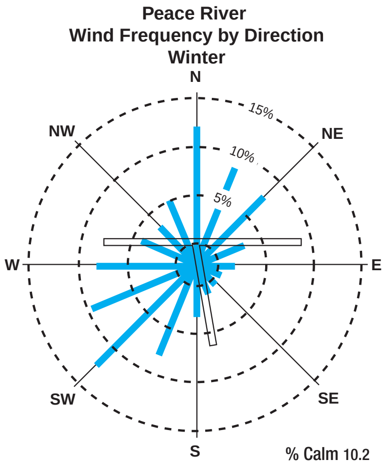


(g) Peace River

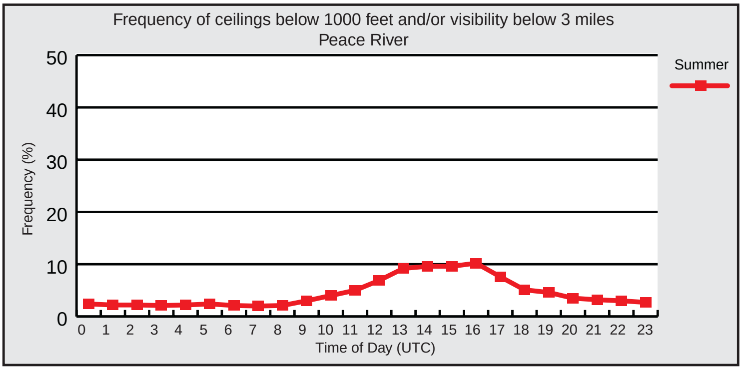


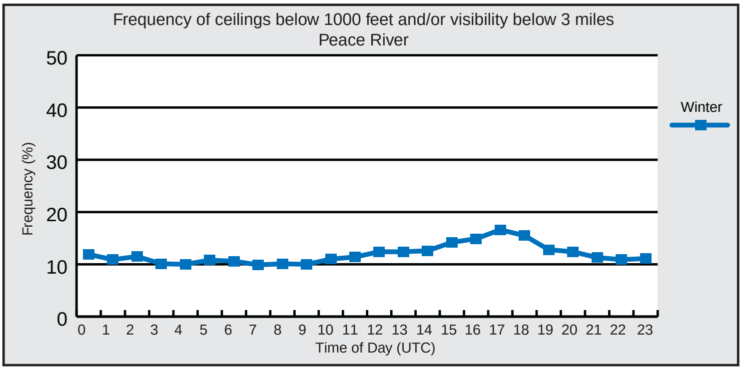
The airport is located midway between the town of Peace River to the east and Grimshaw to the west. The main topographical feature in the area is the Peace River valley that lies in a southwest to northeast orientation. The bottom of the Peace River Valley is 770 feet below the level of the observing site. The Smokey River, also boasting an impressive river valley, discharges into the Peace about 6 miles west of the airport.





Due to cold air drainage, the river valley is often completely filled with stratus and fog while the airport is clear. Winds in town are biased towards the northeast or southwest (along the Peace River Valley) while winds at the airport can be quite variable. During both summer and winter, the winds at the airport are mostly from the southwest or north. The passage of a migratory low to the north of Peace River will cause southwest winds to shift around to the north. Once the low has moved far enough to the east, rising pressure ahead of the next high or ridge approaching from the west will cause the winds to shift back to southwest again.

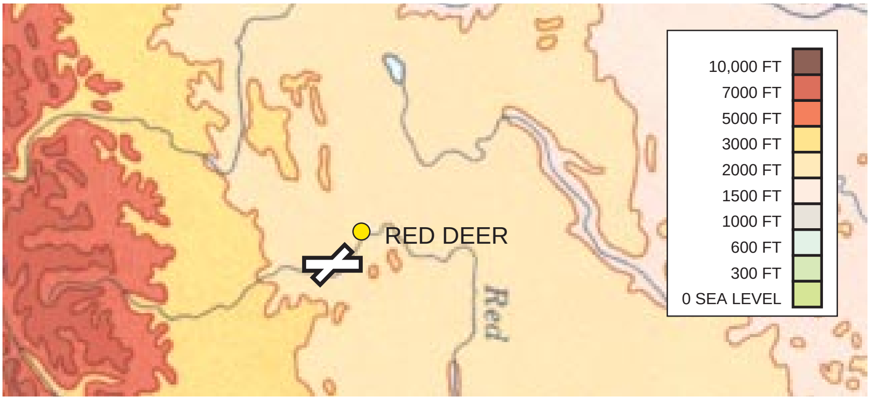




As with most of the airports on the Prairies, flying weather during summer daylight hours is typically very good. After dark, the probability of low ceilings and poor visibility increases to a maximum at 1300 UTC and is constant for several hours afterward. Once stratus or fog forms in the area, it is slow to clear, even in summer.

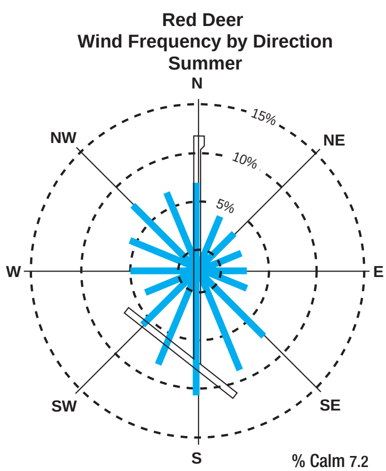
In winter, there is a gradual increase in the frequency of below VFR conditions from evening to about 2 hours after sunrise, after which conditions tend to improve.

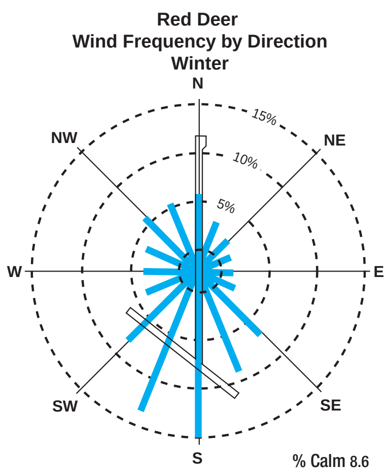
(h) Red Deer



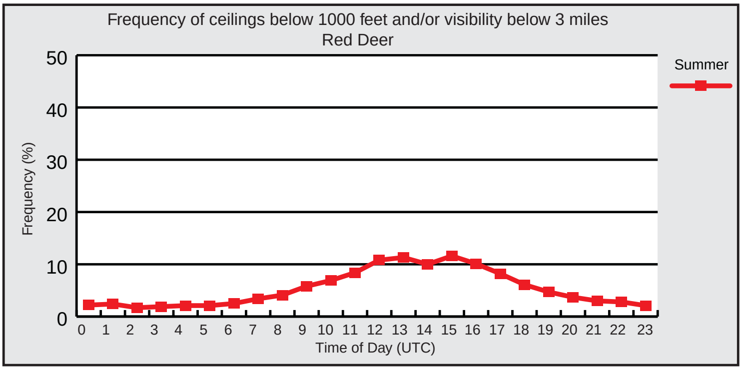
The Red Deer airport is located 6 miles southwest of the city. The Red Deer River flows northeastward across western Alberta and courses within 3 miles of the airport, which was built in a bowl-like depression in the terrain and therefore has poor drainage of air and moisture. With a light flow from any direction, fog tends to form easily here and is slow to dissipate. The terrain to the west of Red Deer and Rocky Mountain House is a genesis area for thunderstorms. If convective cells form over the foothills in the morning, they frequently move through the Red Deer area later in the day.

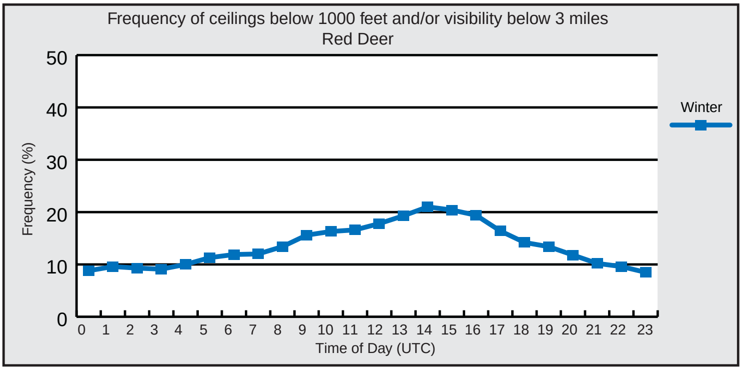
In the wake of a winter cold front, stratocumulus or stratus cloud, based between 1,000 to 3,000 feet above ground, can be very persistent. As the cold front pushes up into the Rockies, the area will experience a northeasterly upslope flow which augments cloud formation. This low cloud will remain in the area until an Arctic high becomes established and clears it out.





The winds here tend to follow the orientation of the Red Deer River Valley, so are generally from the northwest or south all year long. In the winter, there are more southerly winds than northwest winds, which is a reflection of the climatological average pressure pattern that shows a ridge of high pressure over the central Prairies. Since the airport is built in a bowl, there is a high occurrence of calm winds. This is especially true during inversion events in the winter, as weak air mass erosion allows cold air to remain while warm air glides over top.





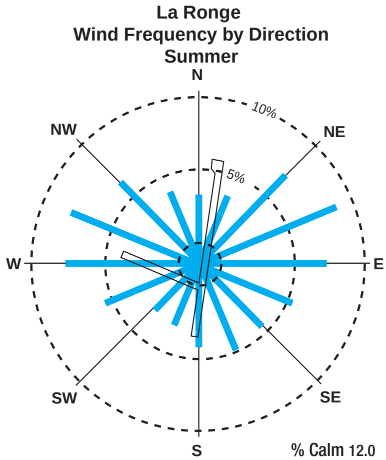
As with many other stations across the Prairies, Red Deer, in summer, enjoys very good flying weather during the day with few cases of low ceilings and visibility. After dark, the frequency of low conditions increases to a maximum near 1200 UTC and is slow to decrease until after 1500 UTC.

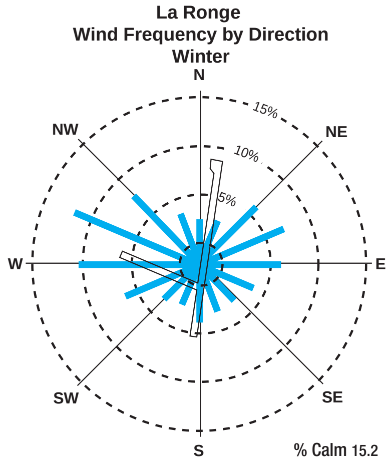
The fact that the airport is in a bowl means it is also subject to local water drainage. This, coupled with the increased occurrence of inversions, causes fog to form more readily overnight in the spring and fall, especially after precipitation episodes. The Red Deer River is also a good source of moisture for fog formation.

Saskatchewan

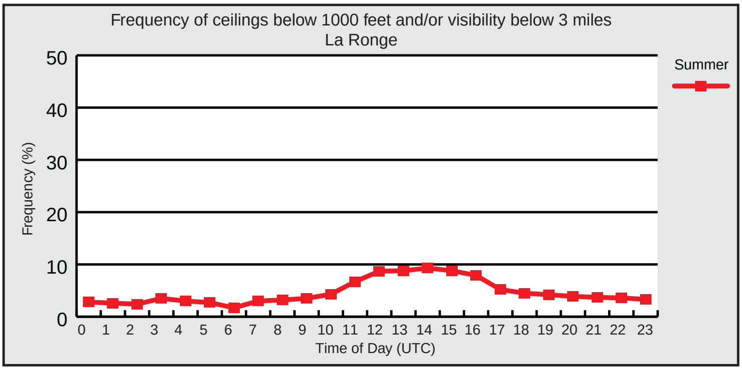
(a) La Ronge

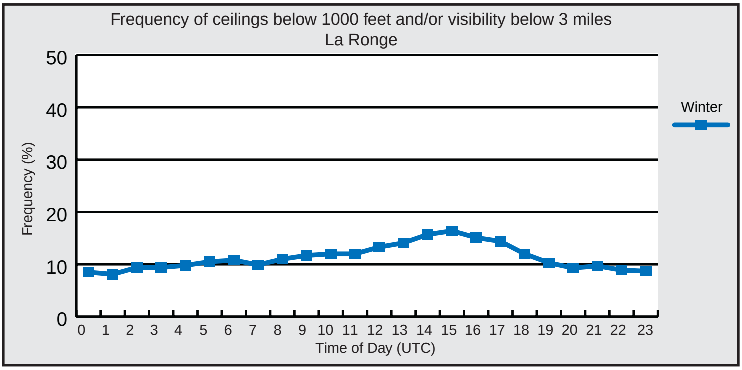
The town of La Ronge is located on the western shore of Lac la Ronge while the airport is a few miles to the north. This part of north-central Saskatchewan is characterized by small, rolling hills, several large lakes and open boreal forest.





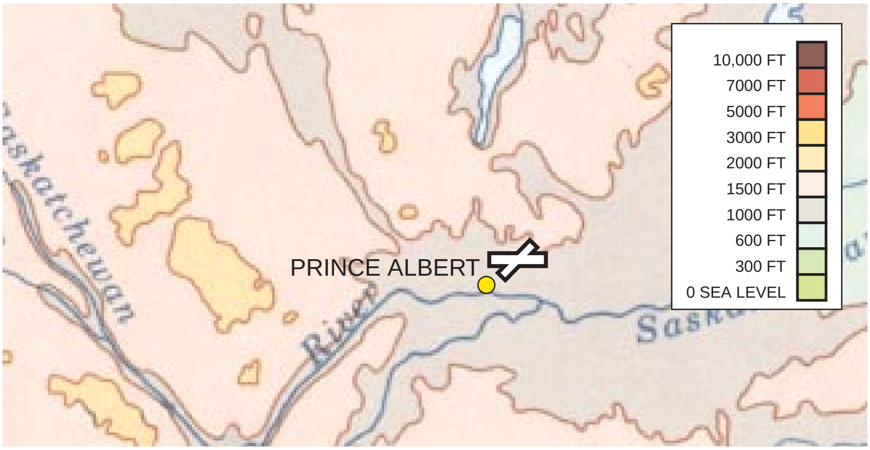
The winds here favour westerly throughout the year with a secondary maximum from the east-northeast. This is the result of being near the centre of the climatological high pressure area which resides over this part of the Prairies. When the centre of high pressure is approaching from the north, the winds are easterly and, after it goes past, the winds shift to westerly. When the high is nearby, the winds under the accompanying inversion are frequently calm.



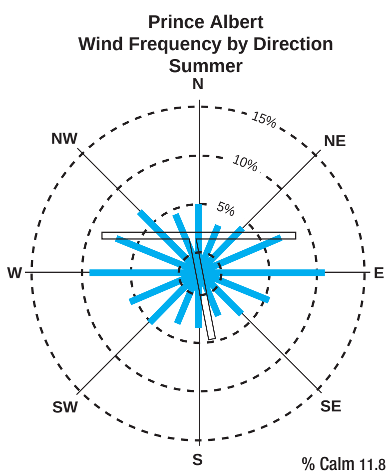


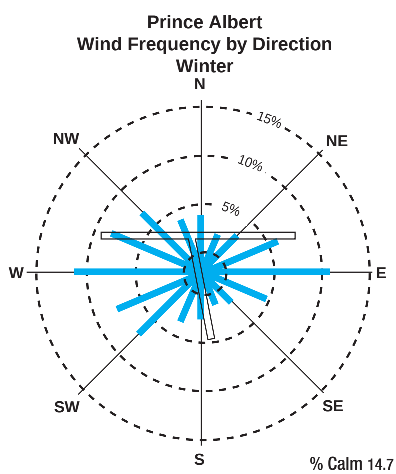
In summer, there is a gradual increase in the frequency of low ceilings and/or poor visibility through the night, up to a maximum near 1200 UTC. Improvement after this time is very slow, exhibiting the influence of Lac la Ronge. Moisture from the lake can reinforce stratus and fog formation at this time or, at least, slow the dissipation process. In winter, there is a gradual increase in the frequency of below VFR conditions to a maximum near 1500 UTC and a gradual decline after that time.

(b) Prince Albert

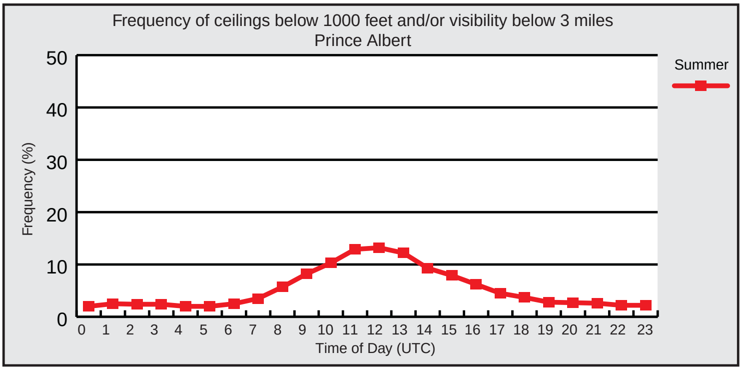


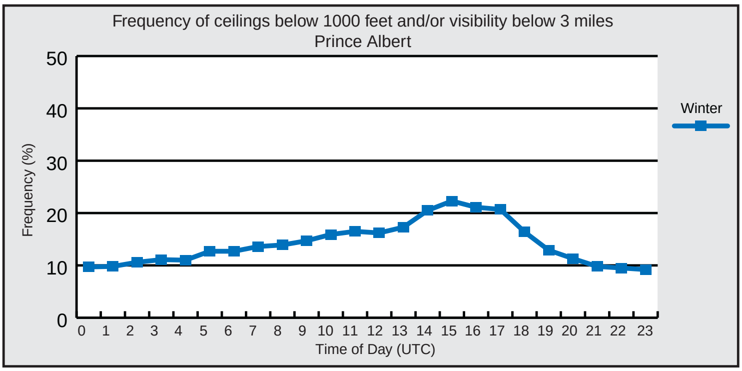
The Prince Albert Airport is located on a flat plain in the valley of the North Saskatchewan River, about one mile east of the city. The river itself approaches from the west, bends around the south side of the facility and exits to the east, but the valley is oriented more or less west to east. There is a gradual rise in terrain from the southeast to the northwest.





Most of the prevailing winds here are either westerly or easterly. North and south winds greater than 10 knots are much less common. The location in the river valley, and a local source of abundant moisture, make Prince Albert a prime candidate for radiation fog on clear skies with light winds.

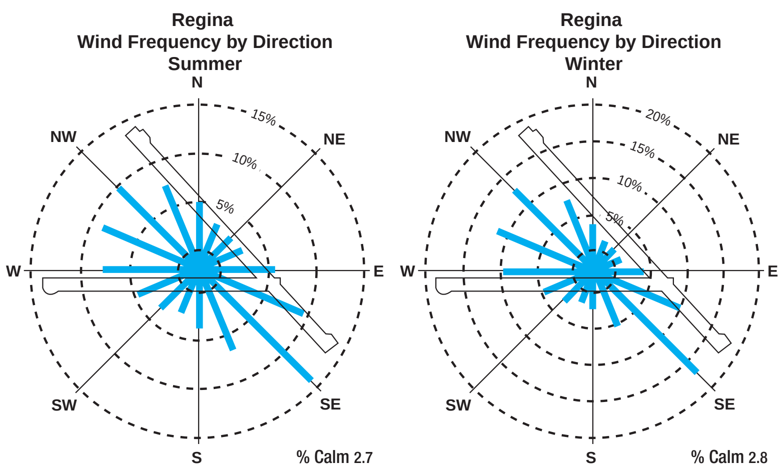




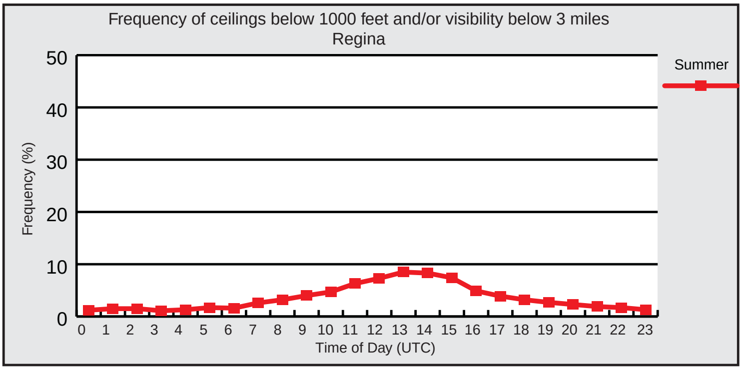
Even with all of these weather parameters working to form low cloud and fog, Prince Albert has very good flying weather during the summer. Overnight, the frequency of low flying conditions increases to a maximum at 1200 UTC and then conditions tend to improve. Radiation fog becomes a concern in August and September when the nights are longer and there is still abundant moisture. If stratus forms over the city during the evening, it is a good indication that Prince Albert will fog in overnight. There is a pulp mill located to the northeast of the airport and, in a northeasterly flow, pollutants from this mill can create fog that will eventually advect over the runway. In winter, the probability of poor conditions increases as night progresses. There is a jump in this trend near sunrise due to aircraft movements and a maximum of 22 percent near 1600 UTC. After this time, conditions tend to improve.

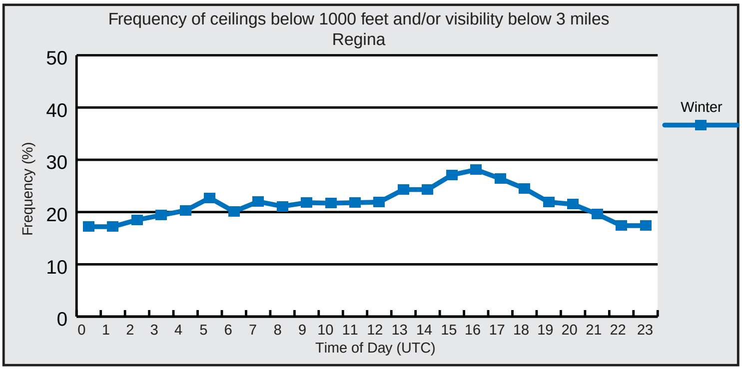
(c) Regina

The airport is located on a level plain at the southwest edge of the city of Regina. The city is located on the banks of Wascana Creek, which lies in a very shallow basin running southeast to northwest. The land rises slowly to the northeast and peaks at an elevation of 2,300 feet, about 19 miles northeast of the airport. The Qu'Appelle River, 32 miles north of the airport, meanders in an easterly direction in a very deep narrow valley.



The winds for Regina strongly favour southeast and northwest directions throughout the year. This is a reflection of the orientation of the Wascana Basin which directs the synoptic scale winds to flow either up or down the valley. Funnelling acts to strengthen such flows, and blowing snow is fairly common in the Wascana Basin as a result. The southeasterly flow, which can sometimes produce blizzard conditions across southern Saskatchewan, will not affect the airport at Regina because of the sheltering effect of the city. Northeast and southwest winds do not occur very often.

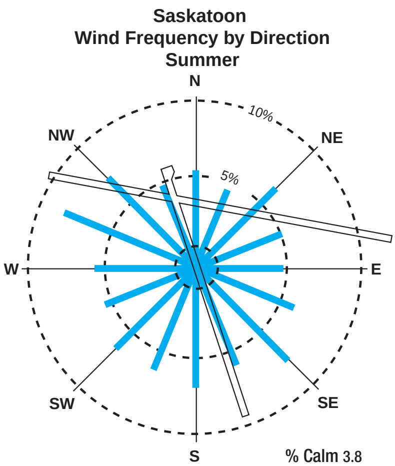


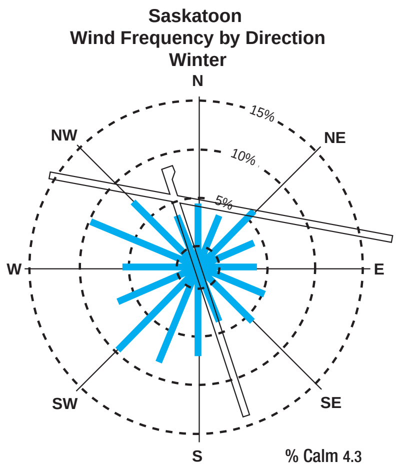


In the summer, the flying weather at Regina is very good most of the time, but there are rare dips below VFR limits. In winter, the frequency of low conditions remains fairly constant through most of the evening and overnight. Near sunrise, the frequency increases more rapidly to a maximum near 1700 UTC, and then diminishes.

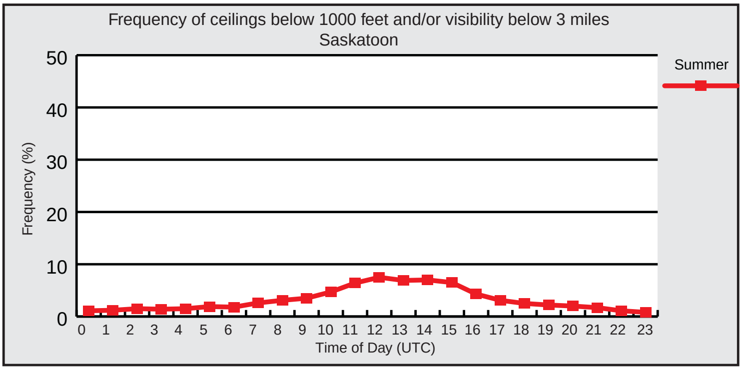
(d) Saskatoon

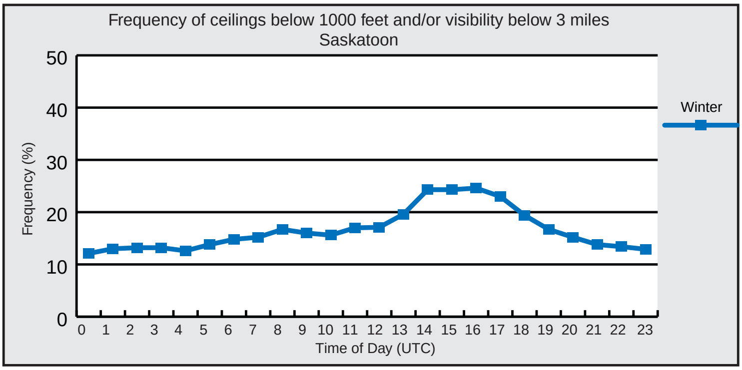
The airport at Saskatoon is located on the plain of the South Saskatchewan River, about 2 miles north-northwest of the city centre. The terrain in the immediate vicinity of the airport is relatively flat. The South Saskatchewan River flows through the city in a northeast direction and passes within 2 miles east-southeast of the runway complex. The terrain to the east of the airport reaches a height of 1,900 feet in the Minichinas Hills, about 8 to 9 miles away. To the southeast, the nearest significant topographical feature is the Allen Hills, about 17 miles from the airport.





Although Saskatoon has no preferred wind direction, the highest average wind speeds (10-12kts) occur from the west-northwest. There is a secondary maximum in wind direction from the southeast that is more obvious in the summer than in the winter. In the wintertime, southwest is another preferred wind direction.



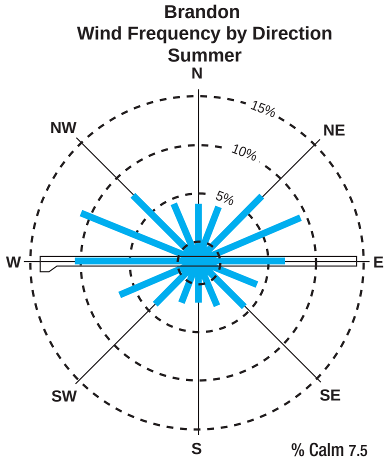


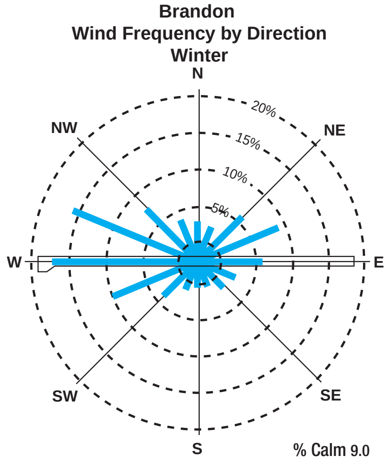
The "Frequency of ceilings below 1000 feet and/or visibility below 3 miles" charts for Saskatoon shown above are much like those for most other sites on the Prairies. In the summer, the flying weather is very good most of the time. Episodes of low conditions tend to occur most often between 1200 and 1500 UTC. Improvement afterward occurs fairly rapidly. In winter, the frequency of low ceilings and poor visibility remains fairly constant through most of the evening and overnight. The frequency increases quite rapidly between 1200 and 1400 UTC (near sunrise), remains high for about 3 hours and then drops.

Manitoba

(a) Brandon

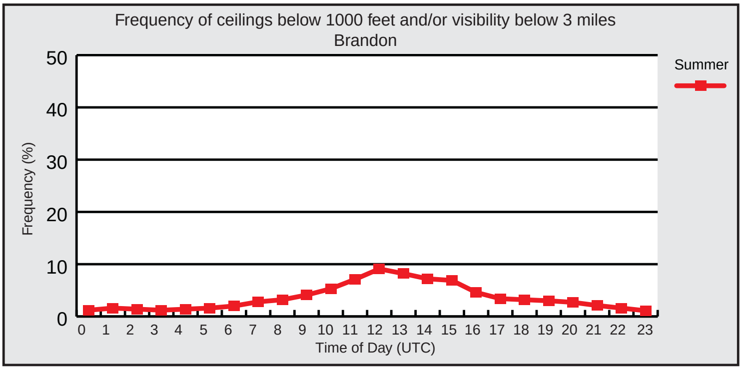
The city of Brandon is situated in the Assiniboine River valley about 3 miles south of the airport. The terrain to the north of Brandon rises slowly but steadily, peaking at 2,400 feet in the Riding Mountains 49 miles north of Brandon. South of the city, the terrain rises slowly to heights between 1,600 and 1,700 feet in the Brandon Hills, some 13 miles south of the city. Further to the south, near the Canada - U.S. Border, are the Turtle Mountains.

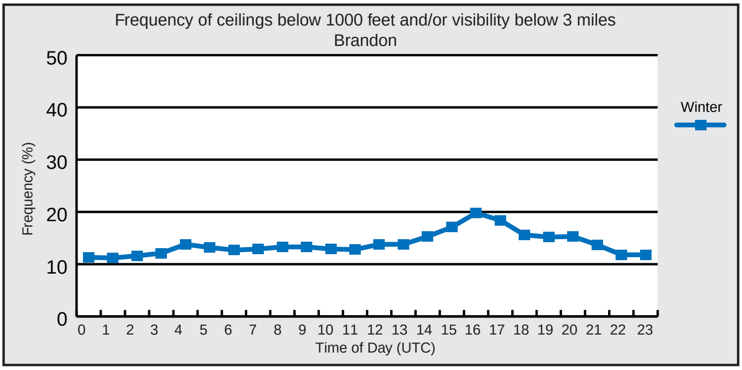




The Assiniboine River Valley forms an east to west channel between the Riding Mountains and the Turtle Mountains. Because of this, Brandon winds blow most often from the west or east. The most common wind is westerly around 10 knots.

Northwesterly winds tend to be stronger than the gradient would suggest, and this is also due to the funnelling effects of the local terrain. In summer, westerly winds are the most frequent, closely followed by those from the east and northeast. Northerly winds are uncommon and southerly winds are even more rare. Calm conditions occur 8 percent of the time in summer. In winter, westerly winds occur more often than in the summer but there is no real increase in easterly winds. A westerly flow is downslope for Brandon and a northwest flow off the Riding Mountains is even more subsident. Since these are the two most common wind directions for Brandon, overall conditions tend to be good. With easterly and northeasterly flows in spring and fall, stratus and fog are a common occurrence. The winds are calm at times at the airport and, hence, radiation fog occurs fairly regularly at the airport. Because of the influence of the river valley, radiation fog will be even more common in town.



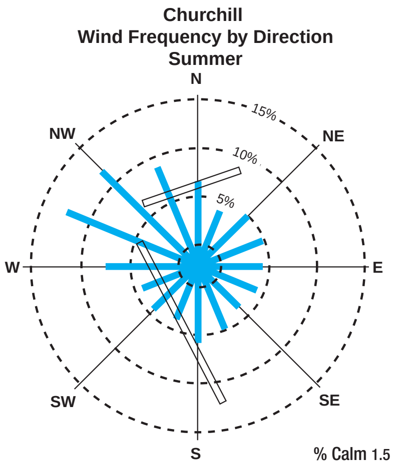


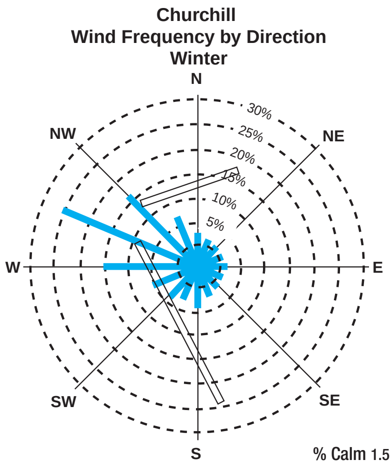
Although flying conditions in Brandon are generally reliable in summer, the chance of poor conditions increases steadily after midnight up until 1200 UTC when it peaks at about 9 percent. There is a gradual decrease in probability after this time. In winter, there is an 11 to 13 percent chance of low ceilings or poor visibility occurring at almost any time of day. There is a higher probability between 1400 and 2000 UTC, with a peak of 20 percent around 1600 UTC.

A typical start for fog dispersal in summer is 1300 UTC, while in winter, dissipation commences around 1700 UTC. The increase in aircraft movement near sunrise, and the delay in sunrise itself, form the best explanation of this phenomenon.

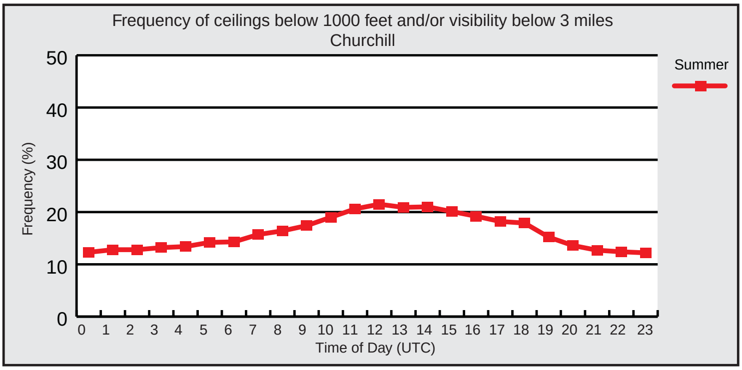
(b) Churchill

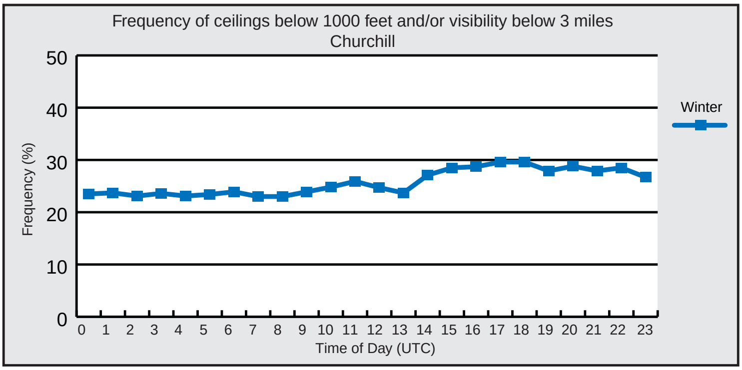
The town of Churchill is located on the Hudson Bay coast. The airport itself sits on a bluff a little over 90 feet above Hudson Bay and roughly one n. mile south of the water's edge, and 3 miles east-southeast of the town. The coastline runs about 27 miles due east to Cape Churchill, then south-southeastward toward the mouth of the Nelson River. Just to the west of the airport, the northward flowing Churchill River spills into the bay. A few miles further west is Button Bay, an inlet about 5 miles across.





Once again, the climatological ridge of high pressure over the central Prairies is responsible for the much of the bias in wind direction at Churchill. During the summer, the winds favour the northwest but any direction is possible at least part of the time. In the fall, flows off Hudson Bay can advect marine stratum over the airport. In winter, the dominant ridge of high pressure over the central Prairies produces northwest winds twice as often as in summer. Strong northwest wind events can produce blowing snow over the nearly treeless coastal area, and this is a major contributor to the high frequencies of poor flying conditions in winter. In spring, these northwest winds can bring in stratus from open water on the Churchill River. The winds are seldom calm at Churchill.



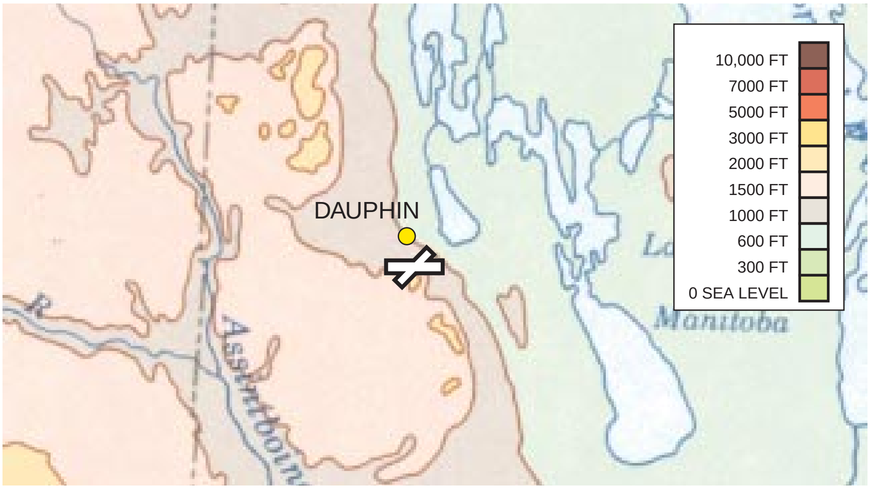


Throughout the year, conditions with low ceilings and visibility are fairly common at Churchill. In the summer, from about 2000 UTC to about 0700 UTC, conditions are poor 12 percent of the time; a frequency more than 4 times higher than at airports further south or inland. While Hudson Bay is the principal source of moisture for low cloud formation in the area, it is not the only one. Even in a westerly or southwesterly flow, it is possible to tap moisture from the Churchill River, Button Bay or any of the myriad of lakes and swamps dotting the region. After about 0700 UTC, the chance for below VFR conditions increases, peaking at 1200 UTC, and then slowly decreases.

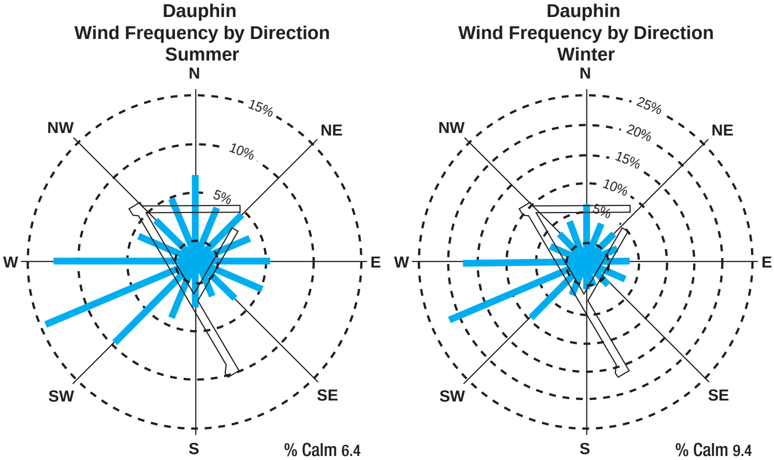
Again, in a northwesterly flow in spring, open water at the mouth of the Churchill River can produce a good deal of stratus. If the temperature is just below zero, freezing drizzle is a good possibility. If the winds shift from northwesterly to northerly, then the stratus drifts southward past the airport. In the fall, any wind direction from the northwest through northeast to the southeast can produce stratus as this flow is, for the most part, directly off the bay.

The likelihood of below VFR conditions in winter at Churchill is the greatest for any major site on the Prairies by far. During the night, poor flying weather occurs 24 percent of the time, which is nearly one day in four. Interestingly, the frequency increases to almost 30 percent in the morning and remains at that level throughout the day. This trend is opposite to that normally seen at other sites on the Prairies. Hence, if weather conditions are marginal or poor in the morning at Churchill in the winter, they very likely will remain poor or get worse through the afternoon and evening.

(c) Dauphin

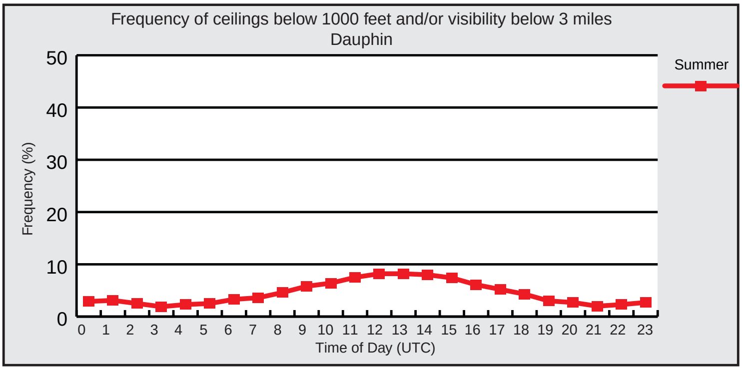


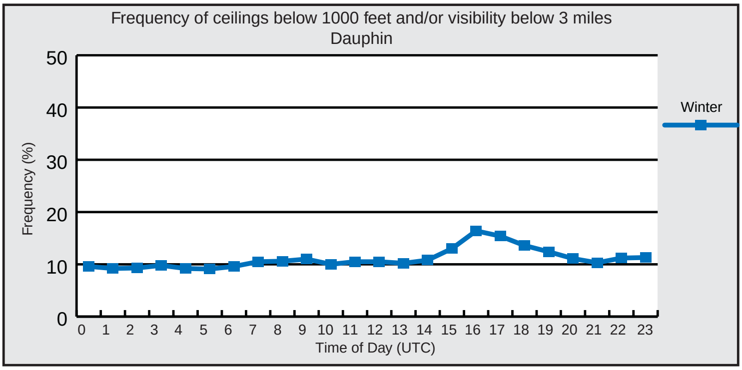
The Dauphin Airport is situated about 3 miles south of the town of Dauphin, and about 8 miles west of Dauphin Lake. Several creeks and rivers, which originate in the Riding Mountains to the south, flow northeastward into Dauphin Lake, which drains into Lake Winnipegosis to the north. The Dauphin area is a broad, flat valley bounded by the Duck Mountains to the northwest and the Riding Mountains, which extend from southeast around Dauphin to the west-southwest. The northern escarpment of the Riding Mountains begins 5 miles south of the airport and the highest peak (2,200 feet), is about 9 miles south. The valley floor slopes gently away to the north and east towards Lake Winnipegosis and Lake Manitoba.



The wind record at Dauphin reflects the strong channelling effect of the valley between the Riding and Duck Mountains. With a high over the central Prairies, the winds generated by the northwesterly gradient over this area are backed significantly by the valley. Winds from all other directions occur with about the same frequency (3-5 percent) with a secondary maximum from the north, indicating that when low pressure systems pass to the east of Dauphin, there is some diversion of the flow around the Duck Mountains to the north of town. South to southeast winds do not occur very often at all.

In winter, the winds favour the west to southwest directions even more strongly; the result of more and stronger highs or ridges over the central Prairies and a northwesterly gradient across Manitoba. Winds from other directions occur even less in winter than in the summer and south and southeasterly winds are very rare.

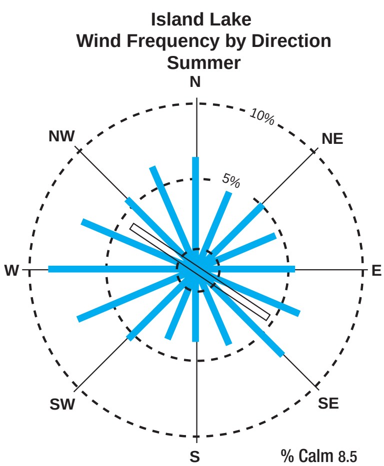


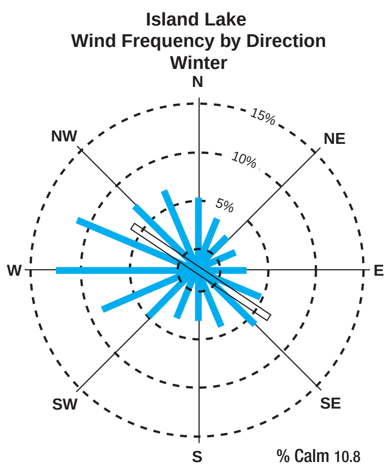


In summer, good flying conditions are the norm in Dauphin. Overnight, there is a gradual increase in the chance of low ceilings and visibility, reaching a maximum near 1300 UTC, after which there is an equally gradual decrease through the morning into the early afternoon. During the evening and overnight in winter, poor conditions occur 10 percent of the time from hour to hour with very little variation. Near, or just after, sunrise the frequency jumps quite quickly to a peak of 17 percent at 1600 UTC, then returns to the normal 10 percent by 2100 UTC.

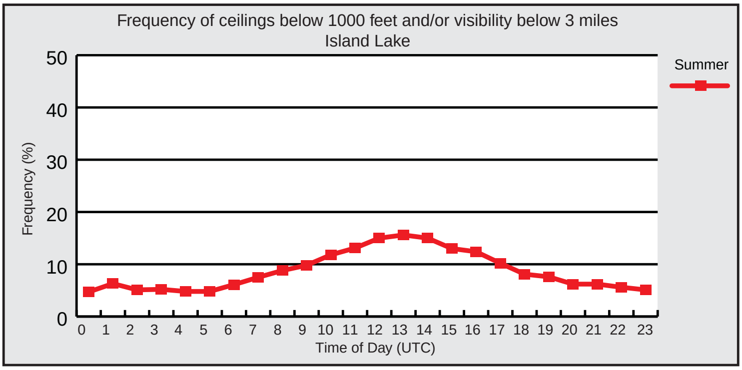
(d) Island Lake

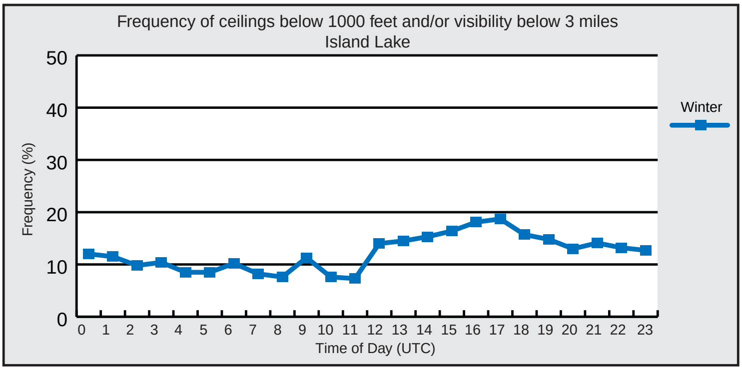
Like most of the sites in central and northern Manitoba, Island Lake is located on the very flat, open forestland of the Canadian Shield with its many lakes and sloughs. True to its name, the airport is located on Stevenson Island and completely surrounded by water. Three miles to the northeast, and about 100 feet higher, is the village of Garden Hill. There are open stretches of water to the northwest, west and southeast. These compass points coincide with the most common wind directions.





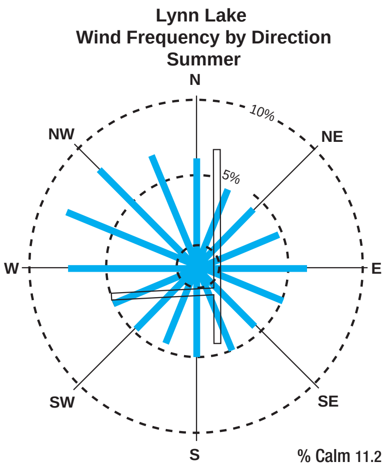
In summer, occurrences of below VFR weather are more frequent at Island Lake than at sites further south, no doubt due to the site being totally encircled by water. The frequency of low flying weather increases during the evening, and overnight, to a maximum at 1300 UTC (near sunrise) and then decreases during the morning. During the winter, there is no strong diurnal increase in the frequency of low ceilings and visibility until about 1200 UTC, or just before sunrise, when it increases sharply. Probabilities increase until about 1700 UTC and then decline fairly rapidly. These summer and winter sunrise peaks are similar to those at other sites in this part of Manitoba. However, a completely different trend is shown at places further south and away from the effects of local large bodies of water.

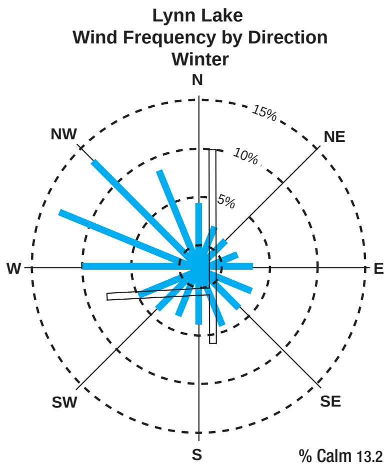




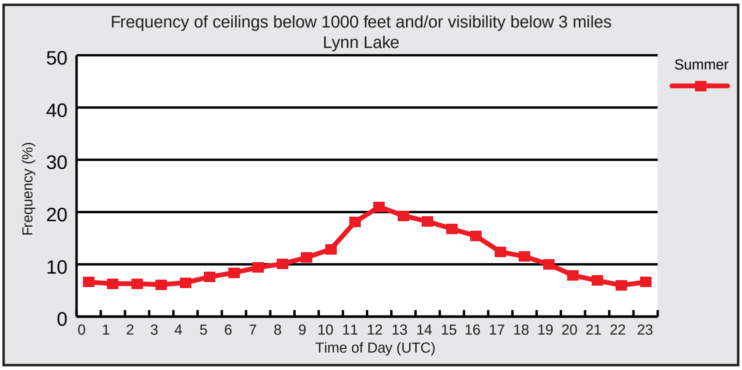
(e) Lynn Lake

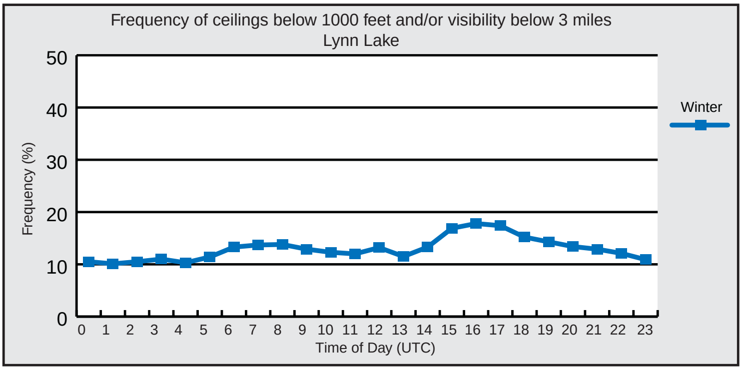
Lynn Lake is located in the forested region of the rocky Canadian Shield that covers northwestern Manitoba. The rolling terrain is home to a profusion of lakes and muskeg that provide (when they are not frozen) lots of low level moisture for stratus and fog development.





Winds can occur from any and all directions, but there is a noticeable maximum from the northwest, particularly in winter when the climatological ridge is in place. Because Lynn Lake is in a forested area, there are frequent occurrences of calm winds.

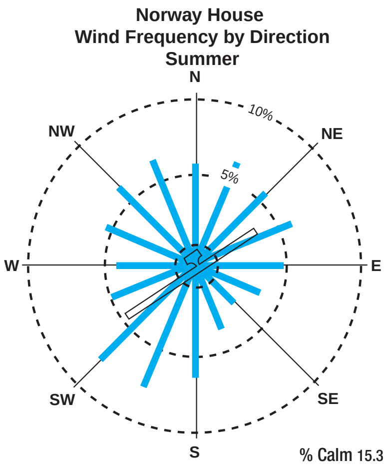


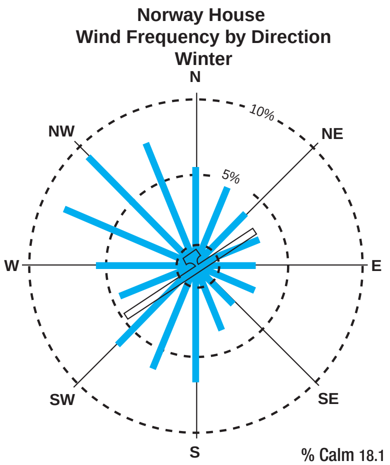


The proximity of water plays a role in the occurrence of low ceilings and poor visibility. Like many other sites with lakes nearby, the probability of poor flying weather in summer at Lynn Lake increases during the night to reach a maximum near 1200 UTC and falls off after that. In winter, the frequency of poor conditions is fairly steady at 11 to 14 percent, from sundown right through the night. After sunrise, conditions tend to be worse until about 1600 UTC, then slowly improve through the afternoon.

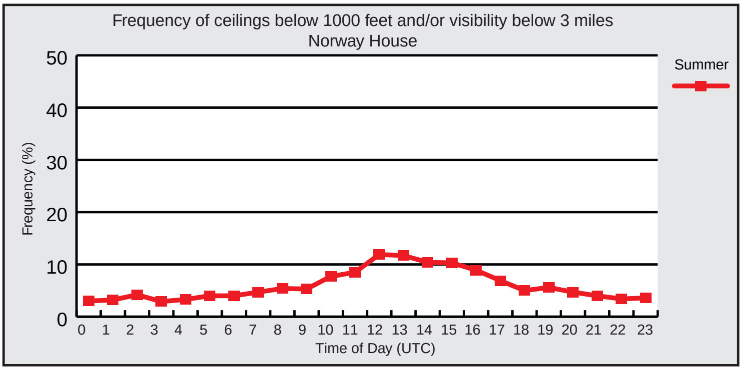
(f) Norway House

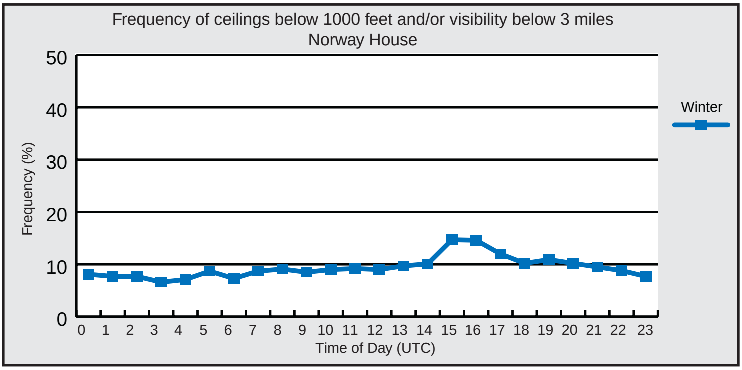
Norway House is located about 13 miles north of Lake Winnipeg in a flat, forested area of the Canadian Shield. There are many smaller lakes and muskeg in the area which can provide low level moisture for stratus formation when not frozen. When stratus ceilings are observed in the fall with a southerly flow, freezing drizzle is likely when the temperature is just below freezing, due to the additional moisture provided by Lake Winnipeg.





Winds blow from all directions at Norway House with about equal likelihood. In summer, there is a slight southwesterly maximum. In winter, a similarly weak preference for the northwest is shown. The east channel of the Nelson River lies in a southwest to northeast orientation through Norway House and provides some funnelling for the southwest flows. Although this effect also occurs in winter, the climatological high over the central Prairies provides a greater number of northwesterly wind events.

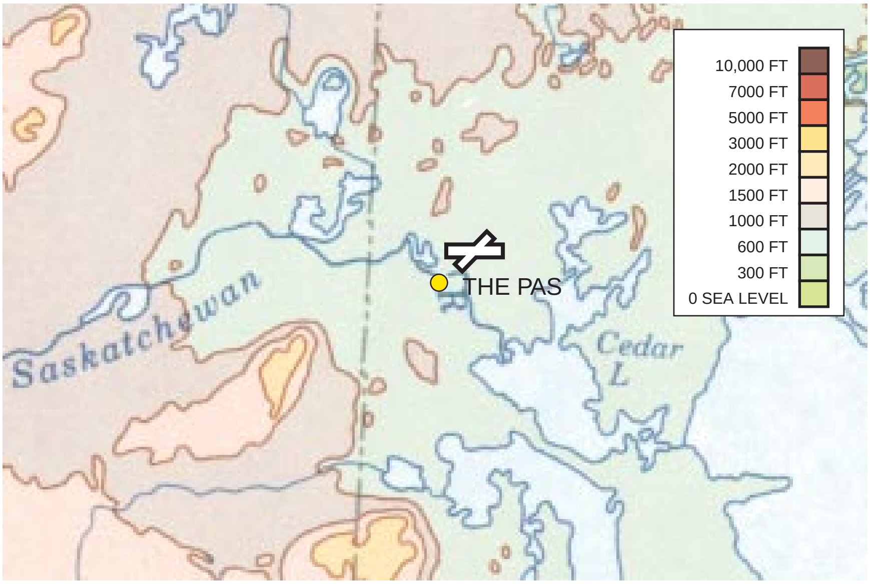




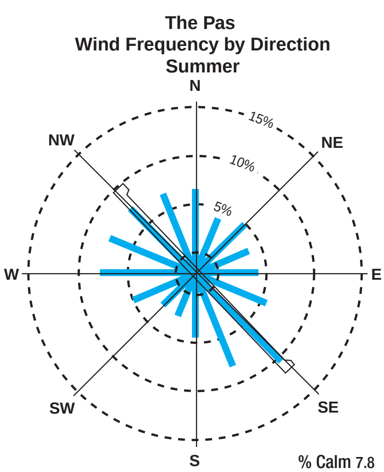
There is a high percentage of calm winds at Norway House, due in part to its forested location and partly because thermal inversions are common, especially in winter.

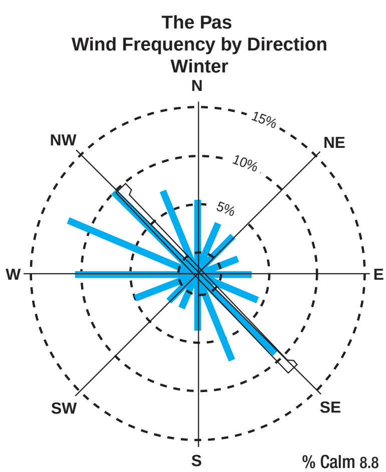
In general, Norway House has good flying conditions. Early on summer mornings, there is a maximum frequency of low flying conditions near 1300 UTC. In winter, the same "after sunrise" increase in the possibility of low ceilings and visibility occurs here, in much the same way as it does at many other sites in northern Manitoba, and elsewhere on the prairies, for that matter.

(g) The Pas



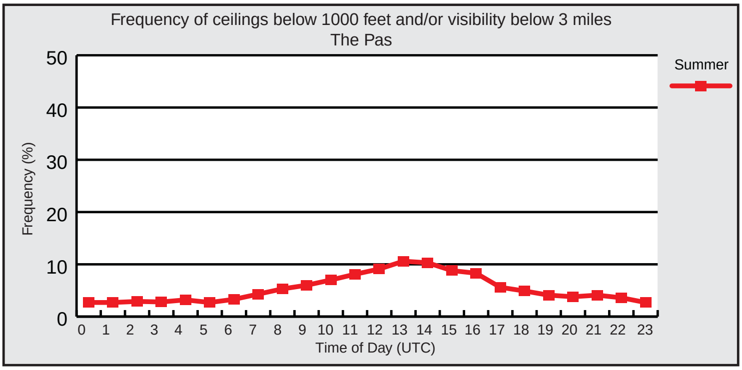
The Pas Airport is located at the southern end of Clearwater Lake, on the very flat terrain of west-central Manitoba. The town itself is about 13 miles to the southwest on the banks of the Saskatchewan River. There are many other large lakes in the area, all great moisture sources for stratus when they are not frozen.

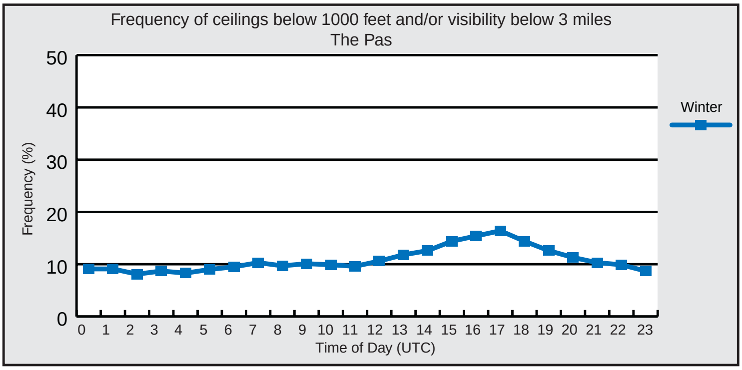




The winds at The Pas favour either northwesterly or southeasterly directions. The northwest winds result from having a ridge of high pressure located to the west or northwest, providing a suitable gradient over the area. The southeasterlies occur during the transits of low pressure systems to the south of The Pas. The Pasquia Hills, part of the Manitoba Escarpment, rising 1,500 feet above the surrounding terrain 46 miles southwest of The Pas, probably play some part in producing this northwest to southeast preference in wind direction. Another topographic feature that may play a role is a prominent terminal moraine left by the most recent ice age. The Pas Moraine extends southeastward from west of Clear Lake, arcs between Cedar Lake and Lake Winnipegosis, and extends out into Lake Winnipeg forming Long Point.

There is a stronger northwesterly maximum in winter, the result of having high pressure most often to the west (the climatological ridge) during this season.

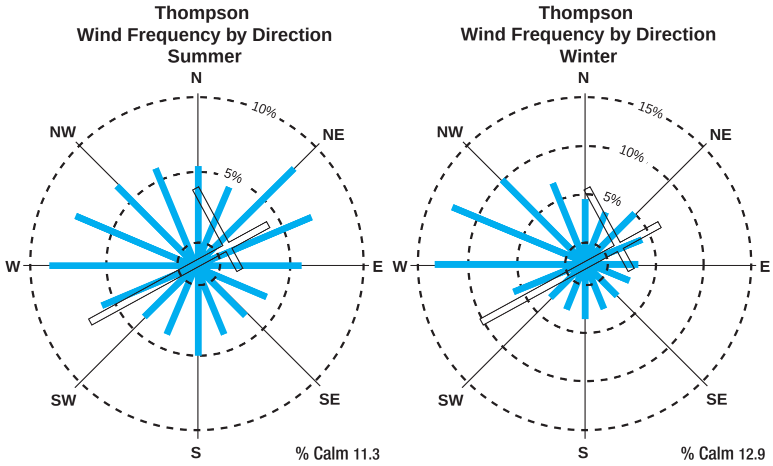




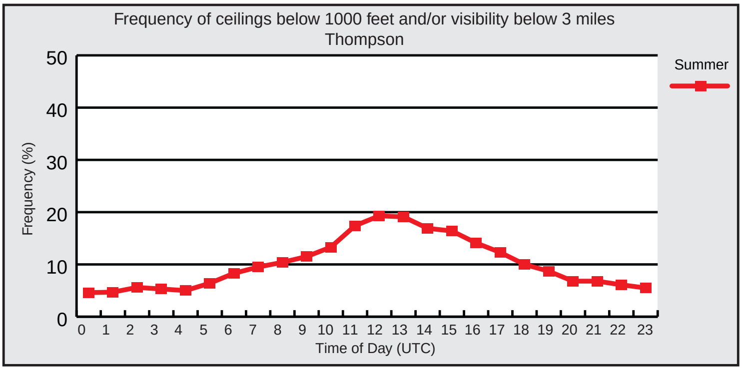
In summer at The Pas, poor conditions do not occur very often, despite having several sources of low level moisture nearby. The period where frequencies are higher than 5 percent extends from 0800 to 1700 UTC, with a peak of 10 percent at 1300 UTC. During winter, the chance of below VFR weather for a given hour hovers around 10 percent from 2100 to 1100 UTC. A peak of 17 percent occurs around 1700 UTC.

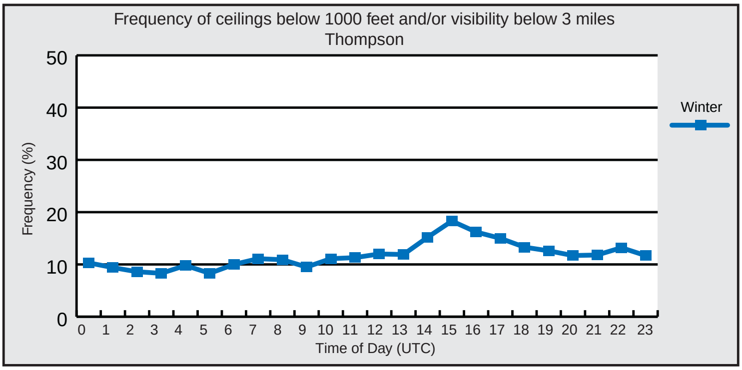
(h) Thompson

Thompson is the transportation hub of northern Manitoba. The city's airport is the second busiest in the province with several companies providing scheduled and charter service to and from Winnipeg, and to many other communities in northern Manitoba and southern Nunavut. Thompson also boasts an active float plane and helicopter base on the Burntwood River and is a principal railway depot on the line serving Churchill. A huge nickel mine and smelting operation, located on the southern outskirts of the city, is a major industry.



Thompson is located in north central Manitoba in the middle of the gently sloping Canadian Shield. There is an abundance of lakes, rivers and trees in the immediate vicinity ready to supply moisture to the local atmosphere. With few topographical features of any significance in the area, winds are a reflection of the synoptic scale weather systems that affect the area.



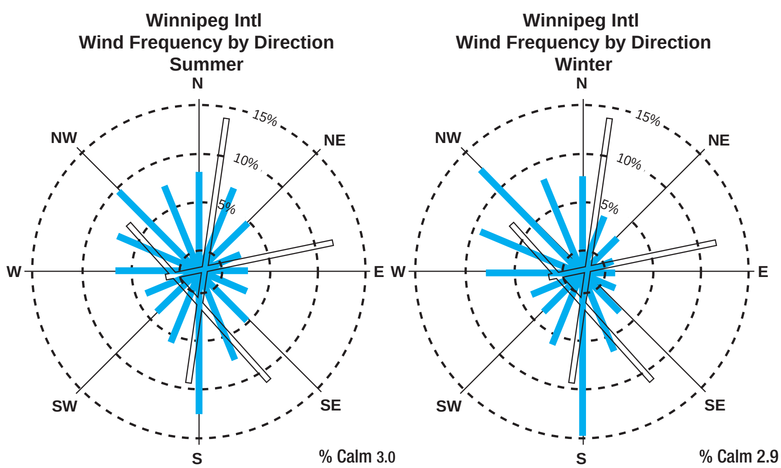


In the summer, there is an equal likelihood of having high pressure to the west generating a west or northwest flow as there is of having an east to northeasterly flow associated with low pressure to the south. During winter, the more common occurrence of a stronger high over the central Prairies produces a west to northwesterly maximum in the wind climatology.

In summer, during the late afternoon and evening, low ceilings or visibility occur at Thompson only about one day in 20. After 0400 UTC, the chances of poor flying conditions increases to one day in 5, or 20 percent, by 1200 UTC. In the winter, low ceilings or poor visibility conditions occur 10 percent of the time during most of sthe day and night. Just after sunrise, conditions get worse until about 1500 UTC, reaching a peak of close to 19 percent. It is interesting to note that there is a slightly higher chance of having poor flying conditions in the summer than in winter. Within the Canadian Shield, the familiar mixture of light winds, clear skies and abundant low-level moisture makes this possible at any time of the year.

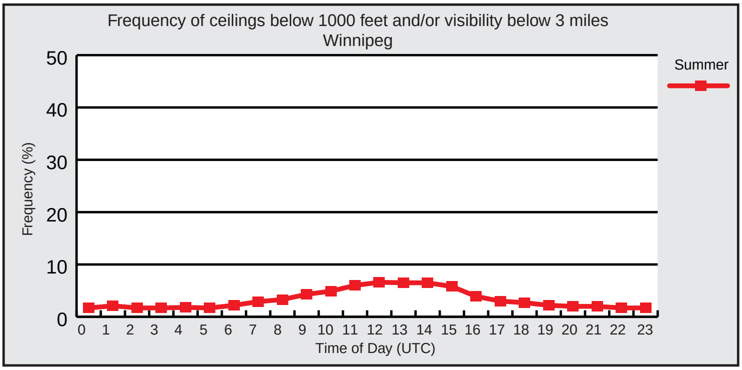
(i) Winnipeg

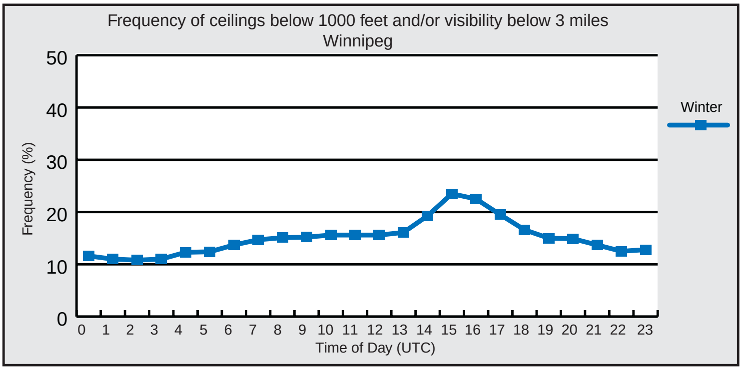
Winnipeg is situated in the broad, flat valley of the Red River where it courses northward toward Lake Winnipeg. The airport is located about 4 miles west of the downtown core of Winnipeg. The surrounding countryside is smooth prairie with almost no change in elevation for nearly 11 miles in any direction. The only exception to this is the Assiniboine River Valley that runs into Winnipeg and joins the Red River in the middle of town.



Since the average annual synoptic surface pressure pattern shows an area of high pressure over the central Prairies, there is a northwesterly maximum in wind frequency in Winnipeg. There is another sharp peak from the south which reflects the channelling efficacy of the Red River Valley, especially with flows ahead of a migratory low pressure system. When one of these lows passes to the south, the winds tend to blow out of the south longer than might be anticipated, based on the large-scale flow. Southwest and easterly winds are not nearly as common. Calm winds seldom occur which is why radiation fog is a very sporadic event.

In winter, the preferred directions from the south and northwest are more pronounced than in summer. The previously mentioned climatological high over the Prairies is more dominant, and normal winter storm tracks carry more migratory lows along the path. This produces strong southerly winds down the Red River valley. Also in winter, hoarfrost will occur, at times, with ice fog and, when it does, the ice fog is slow to clear. This is possibly due to the sublimation of the hoarfrost and subsequent increase in low level moisture after sunrise. With a southerly flow, stratus is frequently reported at Grand Forks, North Dakota. If this flow persists, the stratus will be advected across the border into Gretna and eventually into Winnipeg, often much quicker than expected. Once the fog has arrived, it requires a westerly flow to clear it out.





Good flying weather is commonplace in Winnipeg during the summer. The maximum hourly frequency of below VFR conditions is only 7 percent and occurs between 1100 and 1500 UTC. If fog or stratus does happen to occur during the night, one can expect it to begin to dissipate by 1600 UTC. In the wintertime, poor flying weather occurs much more frequently. During most of the day, the hourly chance of lower conditions ranges from 10 to 15 percent. However, between 1300 and 1900 UTC, the probability jumps sharply, peaking at 24 percent near 15 UTC. Since Winnipeg is a major airport, the high number of aircraft movements at this time of day no doubt augments low level moisture content and the typical maximum expected around sunrise.

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 electromagnetic 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 blizzard, in general, is 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 have a 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 - generally, 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 - in general, 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 - generally, 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 change 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.

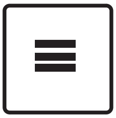
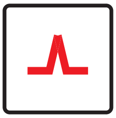
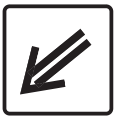
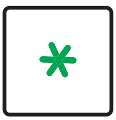
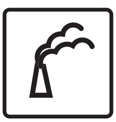
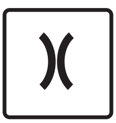
wind direction - the direction from which the wind is blowing.

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.

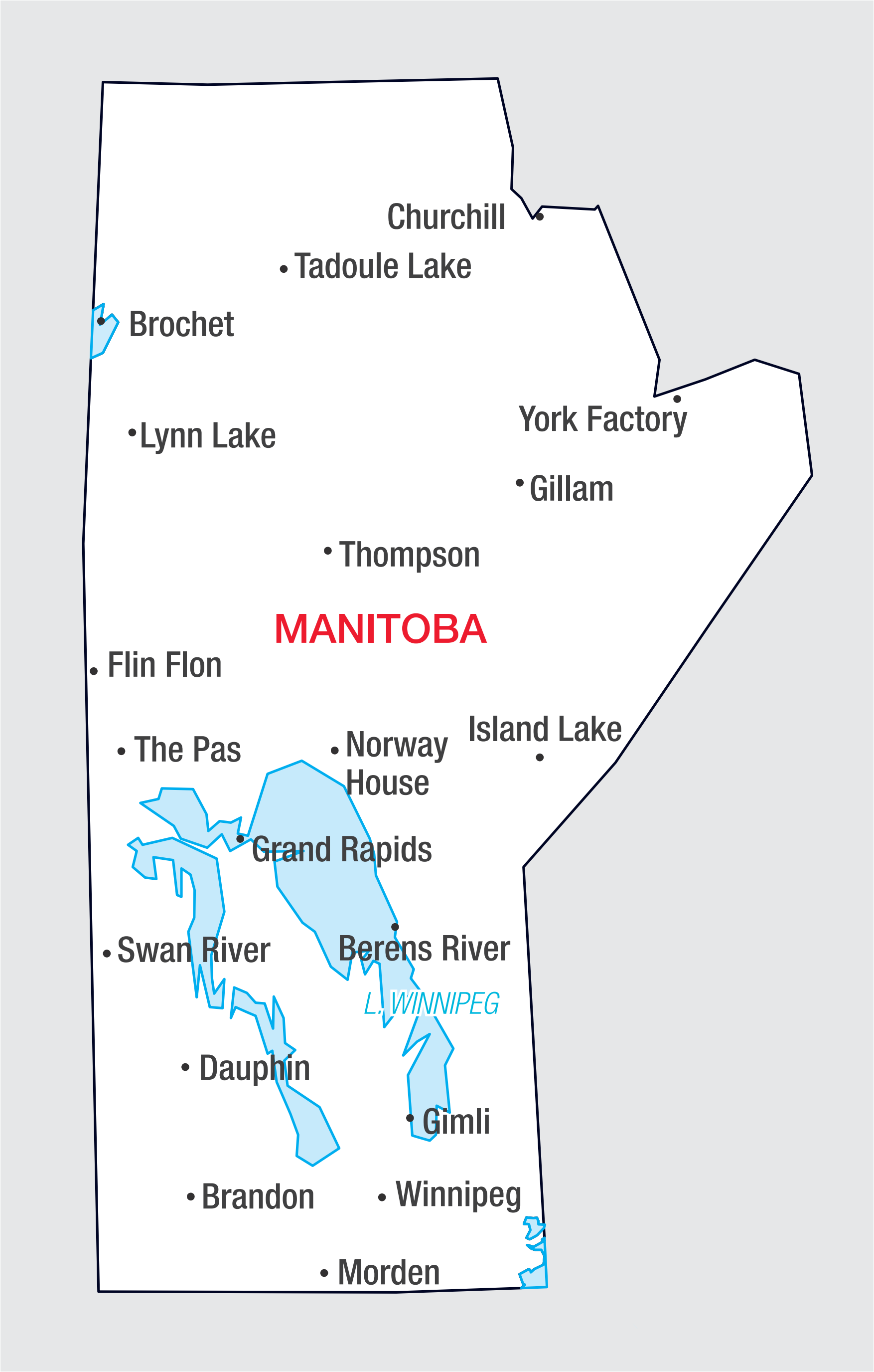
Table 3: Symbols Used in this Manual

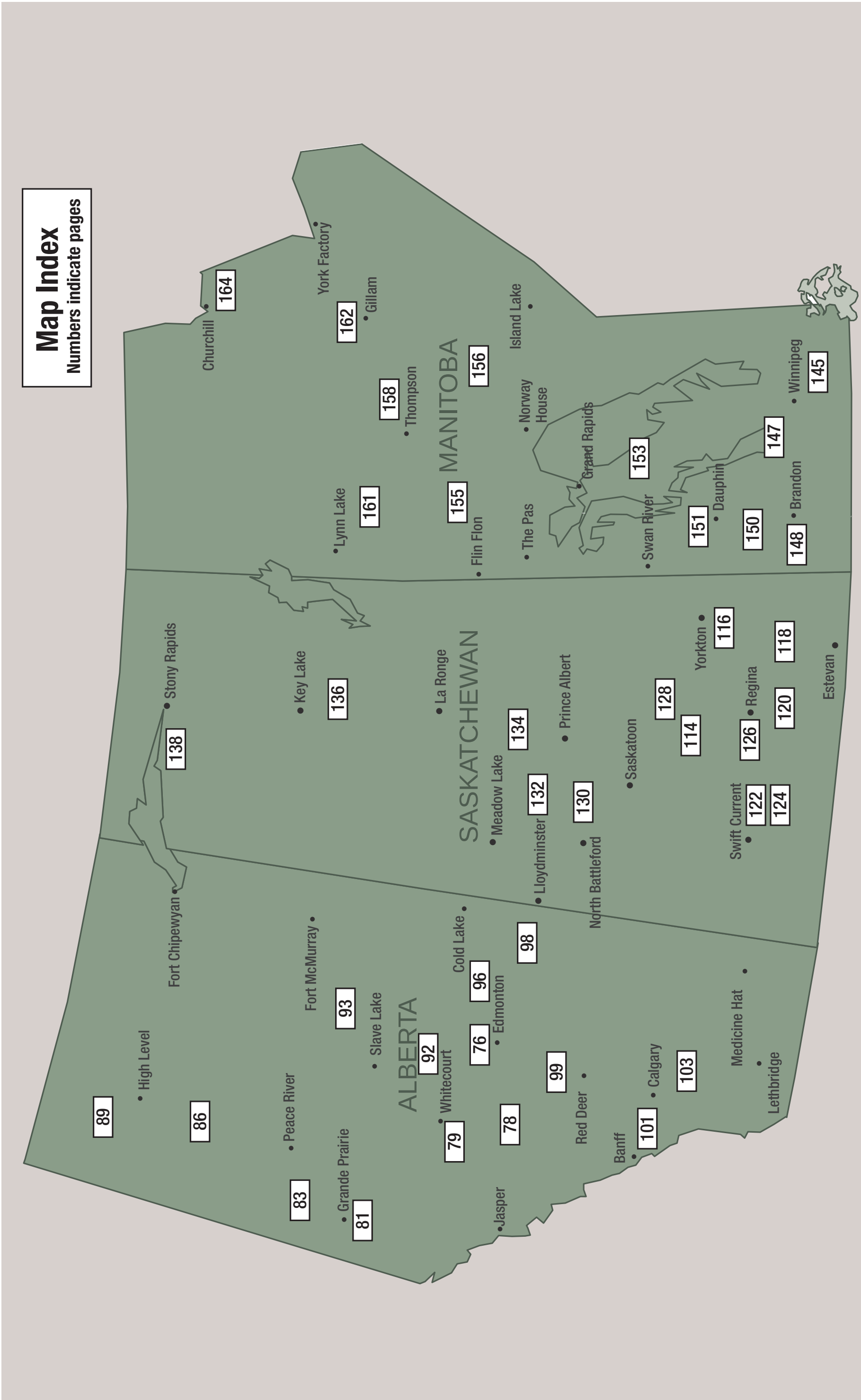
	**Fog Symbol (3 horizontal lines)** This standard symbol for fog indicates areas where fog is frequently observed.
	**Cloud areas and cloud edges** Scalloped lines show areas where low cloud (preventing VFR flying) is known to occur frequently. In many cases, this hazard may not be detected at any nearby 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.

Appendix


High Level
L. ATHABASCA
Fort Chipewyan
Peace River
Fort McMurray
Grande Prairie
Slave Lake
ALBERTA
Grande Cache
Whitecourt
Cold Lake
Edson
Jasper
Edmonton
Red Deer
Coronation
Banff
Calgary
Empress
Medicine Hat
Lethbridge


Stony Rapids
Collins Bay
REINDEER L.
Key Lake
Buffalo Narrows
La Ronge
SASKATCHEWAN
Meadow Lake
Lloydminster
Prince Albert
Nipawin
North Battleford
Saskatoon
Kindersley
Yorkton
Swift Current
Regina
Broadview
Shaunavon
Assiniboia
Estevan


Churchill
Tadoule Lake
Brochet
Lynn Lake
York Factory
Gillam
Thompson
MANITOBA
Flin Flon
The Pas
Norway House
Island Lake
Grand Rapids
Swan River
Berens River
L. WINNIPEG
Dauphin
Gimli
Brandon
Winnipeg
Morden


Map Index
Numbers indicate pages
MANITOBA
SASKATCHEWAN
ALBERTA
Churchill
164
York Factory
162
Gillam
158
Thompson
156
Island Lake
Norway House
Lynn Lake
161
155
Flin Flon
The Pas
Grand Rapids
153
Swan River
151
Dauphin
150
147
Winnipeg
145
Brandon
148
Stony Rapids
138
Key Lake
136
La Ronge
134
Prince Albert
Meadow Lake
132
Lloydminster
130
North Battleford
Saskatoon
128
114
Yorkton
116
118
Regina
126
120
Estevan
Swift Current
122
124
High Level
89
Fort Chipewyan
86
Fort McMurray
93
Peace River
83
Grande Prairie
81
Slave Lake
92
Whitecourt
79
76
Edmonton
96
Cold Lake
98
78
Jasper
99
Red Deer
101
Banff
Calgary
103
Medicine Hat
Lethbridge

NAV CANADA

11/08/05