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.

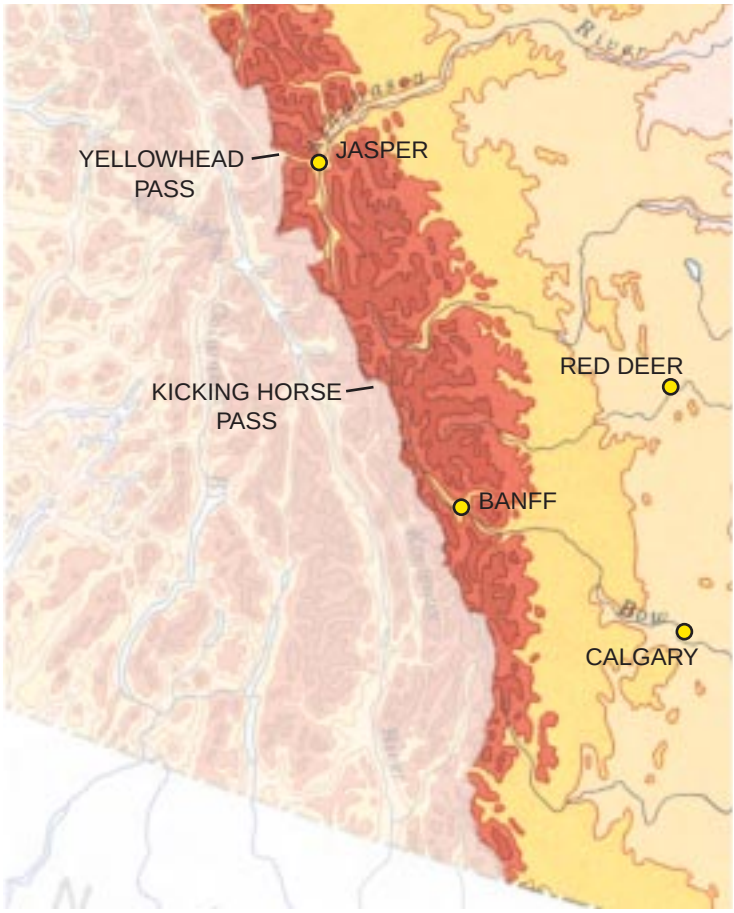
Land elevations are highest in southwestern Alberta and gradually decrease to sea level in northeastern Manitoba, along the Hudson Bay coast. Prominent ranges of hills that influence the weather can be found in all three provinces. These include the Cypress Hills, Swan Hills and Caribou Mountains in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

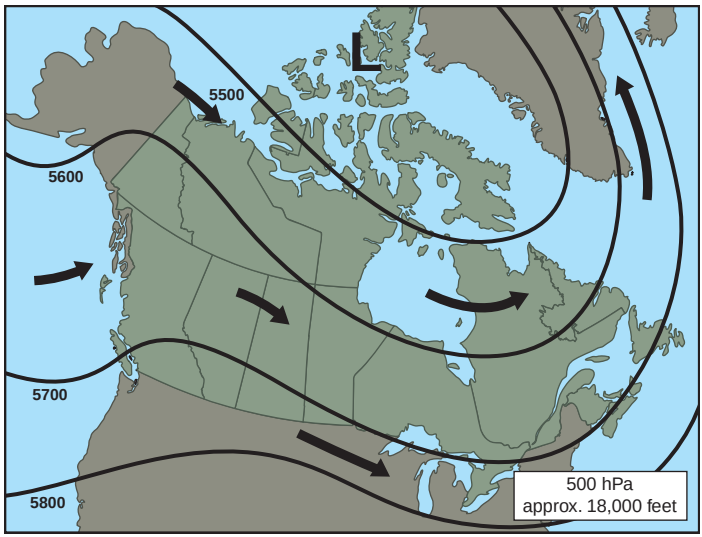


Fig. 3-1 - Mean summer upper winds

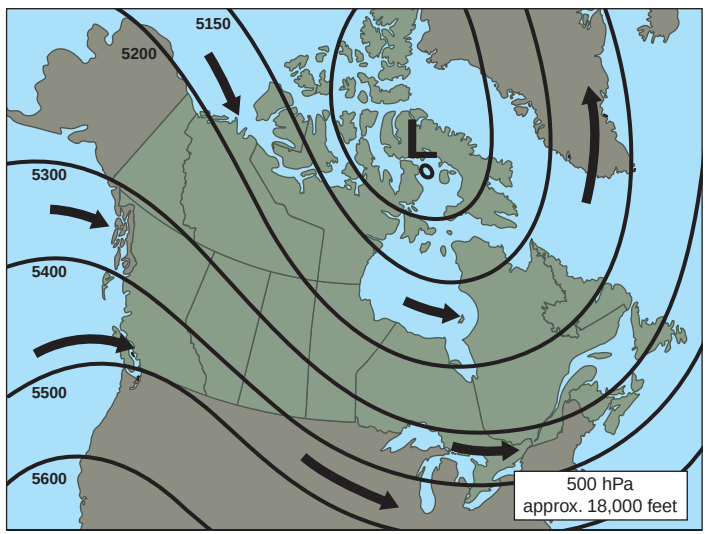


Fig. 3-2 - Mean winter upper winds

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 southeast-

wards 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

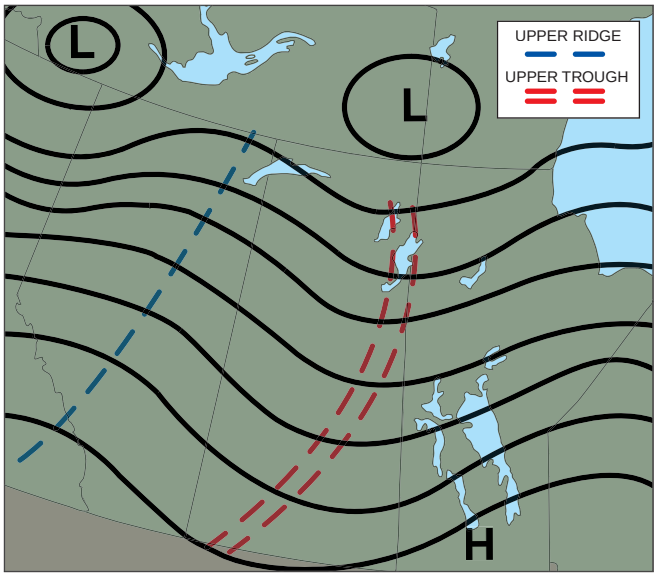


Fig.3-3 - Typical winter pattern with upper troughs and ridges added

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.

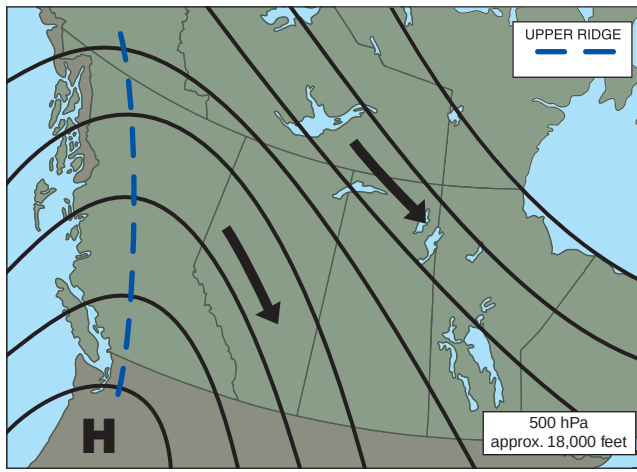


Fig. 3-4 - Upper ridge over BC giving northwest flow to the Prairies

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

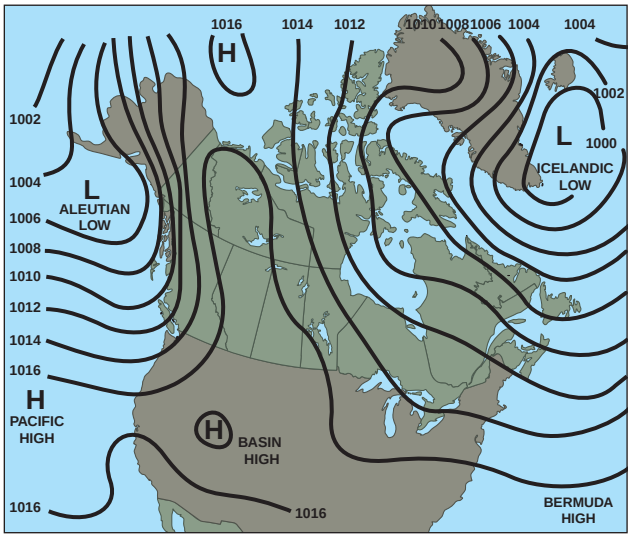


Fig. 3-5 - January mean sea level pressure

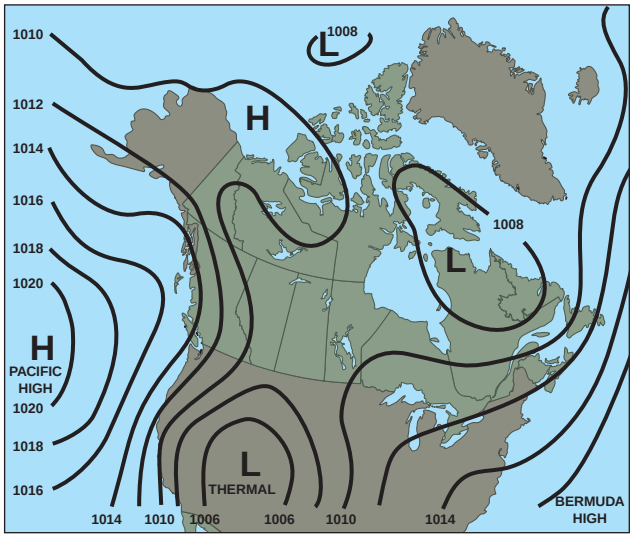


Fig. 3-6 - July mean sea level pressure

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. southwest as having about the same probability of invading the Prairies.

Migratory Surface Weather Systems

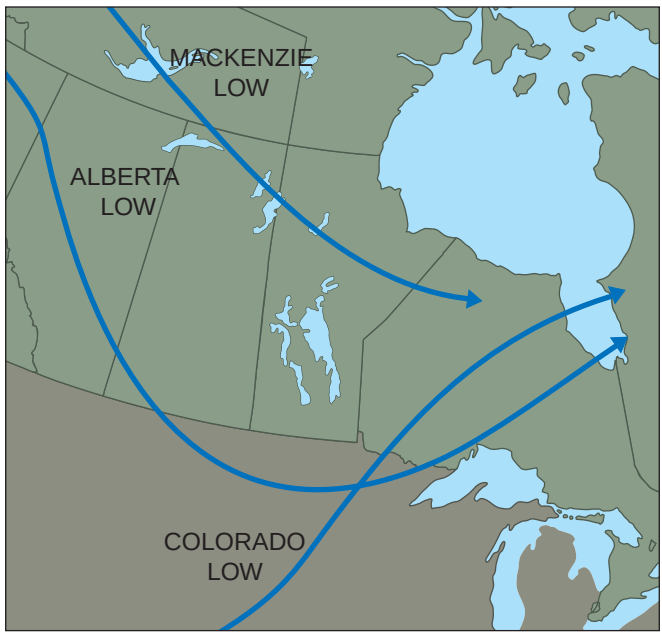


Fig. 3-7 - Major Prairie storm tracks

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

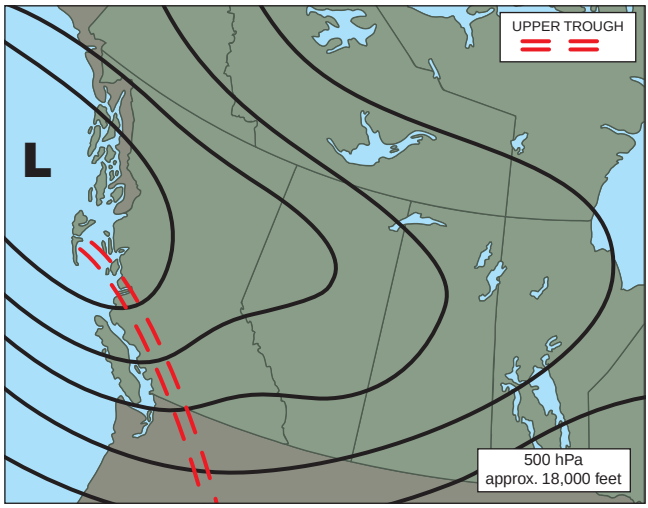


Fig.3-8 - Upper trough moving across BC

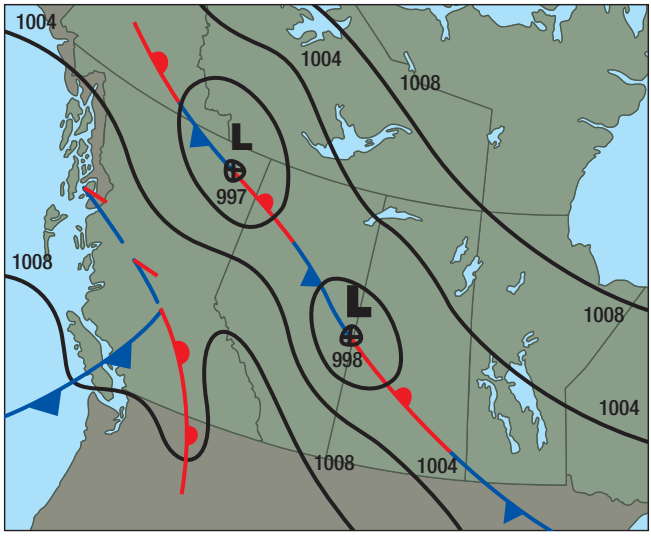


Fig. 3-9 - Surface Analysis

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

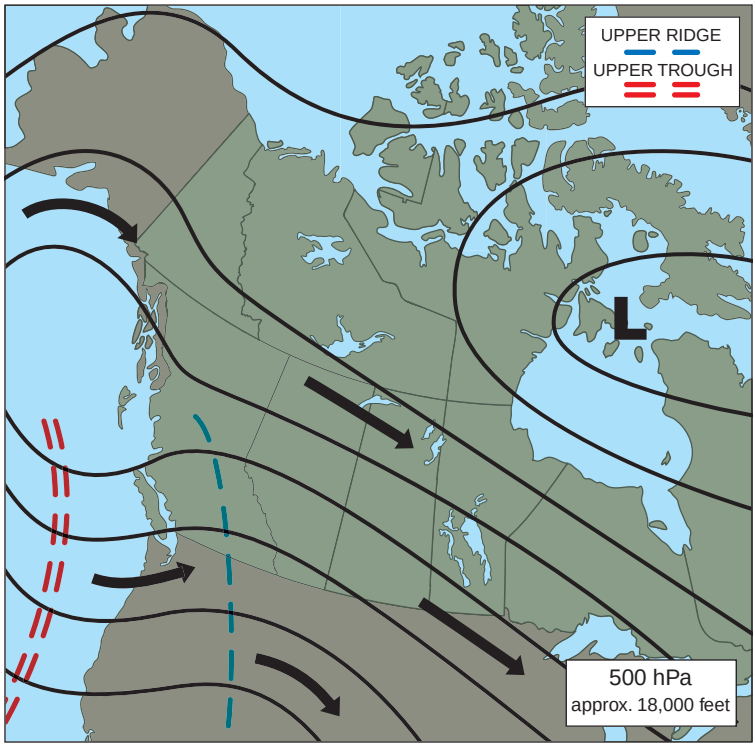


Fig. 3-10 - Upper air pattern for Cold Air Damming

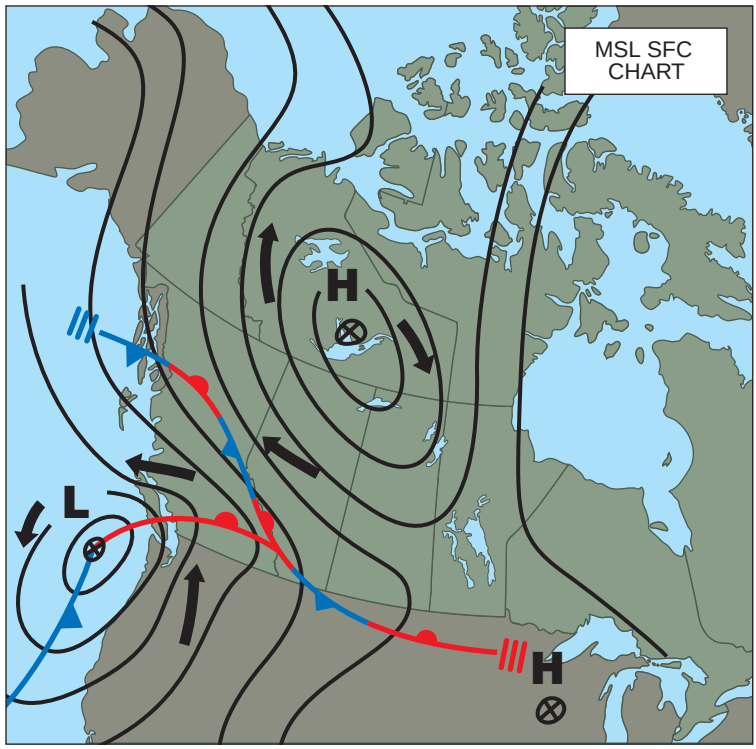


Fig. 3-11 - Surface map for Cold Air Damming

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.

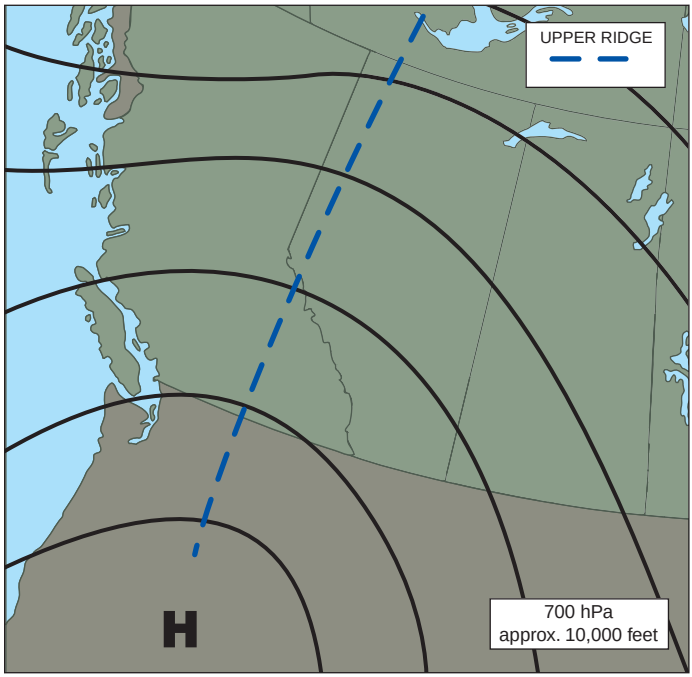


Fig. 3-12 - Upper level Chinook flow

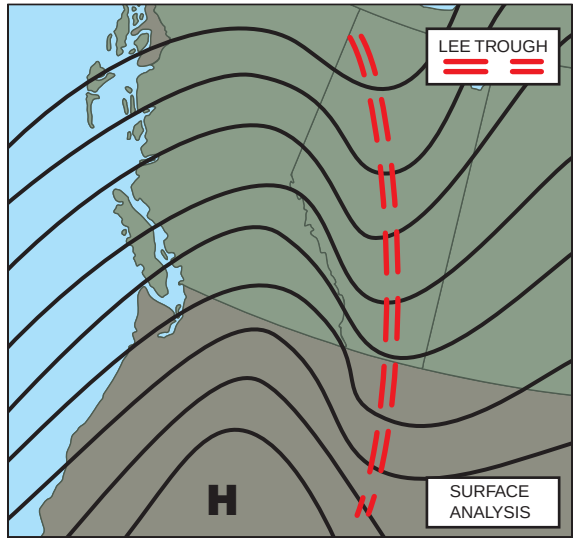


Fig. 3-13 - Basin high surface Chinook flow

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.

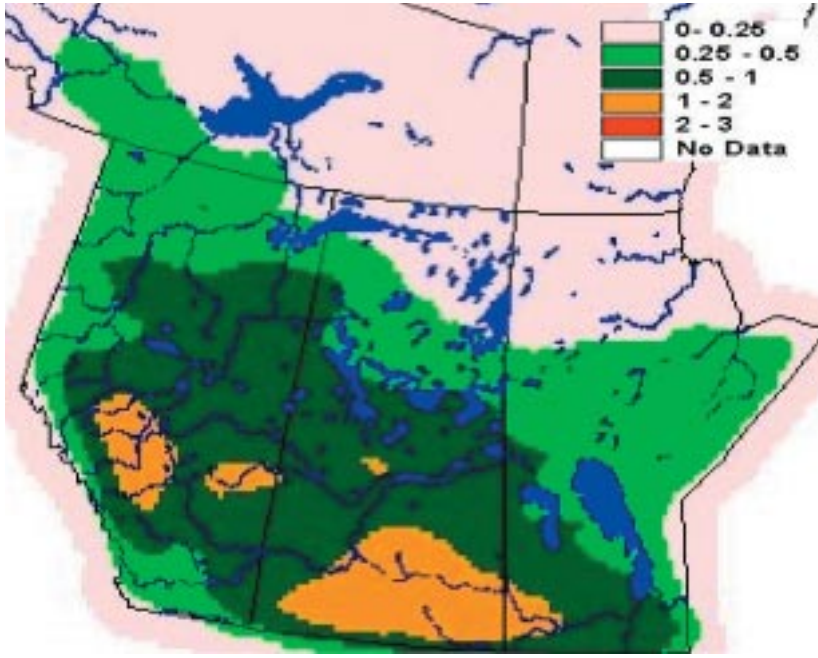


Fig. 3-14 - Lightning strike data for 1998-2000 (lightning strikes per square km)

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.

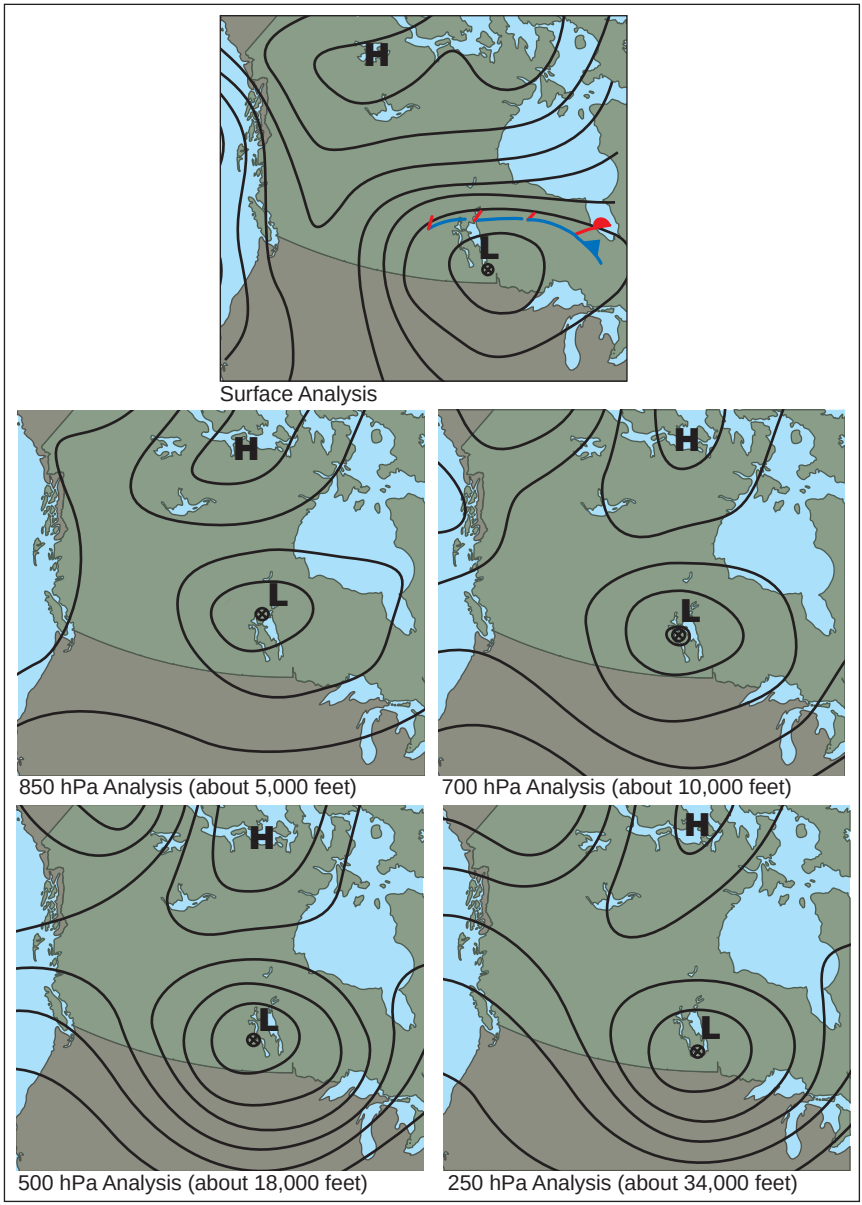


Fig. 3-15 - Typical surface and upper level pattern for a cold low event

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.