Chapter 3

Weather Patterns of the Yukon, Northwest Territories and Western Nunavut

Introduction

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

Topography

The following figure shows the topography of the GFACN35 domain: Yukon, Northwest Territories south of 72°N and Western Nunavut. The GFACN35 domain has the greatest elevation range of all the GFA domains, going from sea level across the Beaufort, to peaks approaching 20,000 feet extreme southwestern Yukon.
Topography: The Yukon section of GFACN 35 domain

Map 3-2 - Topography of the GFACN35 domain

One of the most striking features of the Yukon is its towering mountains and deep valleys. Almost all of the Yukon lies within Western Cordillera, a region of faulted and folded mountains and plateaux. The mountain ranges of the Western Cordillera extend northwestward through British Columbia, then arc to the west across the Yukon and finally southwest over Alaska. The directional shift in orientation that takes place over the Yukon results in a chaotic mass of mountains and valleys. However, at least three major ranges can be identified.

The St. Elias and Coast Mountains rise steeply from the Pacific Ocean, forming an awesome barrier that transects extreme southwestern Yukon. While several river valleys cut deeply into this barrier, these ranges serve to block the free flow of Pacific air masses into the Yukon’s interior. The Coast Mountains vary in elevation from 6,500 feet to almost 10,000 feet ASL (above sea level) but are dwarfed by still higher peaks in the St. Elias range to the west and northwest. These are the highest mountains in
all of Canada and probably the most spectacular group of peaks in North America. Huge icefields flank the rising slopes of Mt. Logan (19,541 feet), Mt. St. Elias (18,008 feet), Mt. Lucania (17,260 feet), Mt. Steel (16,470 feet), and Mt. Wood (15,945 feet). This block of mountains continues northwest into Alaska where it is known as the Wrangell Mountains.

Just to the northeast of the St. Elias and Coast Mountain ranges lies the Shakwak Trench, a corridor of low level terrain within the broader Yukon River basin. The trench extends from the British Columbia border through to Haines Junction, then northwestward to Burwash and Northway, Alaska. To the east of the Shakwak Trench, the Yukon River Basin, often referred to as the Yukon plateau, forms a fairly rough highland area with an elevation of between 3,000 and 5,000 feet ASL, dotted with numerous seemingly random placed mountains rising to over 6,500 feet. Long, narrow, glacier-fed lakes lie at the southern end of the plateau. These lakes feed into the deeply cut Yukon River and its tributaries which flow northwestward along the length of the basin. Flanking the northeastern side of the plateau are the Cassiar and Pelly Mountains.

The Cassiar Mountains of north-central British Columbia meet the Pelly Mountains over south-central Yukon. Together they form a second significant barrier that extends northwestward, gradually blending into the generally rugged terrain of the Yukon Plateau, southeast of Dawson. These mountain ranges are broken along their length by several broad passes but in general they maintain an elevation of between 6,000 and 7,000 feet ASL with a few peaks rising to near 8,000 feet.

In the southeast corner of Yukon lies the Liard Basin, a 95 mile wide plain with an elevation of between 2,000 and 3,500 feet ASL, through which the Liard River and its tributaries wind their way southeastward. The basin is an extension of Rocky Mountain Trench which separates the Cassiar Mountains from the Rocky Mountains in northeastern British Columbia. The Alaska Highway winds its way northward along the floor of these rugged mountain corridors, bordered by peaks rising to heights of almost 10,000 feet. The pass at Summit Lake, just south of the Yukon border, is the highest point along this Alaska Highway route, having an elevation of just less than 4,250 feet ASL. The northern end of the Liard plain narrows into the Tintina Trench which continues northwestward, between the Pelly Mountains to the southwest and the Selwyn Mountains to the northeast.

The Selwyn Mountains, together with the Mackenzie Mountains, form a broad and unbroken, rugged and chaotically staggered, block of peaks ranging in elevation from 8,000 to almost 10,000 feet ASL along the eastern Yukon border. They wrap westward across central Yukon, narrow and fall in elevation, merging into the 7,000 feet tall peaks of the Ogilvie Mountains, north of Dawson, and finally flatten out across the Yukon Plateau, near the Alaska border.
To the north of the Ogilvie, Selwyn and Mackenzie Mountains lie the Peel Plateau and the somewhat more expansive Porcupine River Basin. The Peel River and its tributaries lace the plateau, merge and flow northward into the Mackenzie Delta. The Porcupine River and its tributaries merge and flow westward past Old Crow and into Alaska. Much of the Porcupine River Basin consists of low rolling hills and fairly deep valleys. In general, the terrain ranges in elevation between 1,000 and 2,000 feet except for an almost flat area of numerous interconnected lakes and swamps, some 60 miles in diameter, nestled in the northwest corner of the basin known as Old Crow Flats.

The Richardson Mountains form a rugged 4,000 to 5,200 foot ASL high boundary along the Yukon border, to the east of the Peel Plateau. The range gradually falls in elevation to between 2,000 and 3,000 feet near the Arctic Coast, while the British Mountains, an extension of the Brooks Range in northern Alaska, stretch westward rising to heights of almost 5,000 feet.

A narrow, gently sloping, 6 to 12 mile wide, treeless Coastal Plain separates the rolling foothills of the Richardson and British Mountains from the Beaufort Sea. Herschel Island lies just offshore and east of Komakuk Beach. This low treeless island is the only island along the Yukon coast. Pauline Cove, on the southeast side of Herschel, is the only protected harbour between the Mackenzie River Delta and Point Barrow, Alaska. Permanent pack ice usually lies about 50 miles north of Herschel, drifting in a prevailing clockwise current called the Beaufort Gyre. However, depending on winds and the season, pack ice will press right into the coastline.
**Topography - Northwest Territories and western Nunavut section of GFACN 35 domain**

This section works its way from the mountainous Yukon / NWT border east to the lowlands of Victoria Island on the eastern corner of the domain.

Mountains - The mountainous terrain of the Yukon spills into the Northwest Territories. The Mackenzie Mountains arc east from the Yukon at about 65°N and then run southeast to the west of Norman Wells and Fort Simpson. The highest point of the Mackenzie Mountains and in the NWT, at approximately 9,098 feet ASL, lies almost directly west of Fort Simpson, close to the Yukon / NWT border. Nearby, Mount Sir James MacBrien peaks at approximately 9,062 feet.

Along the northern Yukon / NWT border, the Richardson Mountains, which are predominantly in the northern Yukon, spill into the NWT. These mountains quickly rise to about 2,000 feet ASL from the near sea level Mackenzie Delta and...
peak at near 5,500 feet to the west of Aklavik. These mountains evoke the full gamut of upslope and downslope cloud regimes and the full gamut of channelled, funnelled and gap winds. These mountains and the mountains of the Yukon deplete considerable moisture from airmasses coming into the Northwest Territories from the southwest and west. They also mask low pressure centres that make their way from the Gulf of Alaska into the Northwest Territories.

Low terrain - Great Slave Lake, Great Bear Lake, the Liard River Valley and the Mackenzie River Valley are low spots terrain-wise in the NWT. They range from water levels near 500 ASL across the two Great Lakes to just a few feet above sea level across much of the Delta. Northwesterly winds can - and do - readily push low cloud from the Beaufort / Mackenzie Bay into the Delta and the lower Mackenzie. Flying out from any of the airports in these relatively low spots along the river valleys, or along the shores of Great Slave Lake, has the pilot flying over terrain which is rising below them, giving the potential for lower cloud ceiling heights and deteriorating visibility. In some cases, rises in terrain are almost vertical. The low terrain of the Mackenzie Valley is a favoured area for low pressure centres that lost their identity while moving across the Yukon.

Great Lakes have some spectacular terrain on their shores - Water level on both Great Slave and Great Bear Lake is around 500 feet ASL. Around the shores of Great Bear Lake, there are places where the terrain rises quickly. The Grizzly Bear Mountains, which reside on a peninsula jutting into southwest Great Bear Lake, has peaks close to 2,300 feet. The Scented Grass Hills that reside on the “next” peninsula as we work north has peaks to about 2,150 feet.

The northeast arm of Great Slave Lake has similar spectacular rises (cliffs) from lake level to over 1,600 feet.

More mountains, a few high areas and then some more high terrain - To the immediate east of the Mackenzie Valley, from south of Fort Good Hope to south of Wrigley, the Franklin Mountains rise to about 5,175 feet ASL within a few miles northeast of Wrigley and to about 3,300 feet to the immediate east of Norman Wells. The terrain that pilots talk about is not necessarily this high. For example, Bear Rock, to the immediate northwest of Tulita, rises to close to 1,500 feet and is cited by pilots as being an area prone to turbulence.

Other terrain of note over southwestern NWT are the Horn Plateau (generally at 2,100 feet ASL with rises to about 2,750 feet), the hills around Trout Lake (peaks at just over 2,650 feet) and the Cameron Hills (rises to about 2,900 feet).

High terrain right to the coast east of Great Slave and north and east of Great Bear - To the southeast and east of Great Slave Lake, through east and north of Great Bear Lake up to the Arctic coast, the terrain is generally above 1,400 feet ASL. It rises in
places, ranging from close to 1,886 feet southeast of Great Slave Lake to 2,250 feet east of Contwoyto Lake, to 2,900 feet less than 30 miles southeast of Clinton Point on the Arctic coast. The water level on Contwoyto Lake is about 1,480 feet. The treeline runs across this area. Northeast and east of the treeline, strong winds readily get snow blowing at locations such as the diamond mine area around Lac de Gras.

The drop to sea level is abrupt in an arc from the southwest shore of Franklin Bay, to south of the Parry Peninsula, to the southeast shore of Darnley Bay, and continuing along the coast to the Cape Young area. In onshore flows, the abrupt rises can dam low cloud and fog seaward.

Southern Banks Island - The terrain on the southwest section is relatively flat, about 300 feet ASL, with local hills near 700 feet. The southwest section shows stronger elevation changes especially the southern tip, Nelson Head, that rises to 2,450 feet.

Victoria Island - The higher terrain which began over Banks Island extends into western Victoria Island. While coastal plains are evident, the area has terrain that elevates to 2,150 feet.

The terrain across eastern Victoria Island is low and flat. This is significant in that the area is favoured synoptically for strong northwest winds. This combination facilitates this area being part of blizzard alley - a corridor stretching northwest to southeast from the central Arctic Islands to the shores of western Hudson Bay that is blizzard-prone.

River basins - The major river basins are the Mackenzie and the Yukon. The Mackenzie River, based on estimated annual volume at its mouth, is the fourth largest river that flows into the Arctic basin and the 19th largest in the world. Its watershed drains much of the western Northwest Territories, as well as portions of the Yukon, and the three westernmost provinces. Important tributaries of the Mackenzie within the GFACN35 domain include the Liard, Peel, Slave, and Arctic Red River. The Yukon River watershed drains most of the Yukon Territory. Its major tributaries within the domain include the Porcupine, Stewart, Pelly, and Teslin Rivers.

Some of the other river basins in the GFACN35 domain are the Alsek, Coppermine and Horton.
Map 3-4 - Northwest Territories and Yukon sections of the Mackenzie River Basin

credit: E. Leinberger, UBC, Mackenzie Basin Impact Study
Treeline and vegetation

An important feature of the GFACN35 domain is the treeline. Trees act as a great snow fence and suppress wind speeds. To the east and north of the tree line, winds are stronger resulting in more extensive drifting and blowing snow.

Length of daylight in June and July affects temperature and relative humidity and, hence, fog development

Barring an intrusion of cold air, temperatures remain high through the evening and into the night. The result is that the humidity remains lower than in southern latitudes and the possibility of fog is reduced.

Length of daylight in June and July leads to extended thundershower development

In June and July temperatures remain high through the evening. Thundershowers
can occur in the late evening or even after midnight, versus the afternoon into evening, as is common across the southern latitudes. When thundershowers do occur, they can often be high based, leading to dry lightning.

**Daylight, Twilight, and Night**

The GFACN35 extends from 60° N to 72° N - an area known for long summer days and long winter nights. The days are effectively lengthened and nights shortened by periods of twilight as follows:

![Midnight sun](credit: Government of Northwest Territories web site)

Civil twilight is defined to begin in the morning, and to end in the evening when the center of the Sun is geometrically 6 degrees below the horizon. This is the limit at which twilight illumination is sufficient, under good weather conditions, for terrestrial objects to be clearly distinguished. At the beginning of morning civil twilight, or end of evening civil twilight, the horizon is clearly defined and the brightest stars are visible under good atmospheric conditions, in the absence of moonlight or other illumination. In the morning, before the beginning of civil twilight, and in the evening, after the end of civil twilight, artificial illumination is normally required to carry on ordinary outdoor activities. Complete darkness, however, ends sometime prior to the beginning of morning civil twilight and begins sometime after the end of evening civil twilight. Transport Canada allows VFR flight during civic twilight and for aviation purposes night is defined as the period between the end of civil twilight in the evening and the beginning of civil twilight in the morning.

Nautical twilight is defined to begin in the morning, and to end in the evening, when the center of the sun is geometrically 12 degrees below the horizon. At the beginning or end of nautical twilight, under good atmospheric conditions and in the absence of other illumination, general outlines of ground objects may be distinguishable, but detailed outdoor operations are not possible, and the horizon is indistinct.
Astronomical twilight is defined to begin in the morning, and to end in the evening when the center of the Sun is geometrically 18 degrees below the horizon. Before the beginning of astronomical twilight in the morning, and after the end of astronomical twilight in the evening, the sun does not contribute to sky illumination. For a considerable interval after the beginning of morning twilight, and before the end of evening twilight, sky illumination is so faint that it is practically imperceptible.

Fig 3-1 - Hours of daylight, twilight and illumination: Fort Smith, Sachs Harbour, Dawson, and Old Crow

Of course, in mountainous terrain there is not a flat horizon, making these definitions somewhat inexact.

North of about 65.5° N, 24-hour daylight occurs centred around June 21st. At Sachs Harbour (72° N), the sun rises on May 8th and does not set again until August 3rd. Even at communities much further south, such as Watson Lake and Fort Smith, daylight on the longest day peaks at 18.9 hours.
North of about 67.5°N occurs the winter period of no daylight, centred around December 21st. At Sachs Harbour, the sun sets about November 15th and does not rise again until around January 26th. However, even around December 21st, there are still two hours of civil twilight. Further south at Watson Lake and Fort Smith, there are 5.9 hours of daylight plus almost two hours of civil twilight.

The limits of 24-hour daylight and 24-hours without daylight (not 24-hour night) are not coincidental. Rather they extend about 50 miles north and south of the Arctic Circle, in flat terrain. This is because at the Arctic Circle half of the solar disk remains visible on the northern horizon at solar midnight, on the longest day, and half of the solar disk remains visible on the southern horizon at solar noon, on the shortest day. These limits move considerably southwards in mountainous terrain, particularly in deep valleys.

![Fig 3-2 - 24 hours of daylight vs. 24 hours of no-daylight](image)

**Late to freeze, open water areas, leads, polynyas**

Open water areas are a source of moisture and are prone to low cloud and fog through the entire year. During the fall and winter, the cloud and fog are often composed of supercooled water droplets and, hence, capable of giving both freezing drizzle and significant aircraft icing. Low cloud and fog from the open water areas are routinely transported inland on the windward side.
In the fall, winter and spring, there are preferred areas where open water persists and where leads recur with regularity as offshore winds pull ice away. In some cases, open water areas exist through the entire year defying freeze-up. These areas are known as polynyas. Within the GFACN35 domain, the Cape Bathurst polynya is often cited. In addition to the recurring leads/polynas, there are areas that are slow to freeze-over or are frequently open. A “deep water” area in central Amundsen Gulf is often one of the last areas of the Beaufort Sea to freeze over and, hence, is a lingering source of low level moisture.

The boundary between shore fast and pack ice across Mackenzie Bay and the Tuktoyaktuk Peninsula is tied to the 60 foot depth line. It is along this line that offshore wind regimes, e.g. easterly winds, can move the pack ice away creating an open water lead. Onshore winds bring a return of pack ice, and the boundary between the landfast ice and pack ice becomes almost invisible in satellite imagery.

The following photo shows the fast ice edge across Mackenzie Bay and off the Tuktoyaktuk Peninsula. This is infrared imagery and, hence, a sensing of heat. The darker the area, the more recent there was open water. Some of the darkest areas may be a mix of open water and the thinnest of new ice types, such as grease ice. The figure shows cracks across Amundsen Gulf of various vintage. The cracks extend to the vicinity of Holman Island.
From March into April, as the amount of daylight at 70°N increases, visible satellite imagery becomes useful to “see” open water moisture sources. Indeed, in summer, with water and ice temperatures nearly equal, infrared imagery is of little value in sorting out ice versus water and one must use visible imagery instead.

Open water season for Mackenzie Bay, southern Beaufort and the waterway to Cambridge Bay

Melting begins in early June and puddles are soon extensive on both the fast and the pack ice. The outflow of the Mackenzie River becomes apparent and creates an area of open water in the southeast corner of Mackenzie Bay, while the Cape Bathurst polynya expands southwestward. Melting in summer decreases ice thickness by about three feet in the offshore area and by four to five feet near shore. This implies that the first year floes in the coastal area disintegrate before the full ice thickness has been melted.
In most years, the pack ice gradually retreats northward after the creation of the Cape Bathurst polynya. In one of three years, the pack ice lingers close to its spring position. When the offshore pack retreats northward, an area of open water develops between the edge of the fast ice and the retreating offshore pack. As the shore fast ice fractures and decays, and if the offshore pack retreats further northward, the envelope of open water gradually expands. Even then, ice can linger in places. Pauline Cove, on Herschel Island, is an area where ice can move in and out of the cove rapidly, and ice in some years lingers in this area through the open water season.

Fig. 3-4 - Break-up dates, 1971 to 2000 data. credit: Canadian Ice Service

September is the best month, ice-wise. Melting has been under way for three months and continues, so that even the floes which are present are well weakened by the puddles on them. It is possible in this month to encounter northwest winds that carry pack ice southward.
Freeze-up

Freeze-up occurs in October and is related to the location of the offshore pack ice.

The initial freezing occurs near the floes of the drifting pack but develops in the shallow coastal water as well. In a good year, open pack ice may persist until early November. In a bad year, when the pack is close to shore, freeze-up occurs quickly and by the middle of October, the Arctic water of the GFACN35 domain can be frozen over. There is little difference in timing of freeze-up between Herschel Island, in the west, and Cape Dalhousie, in the east.
Lake Freeze-up and Break-up

Freeze-up

<table>
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<th>FREEZE-UP</th>
<th>GREAT SLAVE LAKE</th>
<th>GREAT BEAR LAKE</th>
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<td></td>
<td>ENTIRE LAKE</td>
<td>BACK BAY, YELLOWKNIFE</td>
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<td>25 NOV</td>
<td>18 OCT</td>
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<tr>
<td>MEDIAN</td>
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<td>26 OCT</td>
</tr>
<tr>
<td>LATE</td>
<td>16 DEC</td>
<td>18 NOV</td>
</tr>
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</table>

Table 3-1 - Freeze-up, Great Slave Lake and Great Bear Lake, 1988-1998 data

Like the ocean areas, the lakes of the area, and in particular the large lakes such as Great Bear Lake and Great Slave Lake, are cloud and fog prone through the fall until they freeze over completely. These lakes are also fog prone during the spring melt period but to a lesser degree. During the fall period, with below freezing air temperatures and the cloud and fog frequently supercooled water droplet laden, freezing drizzle and significant aircraft icing are products of this mix. During the fall, cold air blowing across the relatively warm water - a common occurrence with northwest winds - leads to snow squalls or streamers.
Break-up and freeze-up show considerable variability year to year. The following tables summarize dates as observed during the period 1988 to 1998 inclusive and come from work done by Anne Walker of MSC and others.

**River Break-Up**

**Break-up**

<table>
<thead>
<tr>
<th>BREAK-UP</th>
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<td>1 JUNE</td>
<td>26 MAY</td>
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<td><strong>MEDIAN</strong></td>
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</tr>
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<td><strong>LATE</strong></td>
<td>24 JUNE</td>
<td>5 JUNE</td>
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</tbody>
</table>

Table 3-2 - Break-up, Great Slave Lake and Great Bear Lake, 1988-1998 data

The break-up of rivers is much earlier than lakes. Bottlenecks can cause ice jams and subsequent flooding. This can occur, for example, within the Mackenzie Delta, at the horseshoe bend on the middle channel, at Tununuk and in the channel junctions north of Aklavik. In the Mackenzie Delta, this may be enhanced because the larger channels maintain year-round flow but smaller channels may freeze to the bottom. Other areas that have flooded because of ice jams are the Hay River, as it nears the shores of Great Slave Lake, and the Mackenzie River, in the Fort Simpson area.

Since 1896 the people of Dawson in the Yukon have held a lottery to guess the exact minute the ice will go out. Break-up has always been a matter of interest as Dawson is built on a floodplain at the confluence of the Yukon and Klondike Rivers, and on five occasions in the last 100 years ice dams have caused major floods in Dawson. A dyke was completed along the river in 1987 to protect the town from flooding and is designed to withstand a 200-year flood. Over the 104 years that records on break-up have been kept in Dawson, the average date has been May 9. However, during the last decade, the records kept by Water Resources has shown that the breakup regularly has occurred earlier than normal, possibly due to climate change.

**Mean Upper Atmospheric Circulation**

For the GFACN35 domain, the flow aloft is determined by two features; an upper low whose mean position is over the central Arctic Islands during the summer - and which intensifies and shifts to northern Foxe Basin during the winter - and the Aleutian Low / Pacific High.

Although not shown, equally important to northern sections of the domain is the “cousin” of the Arctic islands’ vortex, the vortex that resides in and around the North Pole.
Across the GFACN35 domain, the mean flow is much stronger in winter than in summer. The flow in winter favours northwesterly and in summer favors westerly. The northwesterly flow aloft in winter holds cold Arctic high pressure systems across the entire domain and often drives these systems south into the Prairies.

When the flow aloft is from the northwest, the focus is on systems coming out of the Arctic Ocean. With such systems, the flow in the lower 3,000 to 4,000 feet ASL is very important as much of the cloud being brought southeast out of the Arctic
Basin is low cloud. The addition of mid-level cloud associated with an upper trough serves to thicken the cloud and generate areas of precipitation.

The previous figures are mean flows. On any given day, the upper flow can be significantly different. For example, in winter particularly, the Foxe Basin low can be in Hudson Bay.

In the following figure, the upper flow in place 25 January 2002 shows an intense upper low to the southeast of Baker Lake with the flow around it encroaching into eastern sections of the GFACN35. Interestingly, the flow aloft over the southern Yukon is one that got its moisture from the Gulf of Alaska.

![Fig. 3-9 - Upper flow 25 January 2002](image)

The upper flow on 7 January 2002 shows the North Pole upper low has dropped into the Alaskan sector of the Arctic Basin, giving a strong west-southwest flow to the northern-most reaches of the GFACN35 domain. At the same time, a southwesterly flow and the suggestion of an upper trough resides over central and southern Yukon.
Upper Troughs and Upper Ridges

The most common features that move with the upper flow are upper ridges and upper troughs. With an upper ridge over an area, the weather becomes stagnant, with light winds at all levels. In the summer, hot, dry, sunny conditions dominate while, in the winter, skies are generally clear under the ridge but can be cloudy with stratus and stratocumulus east of the ridge.

Upper troughs produce areas of cloud and precipitation. Upper troughs 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 summer.

Often the leading edge of cloud associated with an upper trough - usually cirrus
and then altocumulus - will extend right to the upper ridge. Strong upper troughs are often able to suppress an upper ridge. Forecasters call this “upper ridge breakdown.” In the wake of such an upper trough, one frequently sees the trailing upper ridge build north with vigor.

**Upper troughs and ridges - winter example**

In the following winter example, a southwesterly flow aloft carried an upper trough (indicated by red dashed line) into southern Yukon, a westerly flow got the upper trough to the southwestern NWT, and a northwesterly flow eagerly flushed the upper trough - and its cloud - southeast into the prairies. The cloud from such upper troughs shows up “white” on satellite imagery as we are seeing the cold temperatures of cirrus and altocumulus tops. Successive mountain ranges strip lots of moisture from the systems.

![Fig 3-11 - 500 hPa charts and satellite imagery for 0000 UTC January 16 (top) and 0000 UTC January 17 (bottom) 2002](image)
Upper troughs and ridges - summer example

Upper troughs are often as difficult to resolve as the weather that they evoke. While upper troughs are often linked with cloud and thunderstorm activity, they are only part of the equation. When you add factors such as moisture to tap, daytime heating, and orographic lift - it becomes apparent quickly that thundershowers, for example, don't line up with the upper troughs in quite the convenient fashion that one would wish.

In the following summer example, there are 3 upper troughs and an upper low that are causal factors for most of the lightning strikes observed. The lightning data shown is from an array of sensors across the Mackenzie Valley and South Great Slave and is courtesy of the Government of the Northwest Territories Department of Renewable Resources.
Fig. 3-13 - Cloud to ground lightning detected by Government of the Northwest Territories sensor array during the period 1200 UTC 05 August to 1200 UTC 6 August 2001.

Photo 3-4 - Visual satellite photo 2329 UTC 5 August 2001
Note the popcorn-like cloud in the vicinity of the Yukon and Northwest Territories border.
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 and tend to persist in one location for prolonged periods of time. For moving cold lows, the heaviest 24-hour precipitation amounts of rain in summer/fall and snow in fall/winter is primarily associated with the northeast quadrant of the 500 hPa closed low. Rain is generally of lighter intensity in the northwest and southwest quadrants of the low. However, when the upper centre is slow moving, cloud wraps around the centre and when that wrap-around cloud encounters upslope conditions rainfall can be considerable. Such is the case when an upper low resides for a period over, for example Great Slave Lake, making the Simpson-Liard area including Nahanni National Park vulnerable to a significant precipitation event. Associated with the rain will be poor flying weather, with solid stratus, statocumulus, and nimbostratus cloud decks combined with reduced visibility in a mix of rain, mist, and fog.

The surface reflection of an upper cold low is routinely an intense (isobars packed closely together) surface low. Low level turbulence and wind shear are frequent by-products of these intense surface lows.

Cold lows can occur at any time of the year but the most frequent occurrence, “the cold low season,” for southern Yukon and southern Mackenzie is from the end of May to mid-July. At this time, pools of cold air break away from the Aleutian Low and move northeast across northern British Columbia and southern Yukon into the Northwest Territories. Cold lows can also “drop” south from the Arctic Ocean or the Arctic Islands.
The overall effect of cold lows 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. With this situation, cold air funnels and, potentially, even tornadoes can form.

**Arctic Coast and Mackenzie Bay lows, highs and fronts**

Mackenzie Bay is a favoured location for low pressure systems to develop, redevelop, or strengthen. A southwesterly flow aloft can move upper troughs and surface weather systems across Alaska and the Yukon, and into Mackenzie Bay, where the surface features, no longer burdened with fighting mountainous terrain, can re-organize. Similarly, a westerly flow aloft - or an upper trough rotating eastward across the southeastern Arctic Basin - can cycle lows and highs across the Beaufort Sea into the GFACN35 domain. On occasion, a northwesterly flow aloft can drive lows from the Arctic Basin into the Beaufort Sea.

For a low that makes its way into, or forms in Mackenzie Bay, southeasterly winds bring warm air, but the northwesterly flow to the west of the low can tap the ice chilled air of the Arctic Basin. It is such temperature contrasts that fuel low pressure systems. In summer particularly, the feed of cold air creates a cold front or enhances existing cold fronts. The cold front is often very shallow, creating an inversion in the lowest levels that traps moisture below. The cold front routinely makes its way into the Delta and can, on occasion, dip south past Inuvik and reach Norman Wells.

Southeasterly winds and good flying conditions (ranging from clear to broken ceilings of mid and upper level cloud) herald a low pressure system approaching or evolving in Mackenzie Bay. West of the low, or as the low moves off brisk northwesterly winds, low cloud, fog and some precipitation are common.

The mountains of the north Yukon are a barrier and the northwesterly winds, as they converge against the mountains, accelerate. The band of strong northwesterly winds often pushes southeast across the Mackenzie Delta.

High pressure systems preceding and trailing the lows are often low cloud and fog laden. Northerly and northeasterly winds, with the highs approaching, push the cloud and fog inland. These same winds are, for locations such as Sachs Harbour, offshore and favour good flying conditions. On the west side of a high, winds veer to southerly directions and bring clearing skies to the mainland, as they push low cloud into locations such as Sachs Harbour.
Mackenzie Valley lows

The Mackenzie Valley and northern Alberta are also a favoured locations for low pressure systems to develop, re-develop, or strengthen. Easterly and southeasterly winds, and generally fair skies to the east of the developing low, evolve into cloudy skies and areas of precipitation in the vicinity of the low. As the low moves off, generally to the east, brisk northwest winds give cloudy skies and showers or flurries.

Blowing snow

Mackenzie ridge and Nunavut low: Northerly to northwesterly wind blowing snow events east of the treeline

A favoured pressure pattern for the GFACN35 domain, in the winter particularly, is a ridge of high pressure in combination with high centres extending from the Beaufort Sea or northern Yukon/northern Alaska, along the Mackenzie Valley and into the Prairies. Concurrently, there is routinely an area of low pressure over central or eastern Nunavut. The result is a northwesterly wind regime to the east of the ridge, which can be strong enough to generate blowing snow.

![Surface Analysis](image-url)

Fig. 3-15 - Surface pattern favouring strong northwest winds and blowing snow across eastern sections of GFACN35 domain, surface analysis 1800 UTC 5 March 2002
Low developing and intensifying Mackenzie, Great Slave or Beaufort and then moving east: Easterly to southeasterly wind and blowing snow

In winter, developing low pressure systems can result in blowing snow in any quadrant, however it is most common in the northeast to northwest.

Fig. 3-16 - Strong winds and blowing snow east of Cambridge Bay. Note, at the same time, the strong winds and blowing snow over the Beaufort Sea 1800 UTC 25 December 2001
Flow aloft and Stratiform Clouds

There are three common patterns of extensive areas of stratiform clouds across northern Canada and these patterns are related to the upper flow.

Pattern 1 - spring thaw to early fall - In such a pattern, the stratiform clouds are confined to the Arctic flow west of the trough. There is usually a sharp edge to the cloud deck along the boundary between the Arctic and Maritime streams. The solid deck of cloud ends abruptly at the base of the trough. Only patches of scattered or broken stratocumulus are evident east of the trough.

During the period spring thaw to early fall, an extensive low level moisture source is present due to the vast number of lakes and the Arctic Ocean. The strong upper northwesterly flow is reflected by strong surface winds, which produce turbulence to aid in mixing the surface moisture to higher levels.

The northerly Arctic stream is generally subsiding as it moves southward. The subsiding flow creates an inversion necessary to trap the low level moisture. Hence, stratiform clouds persist.

When the upper flow becomes more west-east, the subsidence decreases until, finally, it is not strong enough to maintain an inversion. This results in the clouds dissipating rapidly.
Pattern 2 - fall, winter, and early spring - This upper flow occurs when a warm moist flow from the Pacific overrides a cold layer of Arctic air. This creates a very strong inversion. An upper front exists along the boundary between the warm Maritime stream and the cold arctic stream. The surface front may or may not exist in the area, depending on whether any of the warm air is able to penetrate to the surface. The deck of stratiform clouds lies to the south of the upper front, trapped under the strong inversion. This upper front exists at the level of the top of the clouds, which is typically 5,000 to 6,000 feet ASL.

Since the Arctic airmass is dry and cold, the moisture to produce the clouds comes from the Maritime stream. Enough mixing must take place to saturate the cold Arctic air. The northern edge of the clouds is usually sharply defined and parallel to the northern boundary of the Maritime stream at upper levels. The southern boundary of the cloud is not so well defined, periodically breaking and then reforming.

Pattern 3 - fall, winter, and early spring - The layers of Arctic air at the surface encompass a more extensive area, including most of the Prairies. The over-running Maritime air creates a strong inversion from the northern Mackenzie to the southern Prairies. As a result, an extensive area of stratus and stratocumulus forms beneath the inversion. As with Pattern 2, the northern edge of the cloud is very well defined and parallels the northern boundary of the Maritime stream.

If the southwesterly Maritime flow persists, the warmer air will gradually erode the Arctic air causing the inversion to steadily lower. Consequently, the cloud base will also lower. Once the warm air breaks through to the surface, the inversion will no longer exist and the clouds will clear rapidly.
**Seasonal Migratory Birds**

**Impact with birds can be a hazard** - A four-pound bird striking an aircraft traveling at 130 knots exerts a localized force of more than 2 tons. An aircraft traveling at 260 knots and hitting a bird of the same size would receive a localized force of 9 tons.

**A.I.P. Canada has maps** - Readers are encouraged to consult Transport Canada’s Aeronautical Information Publication - TP2300 for spring and autumn mappings of bird migration routes.

**Weather plays a role** - Associated with seasonal changes in weather, large flocks of migratory birds fly across the GFACN35 domain.

**Spring** - Migratory birds will not leave a staging area against surface winds in excess of 10 knots. Major movements, involving hundreds of thousands of birds, often follow the passage of a ridge of high pressure. Winds of the west side of a ridge are typically southeasterly and, thus, favourable for birds heading north. In spring, barring weather influences, migratory birds normally leave their staging areas between dusk and midnight, and during the first three hours after dawn. However, they may leave at any hour of the day or night, particularly after long periods of poor weather.

**Autumn** - Geese, swans and cranes normally move south when the winds become favourable. For example, they depart from staging areas 12 to 24 hours after the passage of a cold front, especially if there is rapid clearing and there are strong northerly or northwesterly winds behind the front. In the autumn, barring weather influences, migratory birds take off from their staging areas in the late afternoon for night flights. Occasionally, however, they may fly by day as well.