

THE WEATHER OF THE YUKON, NORTHWEST TERRITORIES AND WESTERN NUNAVUT



GRAPHIC AREA FORECAST 35



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by

Ross Klock

Ed Hudson

David Aihoshi

John Mullock



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

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Graphic Area Forecast 35

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 Yukon, Northwest Territories and western Nunavut Local Area Aviation Weather Knowledge 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 the combined GFA 36 and 37 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 weather of the GFACN35 (Yukon - Northwest Territories - western Nunavut). From the treeless tundra of the northeastern reaches of the GFA 35 domain, to the ice and seas of the Beaufort, to the mountains of the Yukon and western Mackenzie, season and topography play their role in local flying conditions.

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 Yukon, Northwest Territories, and western Nunavut that FSS and experienced pilots of the area have acquired over the years, this manual is a collection of such knowledge taken from interviews with local pilots, dispatchers, Flight Service Specialists, National Park Wardens and MSC personnel.

By understanding the weather and hazards in the GFA 35 domain, 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.

The PAAWC meteorologists advise that are indebted to the Edmonton-based climate specialists Patrick Kyle and Monique Lapalme for the myriad of weather statistics that they produced in support of this manual.

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 go to Ross Klock and John Mullock, Mountain Weather Centre, Kelowna, and to Ed Hudson, and his fellow meteorologists John Alexander, Alex Fisher, David Aihoshi, and Paul Yang of the Prairie Aviation and Arctic Weather Centre (PAAWC), Edmonton. Ross' expertise of the Yukon and Ed's and his fellow PAAWC meteorologists' expertise of the Northwest Territories and Nunavut has been instrumental for the development of this Yukon, Northwest Territories and western Nunavut document. PAAWC meteorologists Lydna Schuler and Paul Yang, through their diligent editing, contributed significantly to the manuals' content thereby becoming de facto authors. The PAAWC meteorologists advise that they are indebted to the Edmonton-based climate specialists Patrick Kyle and Monique Lapalme for the myriad of weather statistics that they produced for this manual. John Mullock's experience and efforts have ensured high quality and consistent material from Atlantic to Pacific to Arctic.

This endeavour could not have been as successful without the contributions of many people within the aviation community. We would like to thank all the participants that provided information through interviews with MSC, including pilots, dispatchers, Flight Service Specialists, and National Park Wardens.

Their willingness to share their experiences and knowledge contributed greatly to the success of this document.

Roger M. Brown, May, 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



S E R V I N G A W O R L D I N M O T I O N

A U S E R V I C E D ' U N M O N D E E N M O U V E M E N T

TABLE OF CONTENTS

PREFACE	.....	iii
ACKNOWLEDGEMENTS	.....	iv
INTRODUCTION	.....	ix
CHAPTER 1	BASICS OF METEOROLOGY	1
	Heat Transfer and Water Vapour	1
	Lifting Processes	2
	Subsidence	3
	Temperature Structure of the Atmosphere	4
	Stability	5
	Wind	6
	Air Masses and Fronts	6
CHAPTER 2	AVIATION WEATHER HAZARDS	9
	Introduction	9
	Icing	9
	The Freezing Process	10
	Types of Aircraft Ice	10
	Meteorological Factors Affecting Icing	11
	Aerodynamic Factors Affecting Icing	14
	Other Forms of Icing	15
	Visibility	16
	Types of Visibility	16
	Causes of Reduced Visibility	17
	Wind, Shear and Turbulence	21
	Stability and the Diurnal Variation in Wind	21
	Wind Shear	22
	Relationship Between Wind Shear & Turbulence	22
	Low Levels Jets - Frontal	23
	Low Levels Jets - Nocturnal	24
	Topographical Effects on Wind	24
	Lee Waves	30
	The Formation of Lee Waves	30
	Characteristics of Lee Waves	31
	Clouds Associated with Lee Waves	32
	Fronts	33
	Frontal Weather	34
	Frontal Waves and Occlusions	35
	Thunderstorms	37
	The Life Cycle of a Thunderstorm	37
	Types of Thunderstorms	40
	Thunderstorm Hazards	44

	Cold Weather Operations	46
	Volcanic Ash	48
	Deformation Zone	48
CHAPTER 3	WEATHER PATTERNS OF THE YUKON, NORTHWEST TERRITORIES AND WESTERN NUNAVUT	51
	Introduction	51
	Topography	51
	Topography: The Yukon section of GFACN 35 domain	52
	Topography - Northwest Territories and western Nunavut section of GFACN 35 domain	55
	Treeline and vegetation	59
	Length of daylight in June and July affects temperature and relative humidity and hence fog development	59
	Length of daylight in June and July leads to delayed thundershower development	59
	Daylight, Twilight, and Night	60
	Late to freeze, open water areas, leads, polynyas	62
	Open water season for Mackenzie Bay, southern Beaufort and the waterway to Cambridge Bay	64
	Freeze-up	66
	Lake Freeze-up and Break-up	67
	River Break-Up	68
	Mean Upper Atmospheric Circulation	68
	Upper Troughs and Upper Ridges	71
	Upper troughs and ridges - winter example	72
	Upper troughs and ridges - summer example	73
	Cold Lows	75
	Arctic Coast and Mackenzie Bay lows, highs and fronts	76
	Mackenzie Valley lows	77
	Blowing snow	77
	Mackenzie ridge and Nunavut low: Northerly to northwesterly wind blowing snow events east of the treeline	77
	Low developing and intensifying Mackenzie, Great Slave or Beaufort and then moving east: Easterly to southeasterly wind blowing snow	78
	Flow aloft and Stratiform Clouds	79
	Seasonal Migratory Birds	81
CHAPTER 4	SEASONAL WEATHER & LOCAL EFFECTS	83
	The Yukon North Coast	84
	Northern Yukon including the Porcupine - Peel River Basins	87
	Old Crow - Old Crow Flats	88

The Mountain Passes . . . . .	.89
Eagle Plains - Yukon / Northwest Territories Border .89	
Sapper Hill - Chapman Lake - Blackstone River - Robert Service Creek . . . . .	.91
The Central Yukon River Basin . . . . .	.92
Carmacks - Pelly Crossing - Dawson (Klondike Highway Route) . . . . .	.94
Beaver Creek - Dawson . . . . .	.96
Stewart Crossing - Mayo . . . . .	.97
Carmacks - Faro . . . . .	.97
Southwest Yukon including the St. Elias and Coast Mountains . . . . .	.98
Whitehorse - Haines Junction . . . . .	.101
Haines Junction - Burwash . . . . .	.102
Burwash - Beaver Creek - Alaskan Border . . . . .	.103
Haines Junction - Beaver Creek via Aishihik Nisling River - White River . . . . .	.104
Haines Junction - Haines Alaska - Lynn Canal . . .	.105
Whitehorse - Teslin . . . . .	.106
Whitehorse - Carcross . . . . .	.108
Carcross - Skagway and Haines . . . . .	.109
Carcross - Atlin . . . . .	.110
Whitehorse - Carmacks . . . . .	.111
Southeast Yukon including the Liard River Basin . . .	.112
Watson Lake - Teslin . . . . .	.114
Watson Lake - Faro . . . . .	.115
Watson Lake - Rocky Mountain Trench - Fort Ware . . . . .	.116
Watson Lake - Fort Nelson . . . . .	.116
Weather of Northwest Territories and Western Nunavut . . . . .	.117
Weather by season . . . . .	.117
Weather by area	
Fort Simpson, Wrigley, Jean Marie River, Fort Liard, Trout Lake . . . . .	.120
Disturbances from the Gulf of Alaska . . . . .	.120
Winter warmth but strong gusty winds and low level turbulence and maybe freezing rain . . . . .	.121
Turbulence . . . . .	.121
Low cloud and fog . . . . .	.122
Prevailing winds versus runway orientation . . . . .	.122

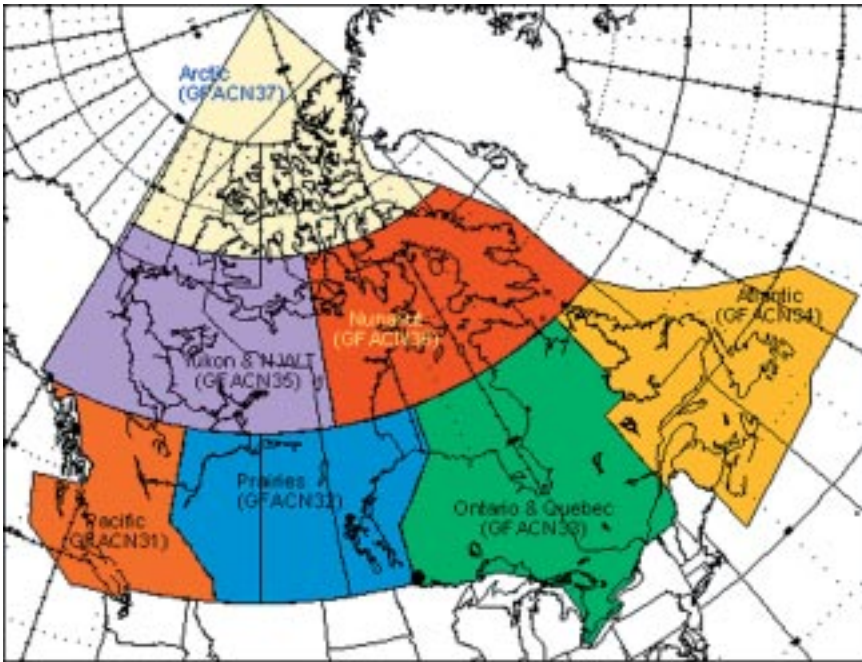
	Thundershowers	122
	Norman Wells, Tulita, Deline, Fort Good Hope, Colville Lake	123
	Favoured areas for low cloud and /or fog	123
	Fall snow showers/streamers	124
	Icing/ Windshield obstruction during fall into winter	124
	Turbulence	124
	Winds	125
	Thundershowers	125
	Inuvik, Aklavik, Fort McPherson, Tsiightchic, Tuktoyaktuk, Paulatuk, Sachs Harbour and Holman	126
	Low cloud and fog through the open water season	126
	“Burst of Beaufort” inland across Delta	126
	Snow streamers and visibility during fall	127
	Strong surface and/or low level winds	127
	Winds, turbulence, and blowing snow	128
	Blowing snow	128
	Thundershowers	128
	Smoke all year	129
	Kugluktuk and Cambridge Bay	130
	Low Cloud and/or fog	130
	Aircraft Icing	131
	Blowing snow and strong winds	131
	Spring storms	131
	Thundershowers	132
	Yellowknife, Hay River, Fort Resolution, Fort Smith, Lutselk’e, Fort Providence, Kakiska, Wha Ti, Rae Lakes, Lupin, Ekati	132
	Low cloud	132
	Fall snow showers / streamers	133
	Low cloud, poor visibility, wind, blowing snow	133
	Icing	133
	Winter ice fog	134
	Winds	134
	Thundershowers	134
CHAPTER 5	AIRPORT CLIMATOLOGY FOR THE YUKON	137
GLOSSARY	. . . . .	211
TABLE OF SYMBOLS	. . . . .	217
APPENDIX	. . . . .	218
MAP INDEX	Chapter 4 Maps	Inside Back Cover

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, superseding 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 Yukon, Northwest Territories and western Nunavut 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 specific graphic forecast area (GFA) domain, with the exception of the Nunavut - Arctic manual that covers the combined GFA 36 and 37 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 weather on a daily basis, however, best understand the local weather. Interviews with local pilots, dispatchers, Flight Service Specialists, and National Park Wardens 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 GFACN35 Yukon, Northwest Territories and western Nunavut. This area often has beautiful flying weather but challenging conditions frequently occur, particularly in the fall and winter. As most aviators in the region can attest, these variation in flying weather can take place quite abruptly. From the flat treeless barrens of the northeastern reaches of the GFACN35 domain to the mountains of the western Mackenzie and Yukon, 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 the GFA35 domain in a general sense. It is not “experience” and it is not the actual weather of a given day or weather system. The information presented in this manual is by no means exhaustive. The variability of local aviation weather in the Yukon Northwest Territories and western Nunavut could result in a larger publication. 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.

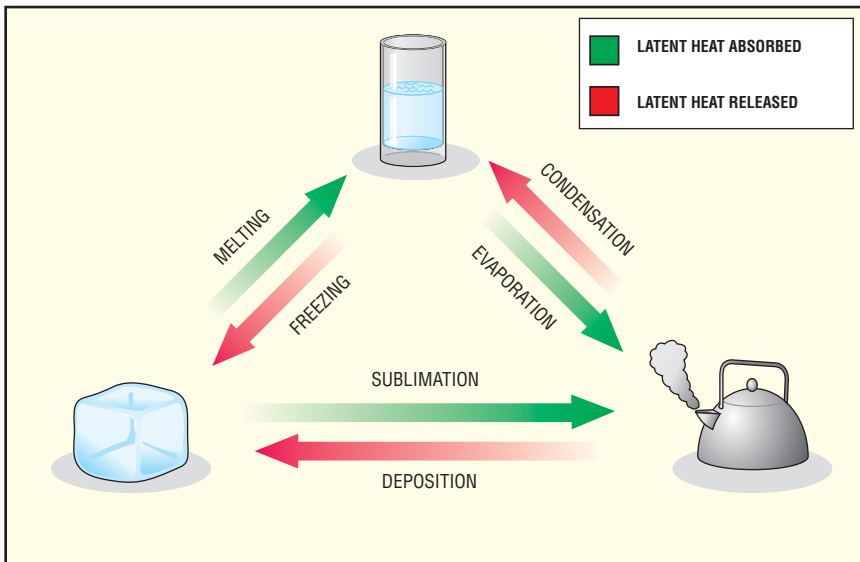


Fig. 1-1 - Heat transfer and water vapour

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.

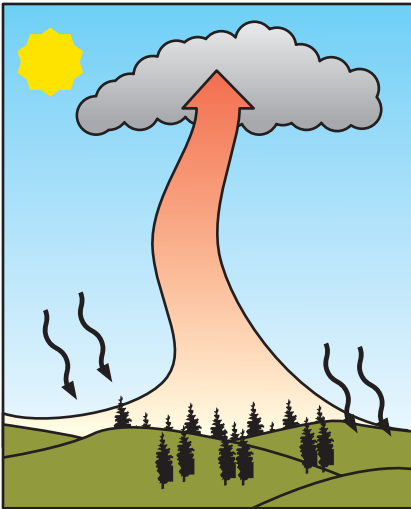


Fig. 1-2 - Convection as a result of daytime heating

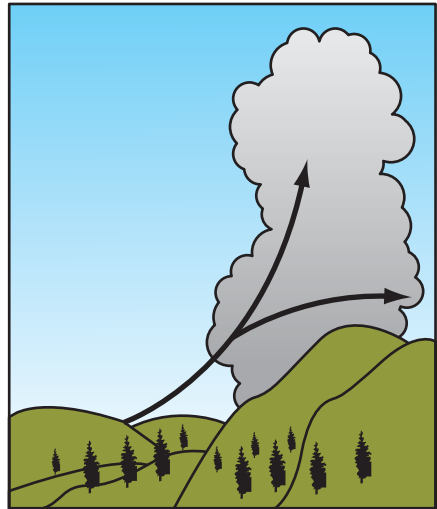


Fig.1-3 - Orographic (upslope) lift

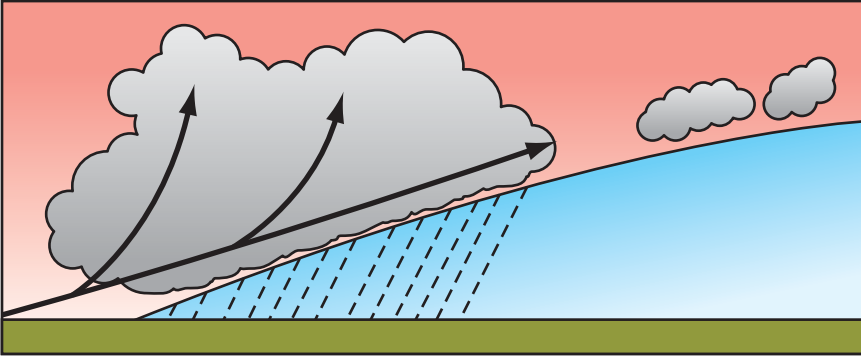


Fig.1-4 - Warm air overrunning cold air along a warm front

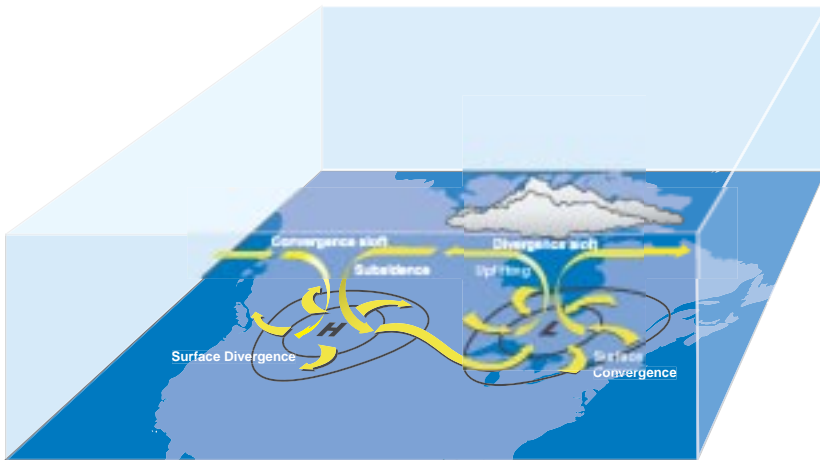


Fig. 1-5 - Divergence and convergence at the surface and aloft in a high low couplet

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.

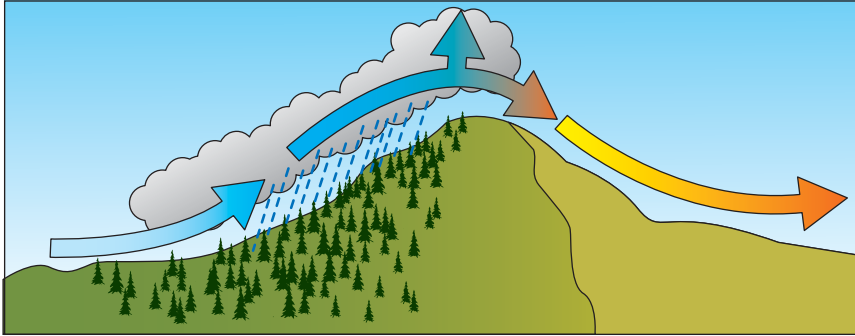


Fig.1-6 - Moist air moving over mountains where it loses its moisture and sinks into a dry subsidence area

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.

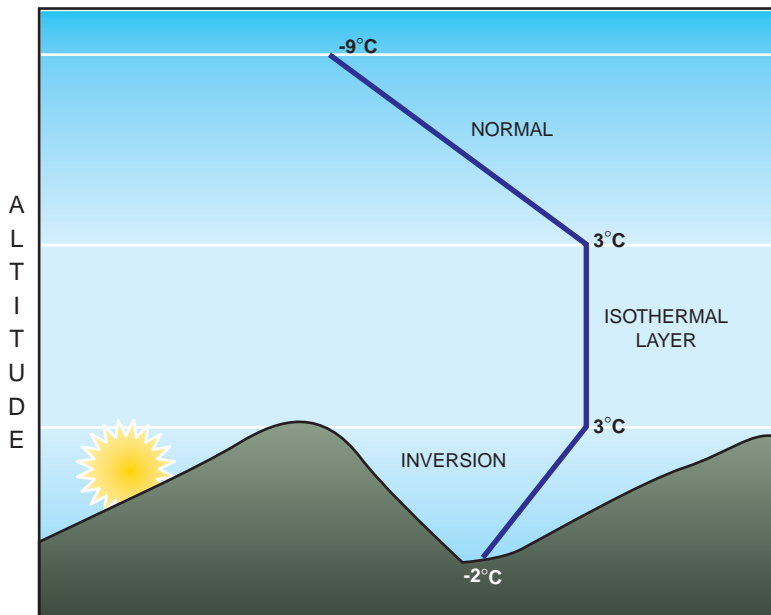


Fig. 1-7 - Different lapse rates of the atmosphere

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.

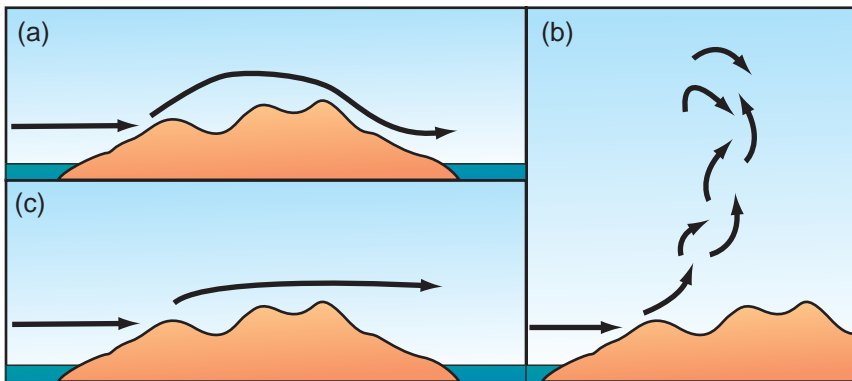


Fig. 1-8 - Stability in the atmosphere - (a) Stable (b) Unstable (c) Neutral

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 thunder-showers 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.

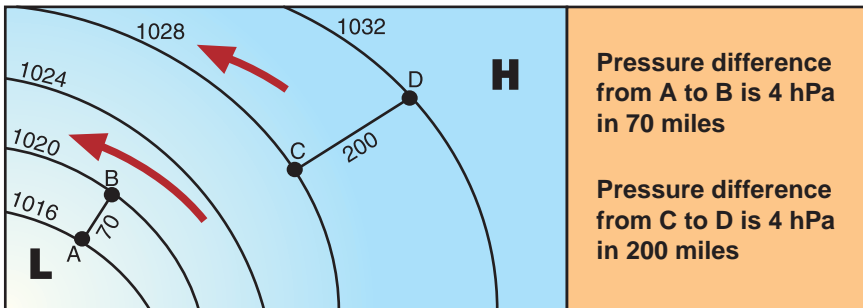


Fig. 1-9 - The greater pressure changes with horizontal difference, the stronger the wind

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:









<p>Cold Front - The cold air is advancing and undercutting the warm air. The leading edge of the cold air is the cold front.</p>		
<p>Warm front - The cold air is retreating and being replaced by warm air. The trailing edge of the cold air is the warm front.</p>		
<p>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.</p>		
<p>Trowal - Trough of warm air aloft.</p>		

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:

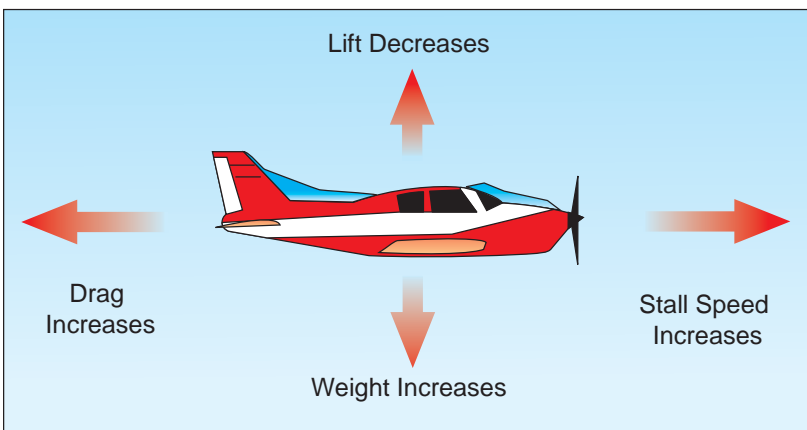


Fig. 2-1 - Effects of icing

- 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 the windshield glazes over.

The Freezing Process

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

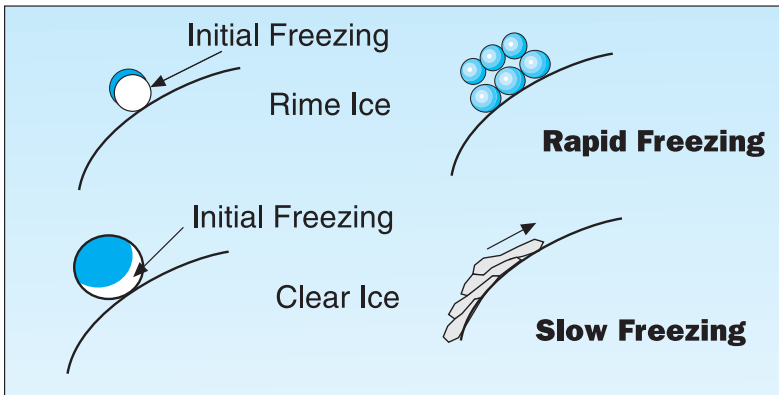


Fig. 2-2 - Freezing of supercooled droplets on impact

Types of Aircraft Ice

Rime Ice

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

Clear Ice

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

Mixed Ice

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

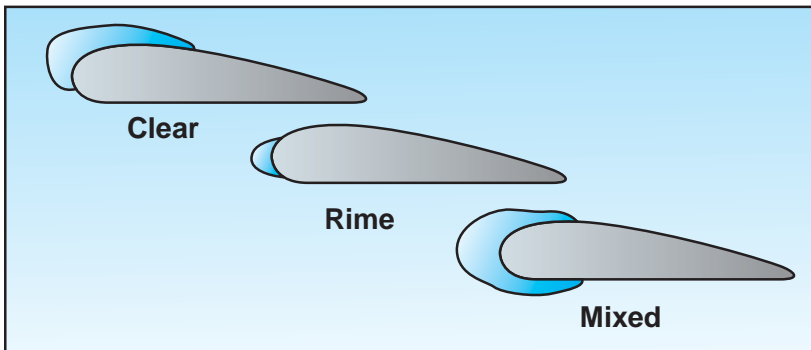


Fig. 2-3 - Accumulation patterns of different icing types

Meteorological Factors Affecting Icing

(a) Liquid Water Content of the Cloud

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

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

(b) Temperature Structure in the Cloud

Warm air can contain more water vapour than cold air. Thus, clouds that form in

warm air masses will have a higher liquid water content than those that form in cold air.

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

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

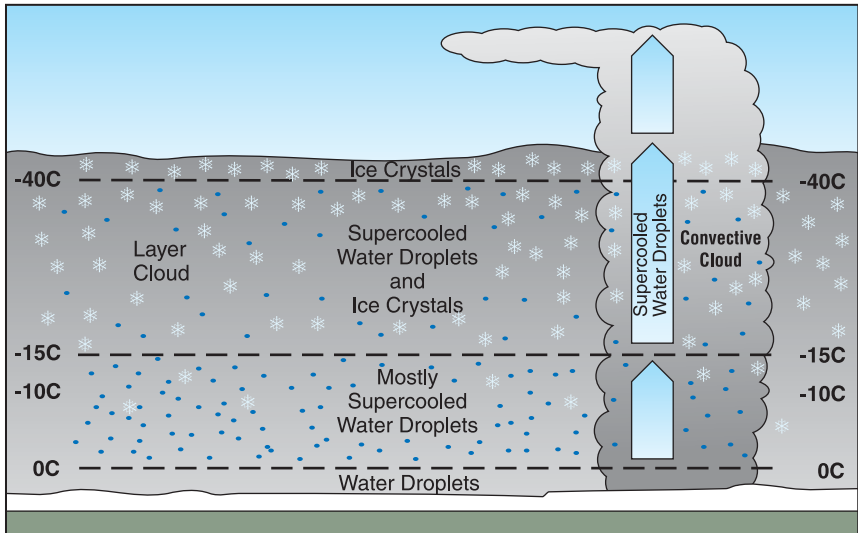


Fig. 2-4 - Distribution of water droplet-ice crystals in cloud

(1) Within large cumulus and cumulonimbus clouds:

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

(2) Within layer cloud:

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

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

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

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

Supercooled Large Drop Icing

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

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

SLD icing-producing clouds are common in easterly flows off Hudson Bay prior to freeze-up, flows off Great Slave Lake and Great Bear Lake prior to freeze-up and

in flows off open water / open leads of Mackenzie Bay and the waterway along the arctic coast during the fall and winter. 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.

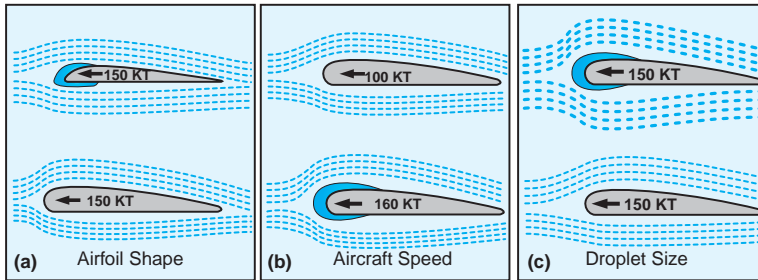


Fig. 2.5 -Variations in collection efficiency

Collection efficiency is dependent on three factors:

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

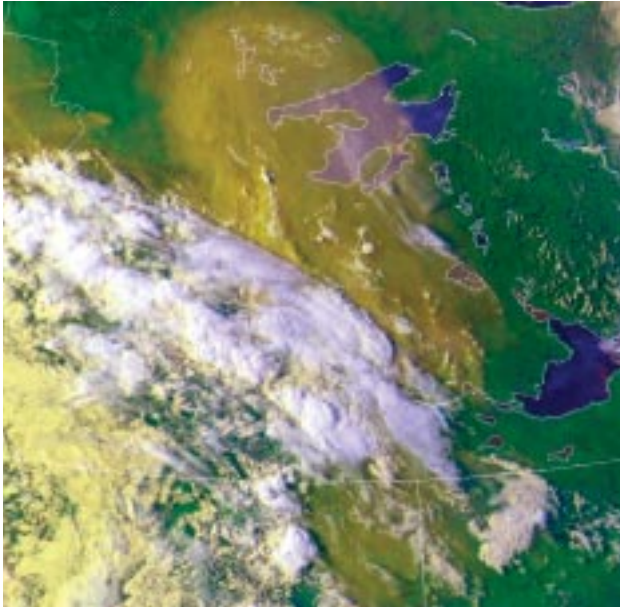


Photo 2-2 - Smoke (yellowish)
as seen by satellite 15 July 1995

credit: R. Goodson

(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 2-3 - Radiation fog, Inuvik airport tower from weather instrument site, September 2001

credit: Ken Kehler

A fog moment - "Increment weather (thick fog) kept Pope John Paul II from visiting Fort Simpson 18 September 1984. About 3,000 people, most of them native Indians, many of them traveling hundreds of kilometres by boat, plane, and vehicle converged on this northern town for the day. But, because of thick fog, the Pope's plane could not land. For 12 hours during the day, visibility was near zero. Before the fog cleared, His Holiness had to move on. A disappointed Pontiff vowed to return for a short visit during his United States tour 1987. As he had promised, three years later on September 20, 1987 the Pope flew to Fort Simpson and met with peoples of the Northwest Territories. The day began with cold rain but a brilliant rainbow by mid morning signaled a change to sunshine for most of the day." Phillips, 1990

(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. Ice fog is also called habitation fog. The fog may only extend for a few hundred feet.



Photo 2-4 - Yellowknife downtown at -46°C credit: J. Phillips

(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 Great Slave Lake, 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.

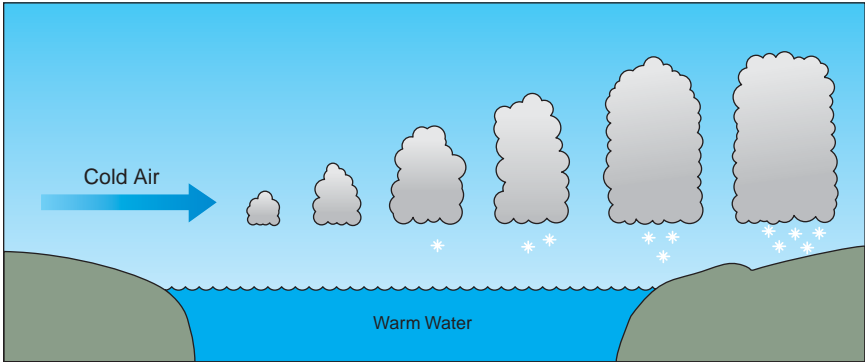


Fig. 2-6 - Snowsqualls building over open water

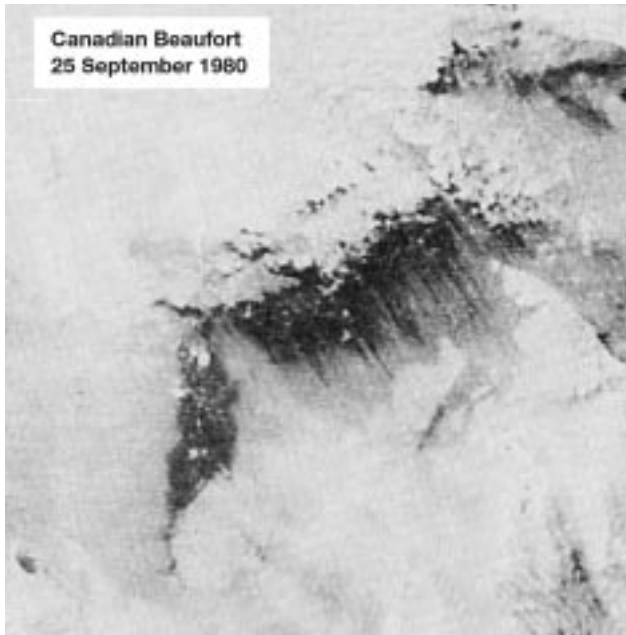


Photo 2-5 - Streamers developing over the open water of the Beaufort in northwest flow. Streamers are not always this photogenic in satellite images.

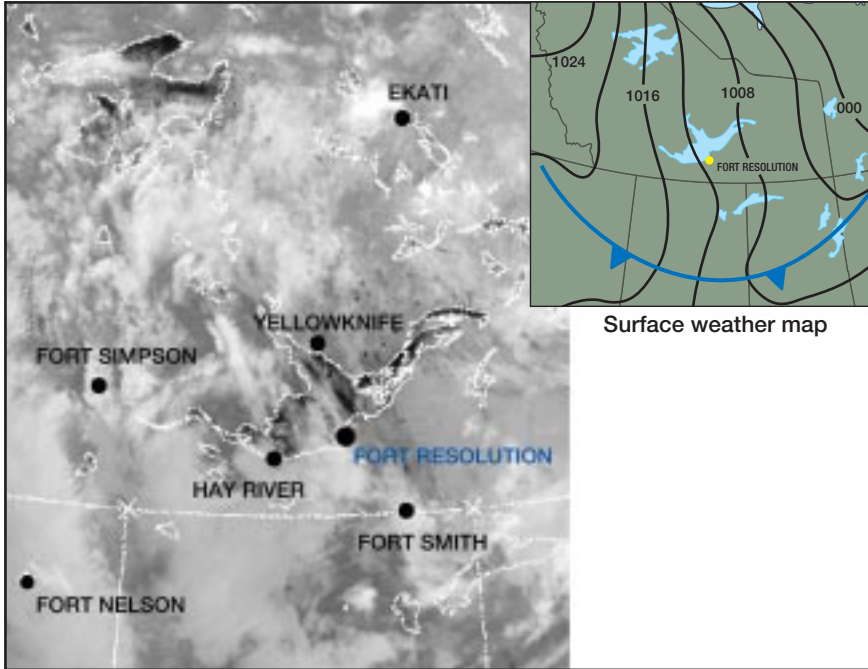


Photo 2-6 - Streamers gave about 40 centimetres of snow to Fort Resolution overnight 9 into 10 November 1998. Satellite photo 1229 UTC 10 November 1998.

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.

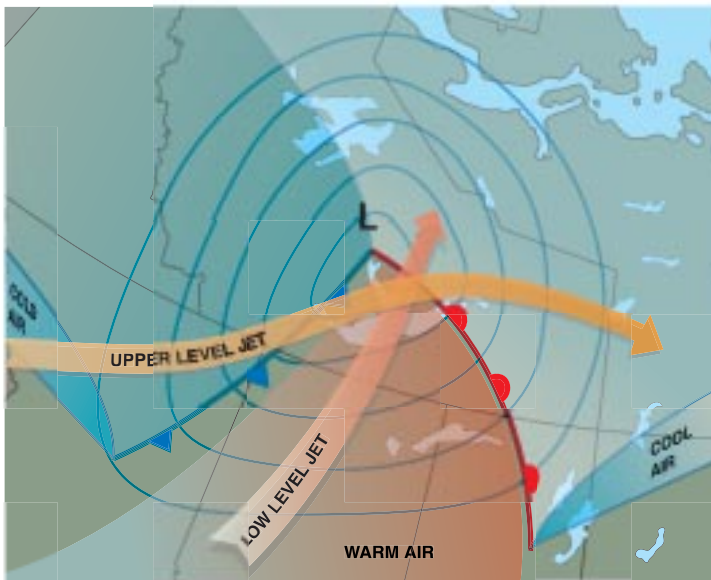


Fig. 2-7 - Idealized low and frontal system showing the position of the low level and upper level jet

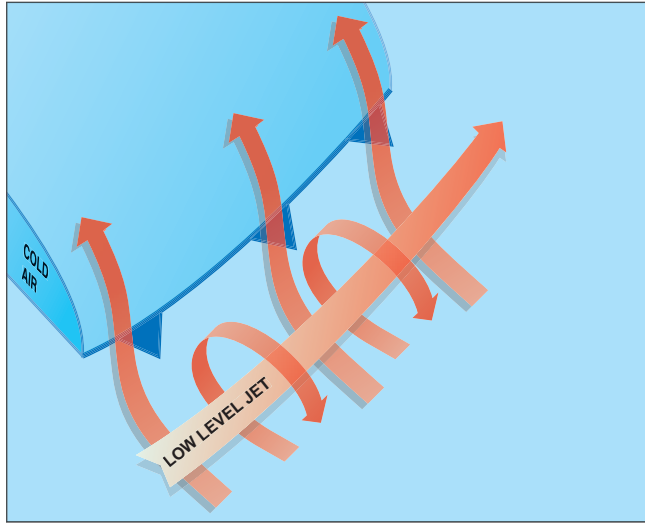


Fig. 2-8 - Complex winds around low level jet can result in significant low-level wind shear and turbulence

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.

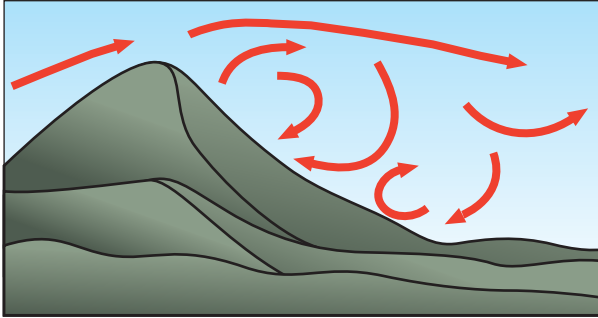


Fig. 2-9 - Lee effects

(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.

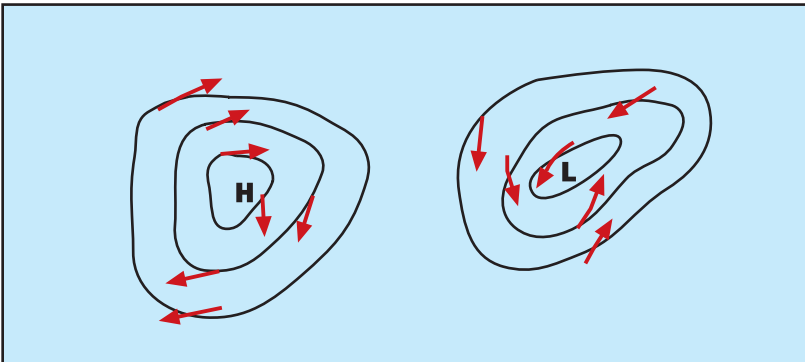


Fig. 2-10 - Friction effects

(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.

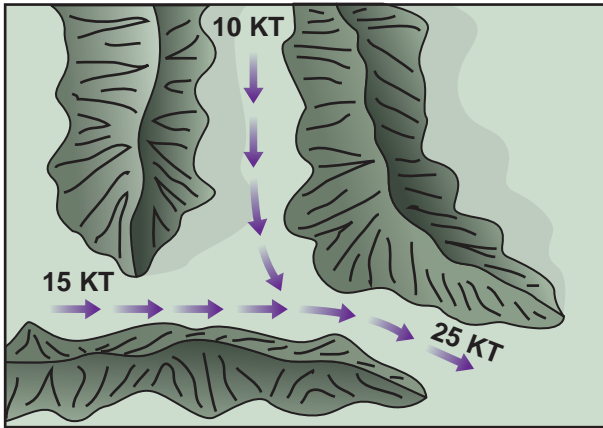


Fig. 2-11 - Converging winds

(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.

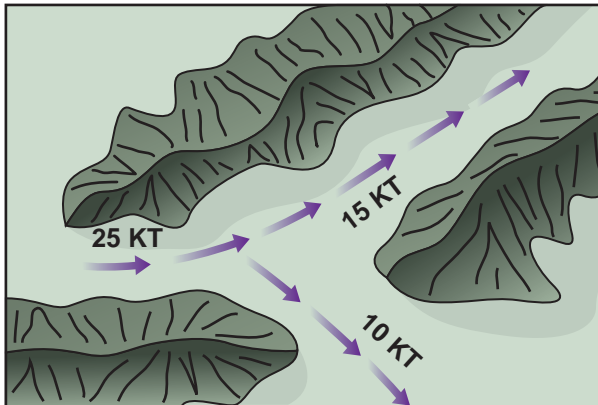


Fig. 2-12 - Diverging winds

(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.

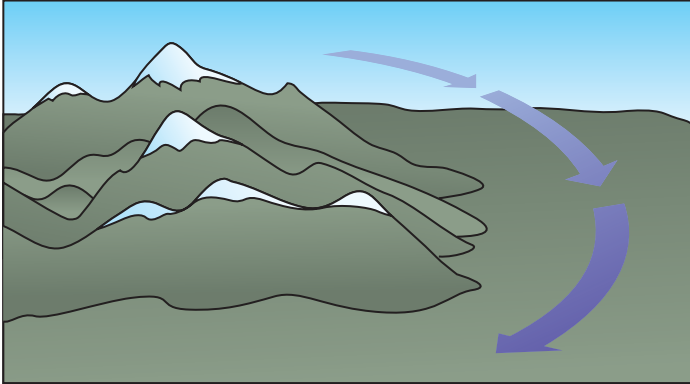


Fig. 2-13 - Corner winds

(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.

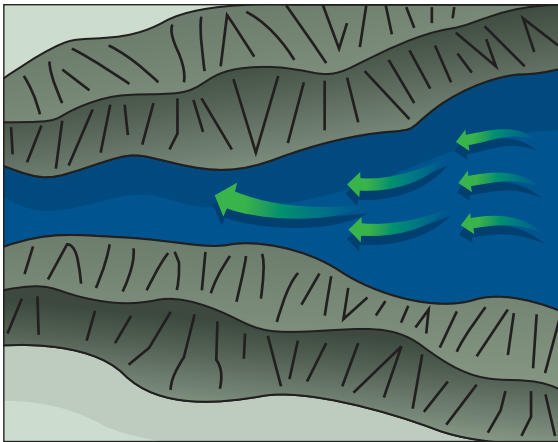


Fig. 2-14 - Funnelled winds

(g) Channelled Winds

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

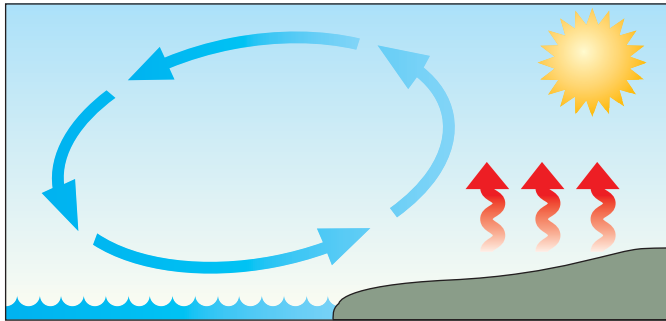


Fig. 2-15 - Sea breeze

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

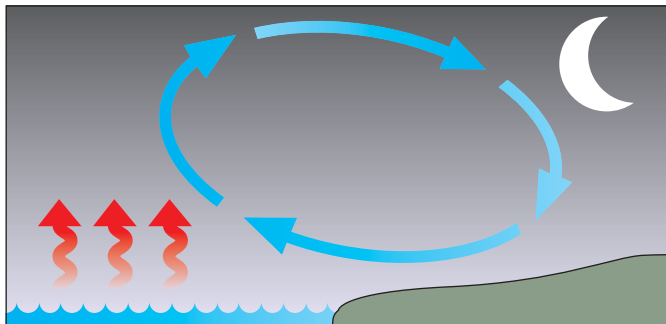


Fig. 2-16 - Land breeze

Both land and sea breezes can be influenced by channelling and funnelling resulting in almost frontal-like conditions, with sudden wind shifts and gusty winds that may reach up to 50 knots. 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 is generally a low-level effect and only noticeable up to 200 to 300 feet above the bluffs.

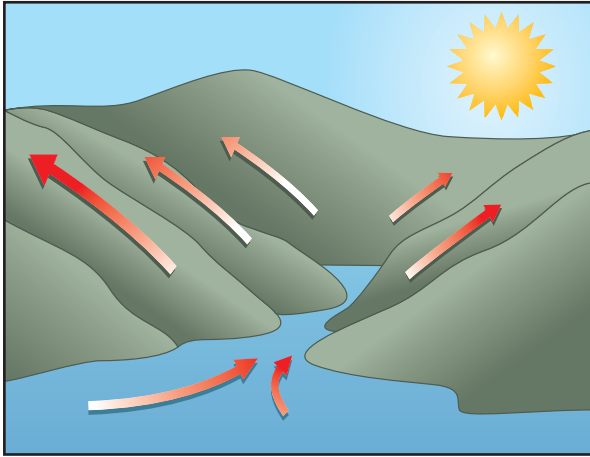


Fig. 2-17 - Anabatic winds

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

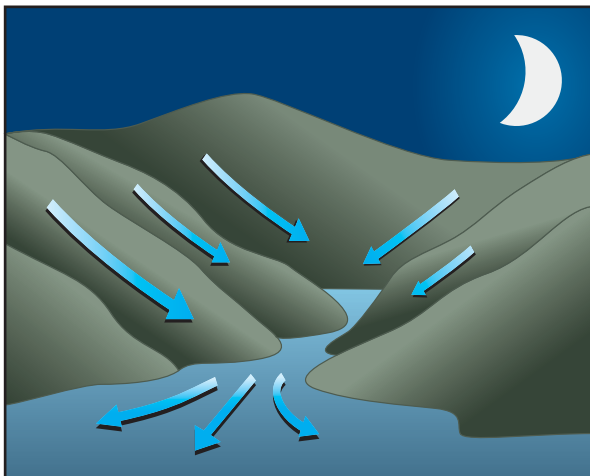


Fig. 2-18 - Katabatic winds

(j) Glacier Winds

Under extreme cooling conditions, such as an underlying ice cover, the katabatic winds can develop to hazardous proportions. As the ice is providing the cooling, a shallow wind of 80 knots or more can form and will persist during the day and night. In some locations the katabatic flow “pulsates” with the cold air building up to some critical value before being released to rush downslope.

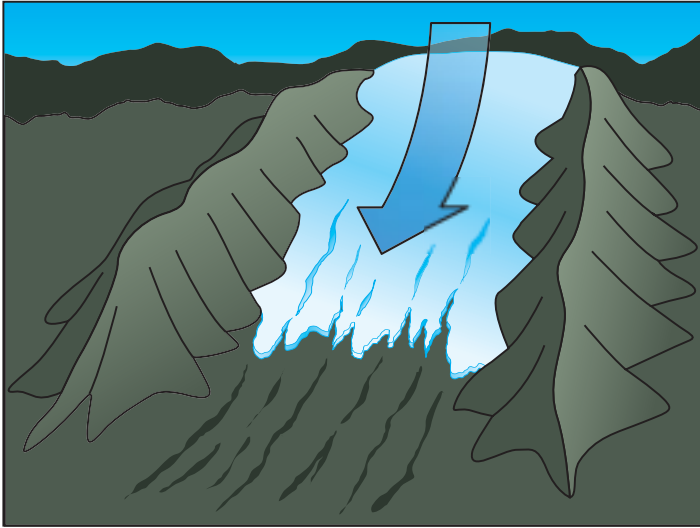


Fig. 2-19 - Glacier winds

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.
- (d) 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.

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.

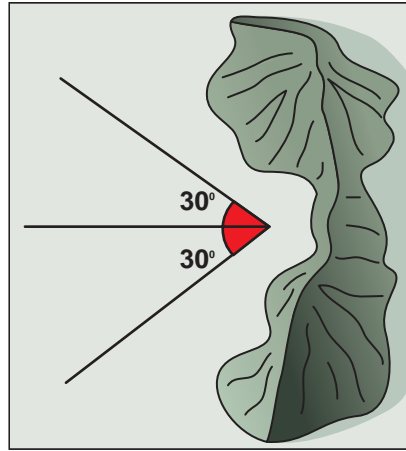


Fig. 2-20 - Angles for lee wave development

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.

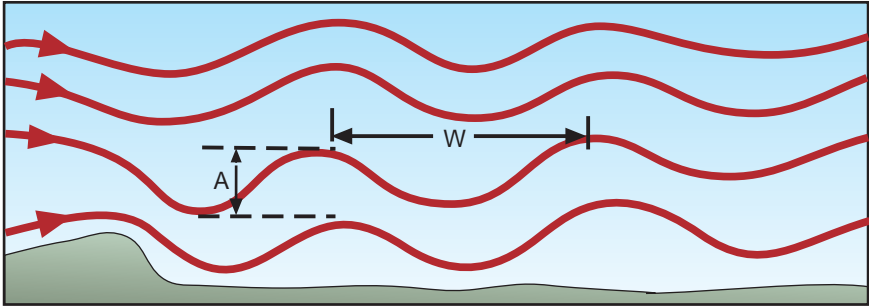


Fig. 2-21 - Amplitude (A) and wavelength (W) in lee waves

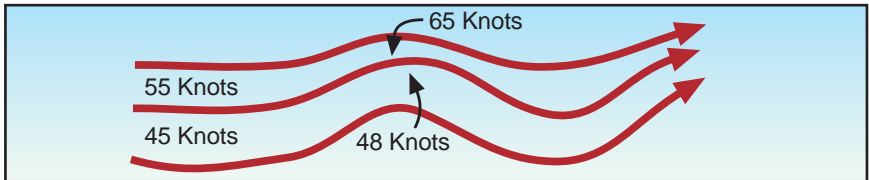


Fig. 2-22 - Stronger wind in wave crest in lee waves

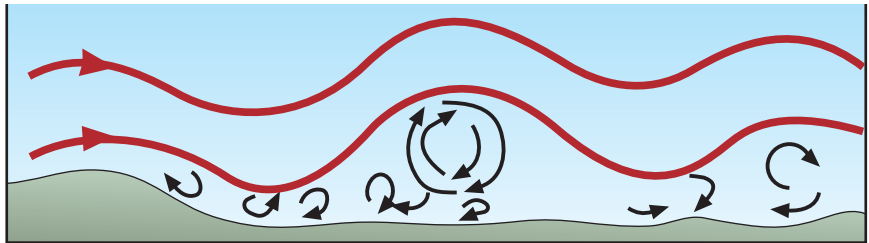


Fig. 2-23 - A rotor may form beneath wave crests

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.

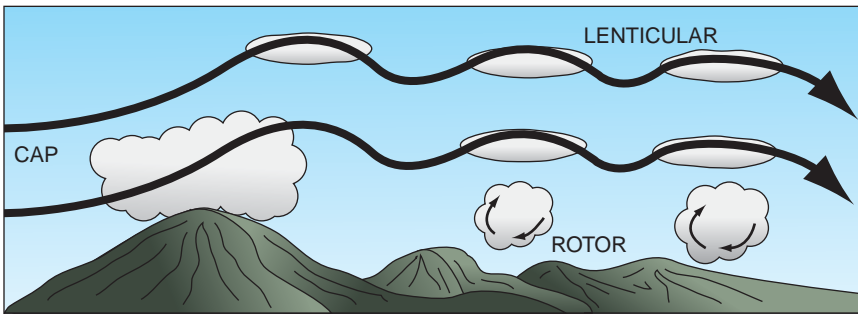


Fig. 2-24 - Characteristic clouds formed by lee waves

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.

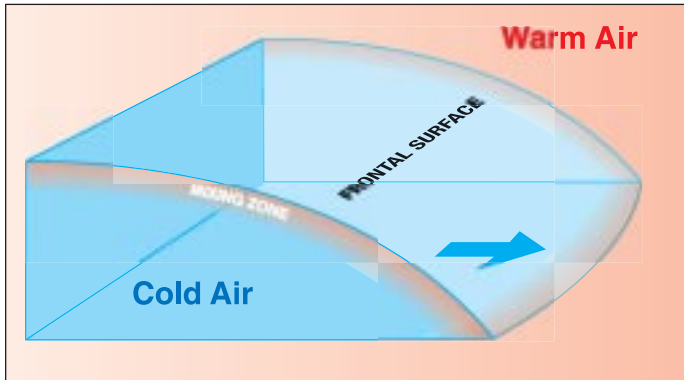


Fig. 2-25 - Cross-section of a cold front

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.

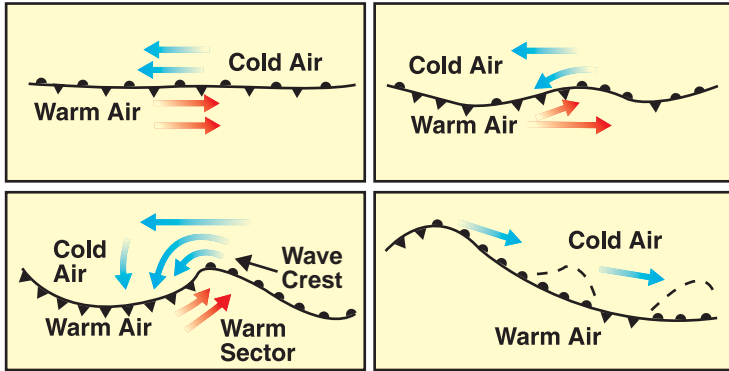


Fig. 2-26 - Stable wave

(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.

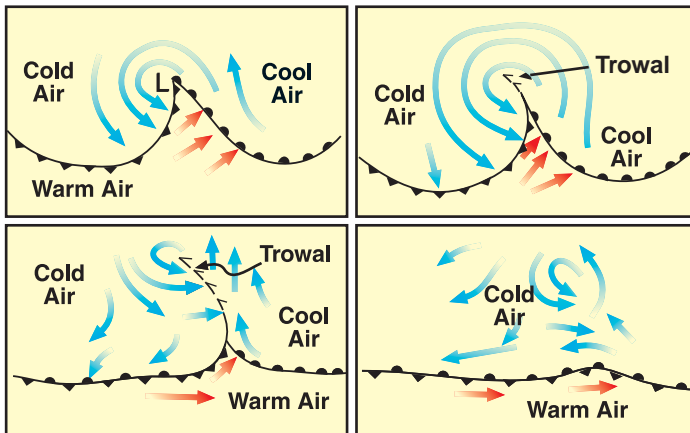


Fig. 2-27 - Formation of an occluding wave

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 .

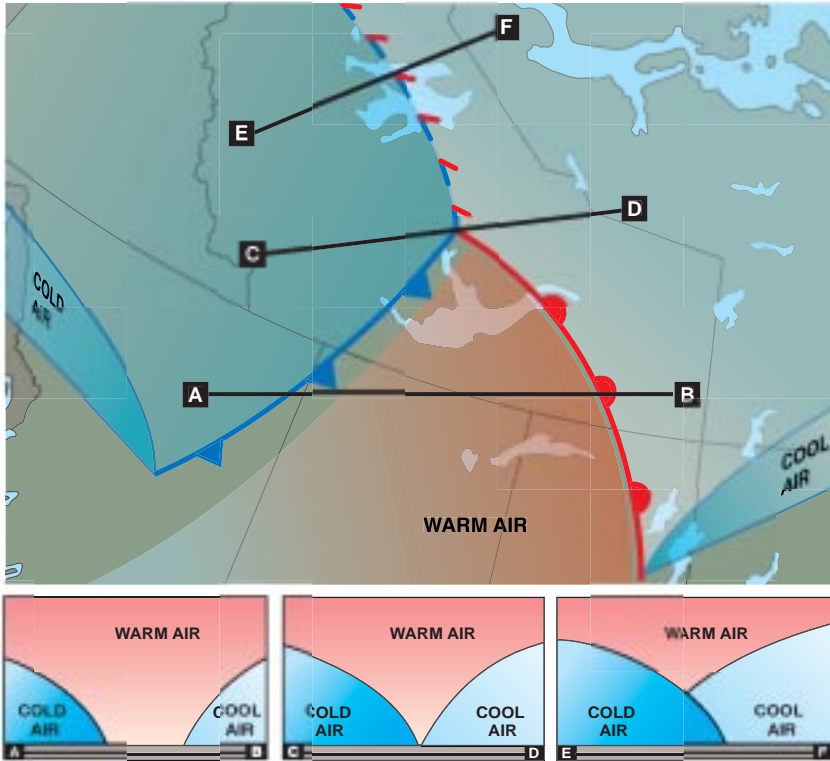


Fig. 2-28 - Frontal cross-sections

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, it's 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:

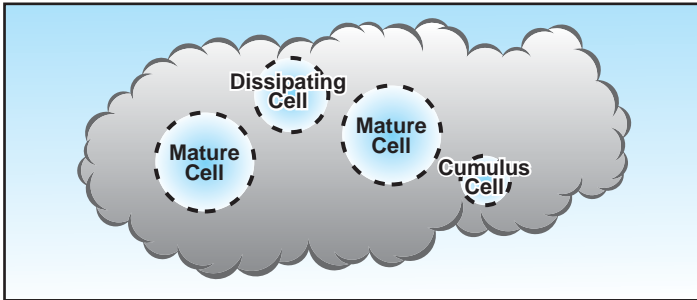


Fig. 2-29 -Top-down view of a thunderstorm "family" containing cells in different stages of development

(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 downdraft of accelerating cold air. Typical downdraft speeds can reach values of 2,500 feet per minute.

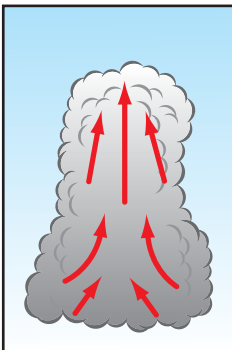


Fig. 2-30 - Cumulus stage

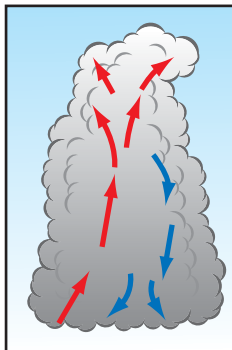


Fig. 2-31 - Mature stage

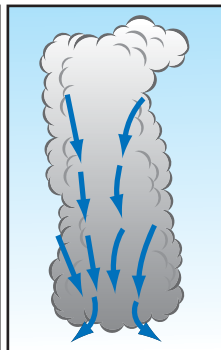


Fig. 2-32 - Dissipating Stage

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 of 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.



Photo 2-7 - From the town of Fort Simpson looking south-east early morning 11 May 1999



Photo 2-8 - Later in the day, looking southwest from Fort Simpson airport at approaching thundershower



Photo 2-9 - Thundershower at the airport

credit: D Whittle

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 and tend to be isolated. In the Yukon and Northwest Territories airmass thunderstorms often develop late in the day due to maximum heating occurring early in the evening. These storms also persist through the evening due to the extended hours of sunshine in the north.

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.

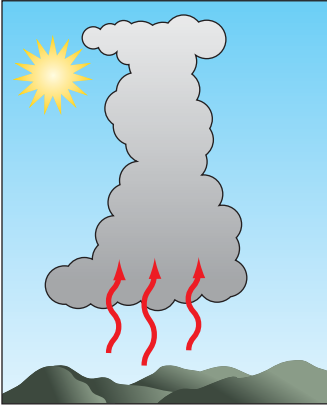


Fig. 2-33 - Air heated by warm land

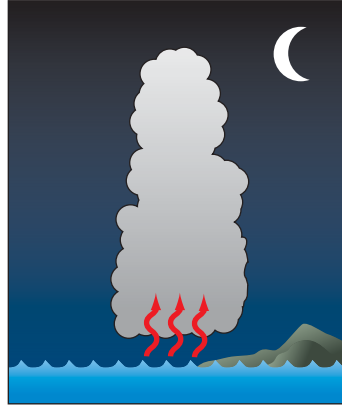


Fig. 2-34 - Cool air heated by warm water

Airmass thundershowers are often visible on satellite imagery as “popcorn”. Note the fuzziness of the thundershowers to the east of Great Slave Lake. The satellite is seeing the cloud at the top of the thundershowers that has popped through the troposphere and has spread downwind. We cannot tell from the image if there are thundershowers or not in the large areas of cloud. Hence the “?”.

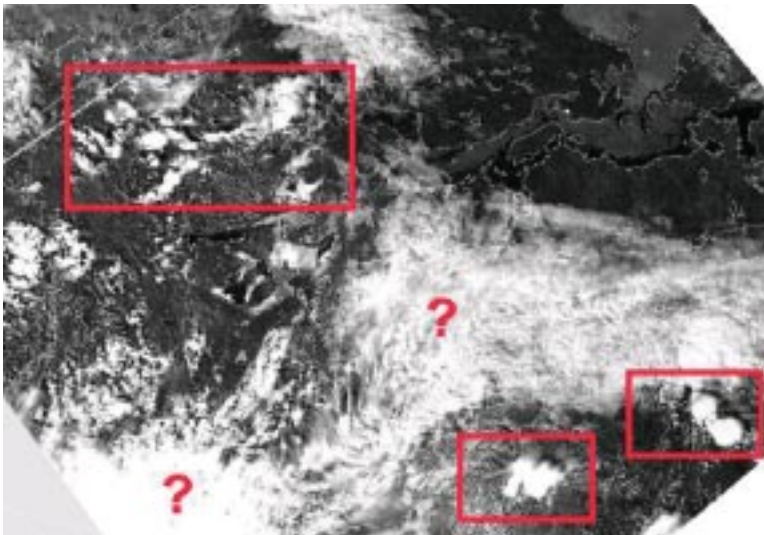


Photo 2-10 - Airmass thundershowers on satellite image, 2200 UTC 18 July 2001

(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 troughs. 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.

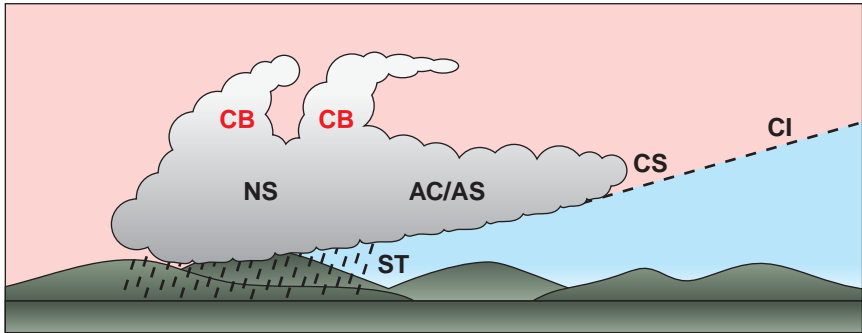


Fig. 2-35 - Warm frontal thunderstorms

(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 Yukon or along foothills of the Mackenzie 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.

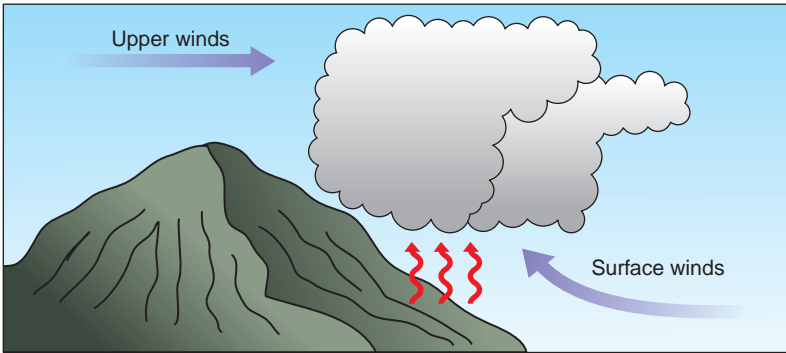


Fig. 2-36 - Orographic thunderstorms form on the foothills of the Rocky Mountains

(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. That said, supercells have been observed across the south Great Slave Lake.



Photo 2-11 - Severe thunderstorm

credit: Alister Ling

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

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 downdraft, 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.

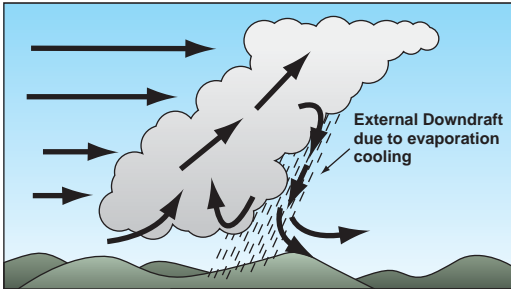


Fig. 2-37 - “Steady state” tilted thunderstorm

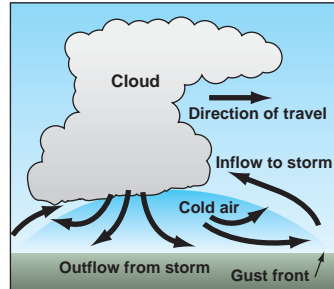


Fig. 2-38 - The gust front

(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 produce 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 referred to as a tornado and if it touches water, it is a waterspout.

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, for example, Dawson or Yellowknife, 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 northern and alpine tundra such as along the Haines-Skagway Roads and Dempster Highway. 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 in the induced vertical currents.

For meteorologists, the most common form of deformation zones are the ones asso-

ciated 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, the upslope areas can see prolonged precipitation. Wind 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.

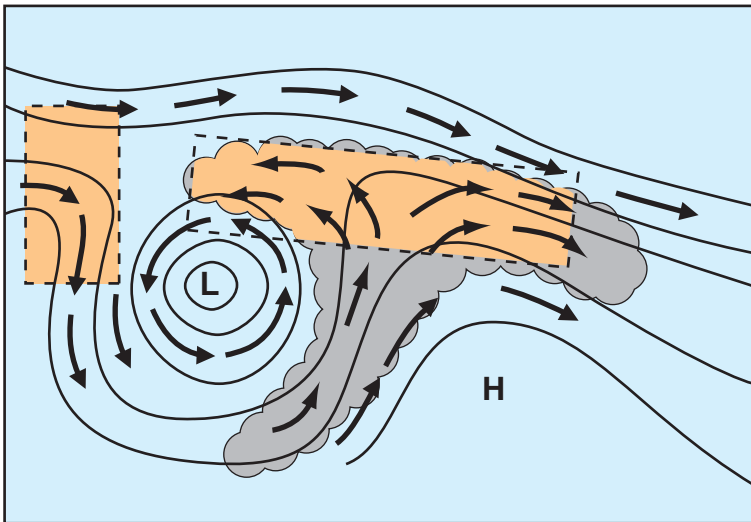


Fig. 2-39 - Deformation zones

Chapter 3

Weather Patterns of the Yukon, Northwest Territories and Western Nunavut

Introduction

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

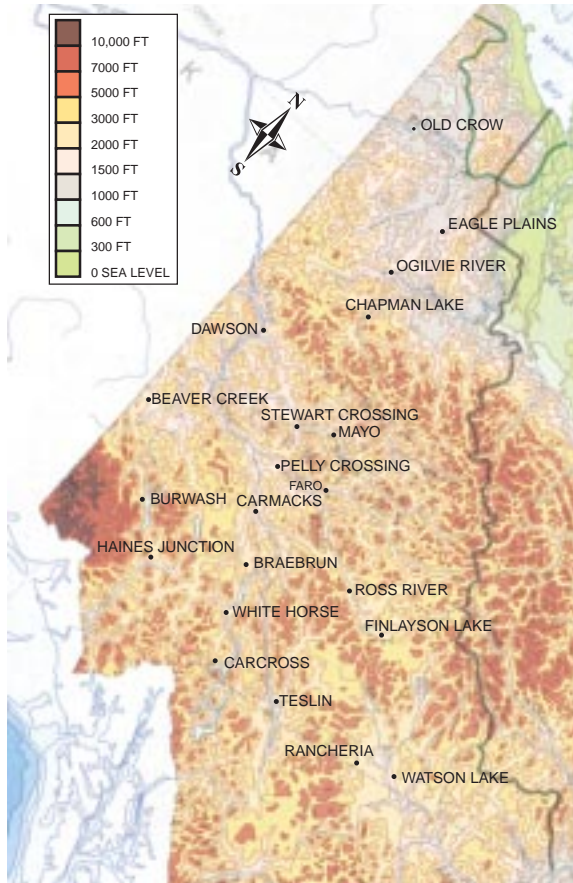
Topography

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.



Map 3-1 - Topography of the GFACN35 domain

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.

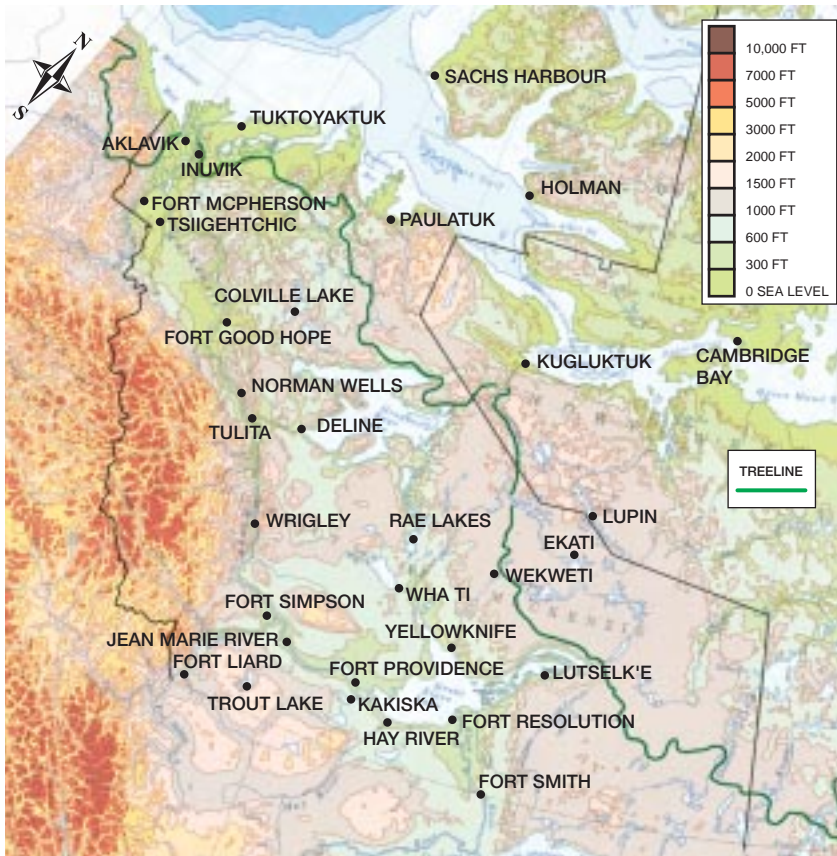
To the north of the Ogilvie, Selwyn and Mackenzie Mountains lie the Peel Plateau and the somewhat more expansive Porcupine River Basin. The Peel River and its tributaries lace the plateau, merge and flow northward into the Mackenzie Delta. The Porcupine River and its tributaries merge and flow westward 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.



Map 3-3 - Topography of Northwest Territories and western Nunavut section of GFACN 35 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 tree-line 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 Alesk, Coppermine and Horton.

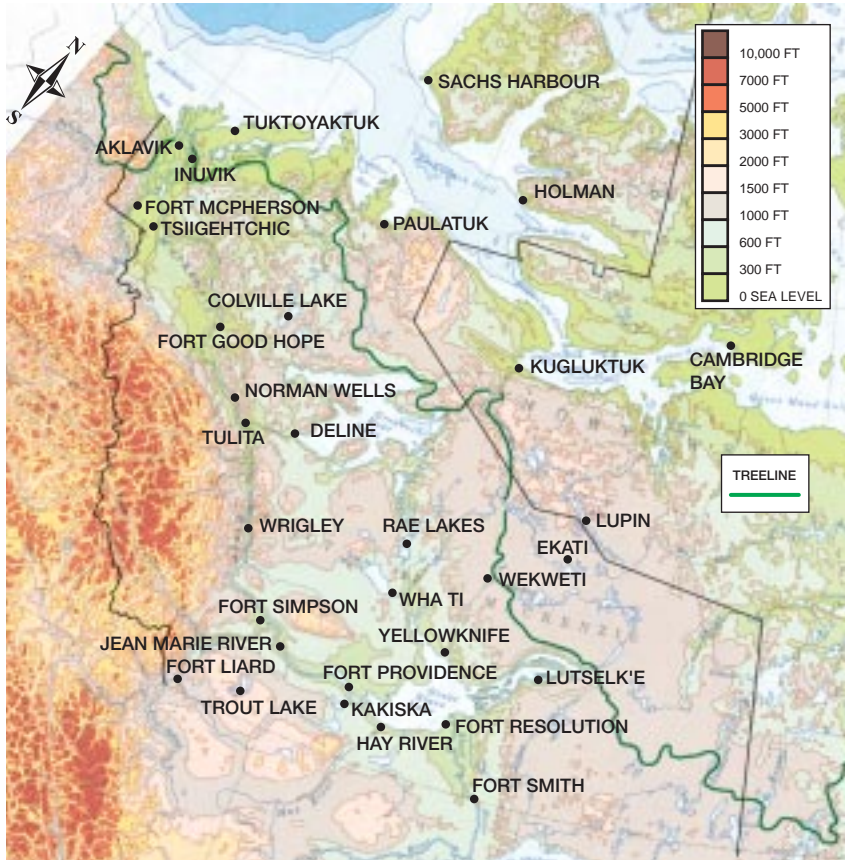


Map 3-4 - Northwest Territories and Yukon sections of the Mackenzie River Basin

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.



Map 3-5 - Treeline across GFACN35 domain

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:



Photo 3-1 - 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.

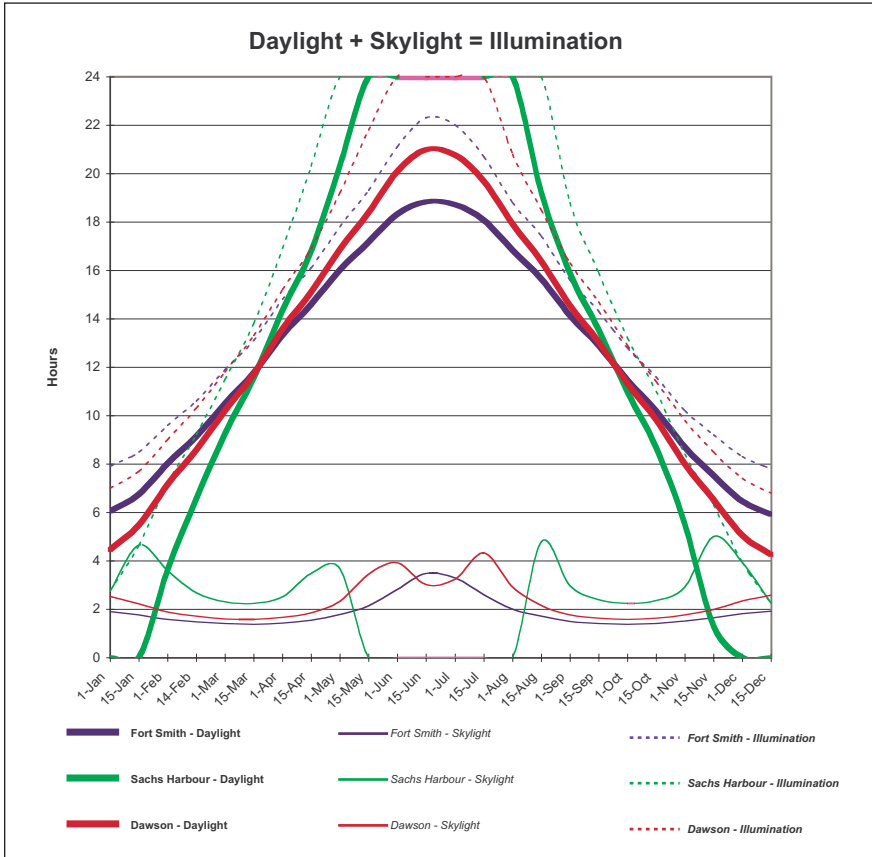


Fig 3-1 - Hours of daylight, twilight and illumination: Fort Smith, Sachs Harbour, Dawson, and Old Crow

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.

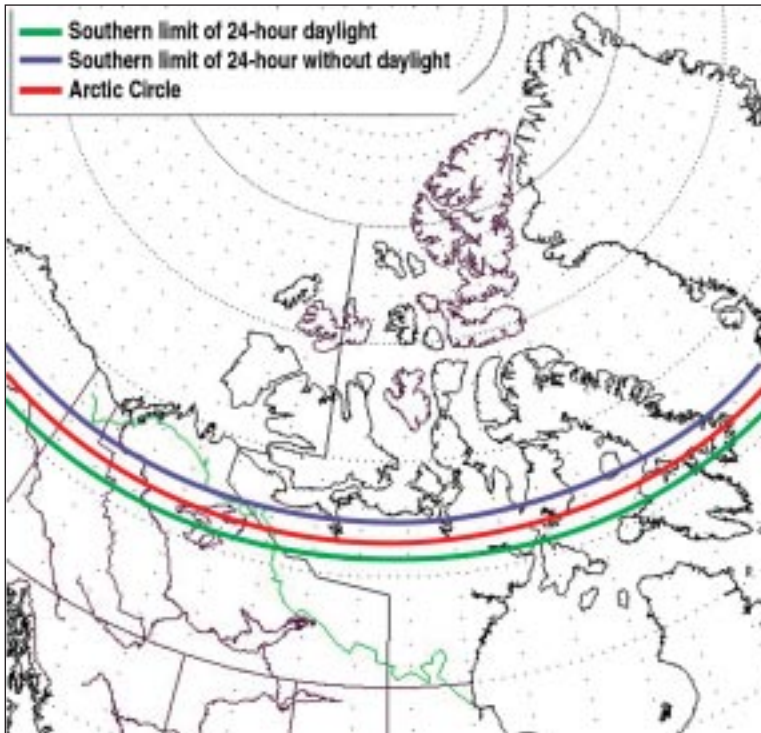


Fig 3-2 - 24 hours of daylight vs. 24 hours of no-daylight

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/polynyas, 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.

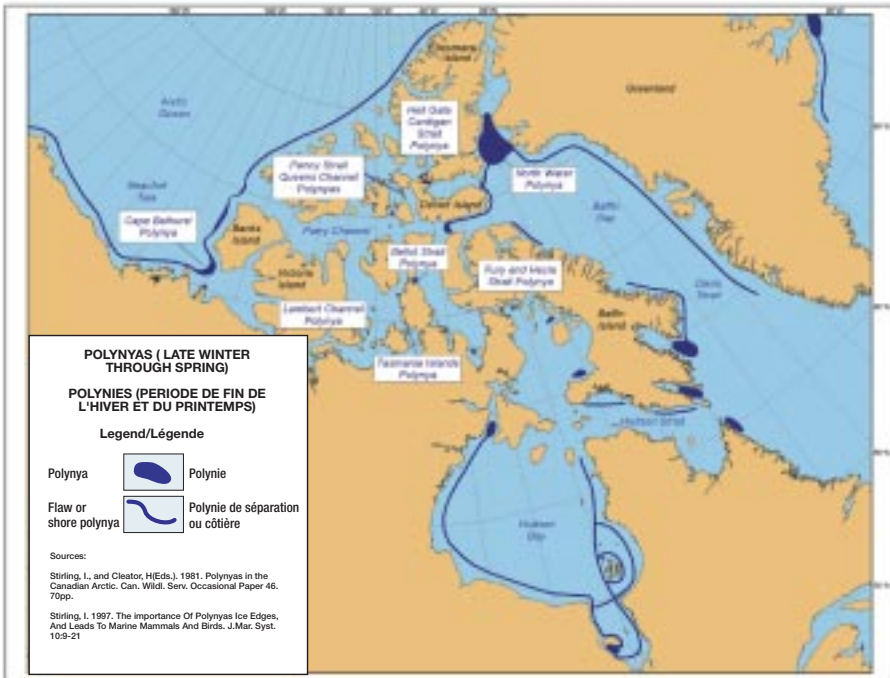


Fig. 3-3 - Polynyas credit: Canadian Ice Service and Dr. Ian Stirling

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.

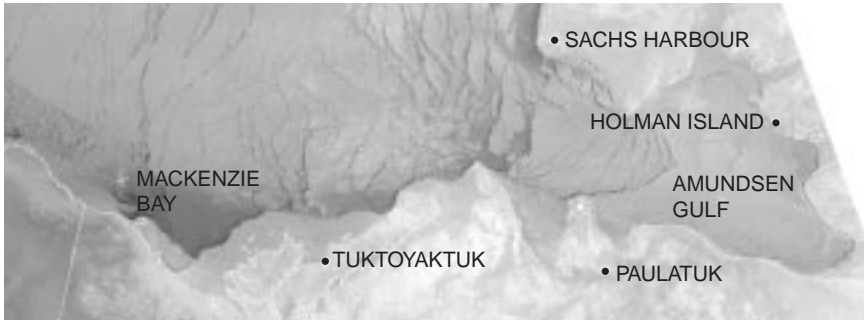


Photo 3-2 - Infrared satellite imagery from 19 January 2002 showing leads and thin ice area across Mackenzie Bay and Amundsen Gulf. credit: Meteorological Service of Canada

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.

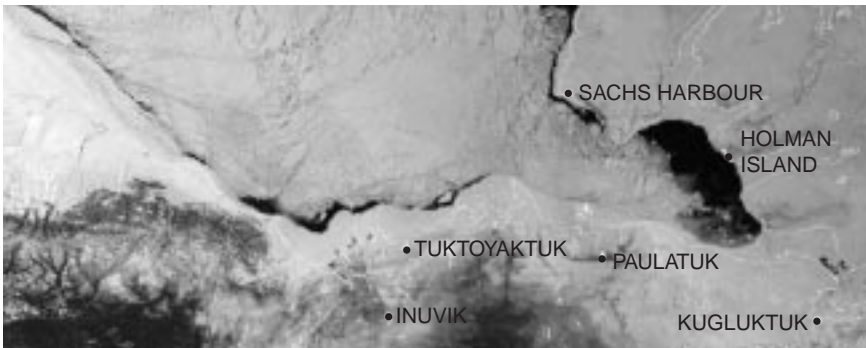


Photo 3-3 - Visible satellite imagery from 29 May 2001, showing the open water area Amundsen Gulf and the lead off the Mackenzie Bay and Tuktoyaktuk shorefast ice edge. credit: Meteorological Service of Canada

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.

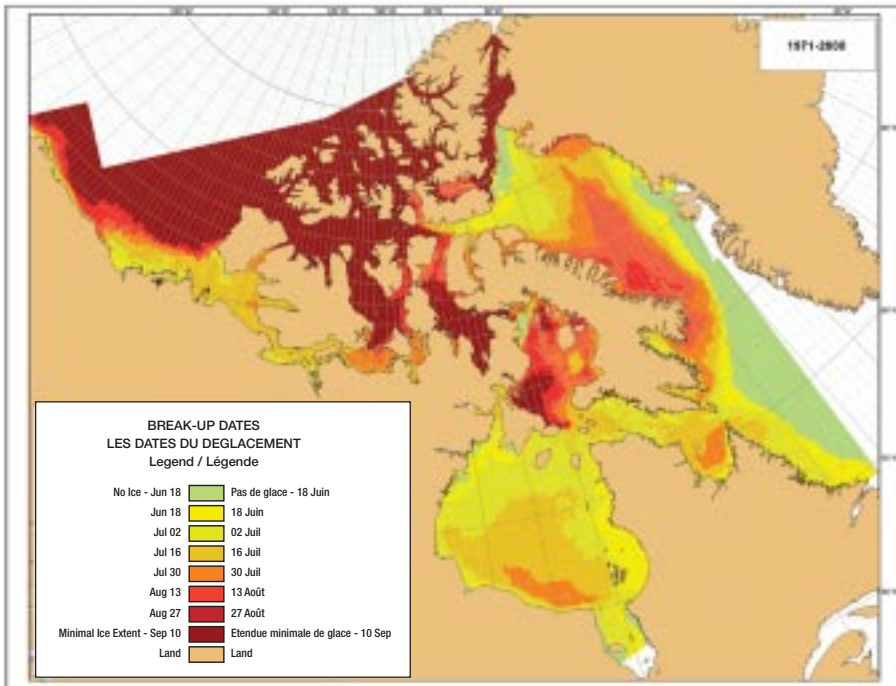


Fig. 3-4 - Break-up dates, 1971 to 2000 data. credit: Canadian Ice Service

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.

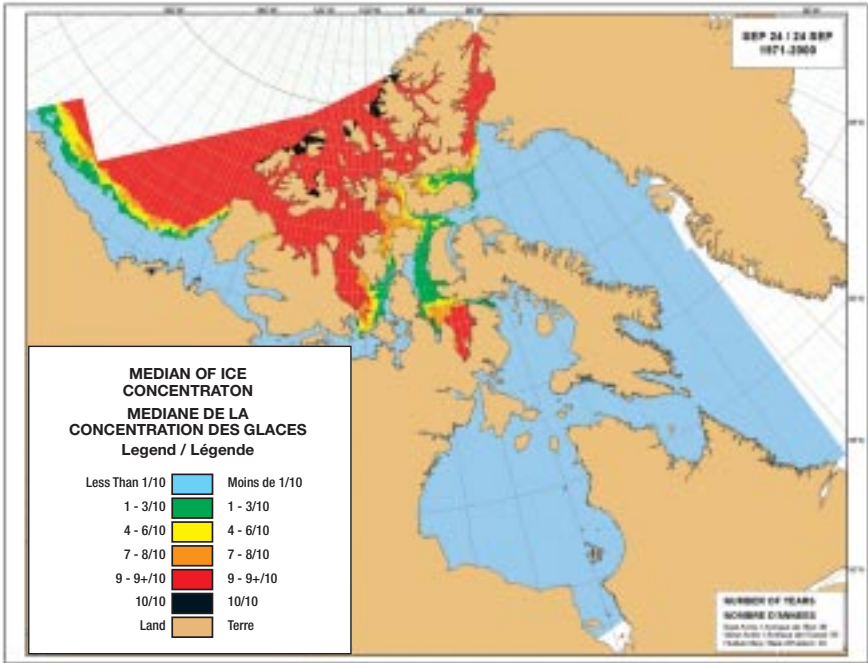


Fig. 3-5 - Median ice conditions
24 September, 1971 to 2000 data

credit: Canadian Ice Service

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.

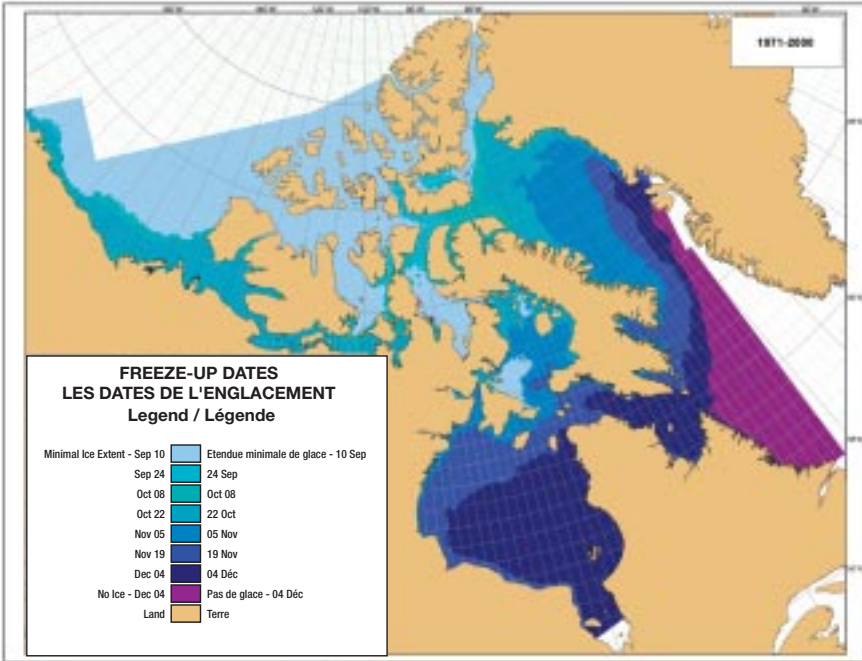


Fig. 3-6 - Freeze-up dates, 1971 to 2000 data. credit: Canadian Ice Service

Lake Freeze-up and Break-up

Freeze-up

FREEZE-UP	GREAT SLAVE LAKE		GREAT BEAR LAKE
	ENTIRE LAKE	BACK BAY, YELLOWKNIFE	
EARLY	25 NOV	18 OCT	13 NOV
MEDIAN	8 DEC	28 OCT	25 NOV
LATE	16 DEC	18 NOV	10 DEC

Table 3-1 - Freeze-up, Great Slave Lake and Great Bear Lake, 1988-1998 data credit: Anne Walker

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

BREAK-UP	GREAT SLAVE LAKE		GREAT BEAR LAKE
	ENTIRE LAKE	BACK BAY, YELLOWKNIFE	
EARLY	1 JUNE	28 MAY	30 JUNE
MEDIAN	21 JUNE	1 JUNE	5 JULY
LATE	24 JUNE	5 JUNE	19 JULY

Table 3-2 - Break-up, Great Slave Lake and Great Bear Lake, 1988-1998 data credit: Anne Walker

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.

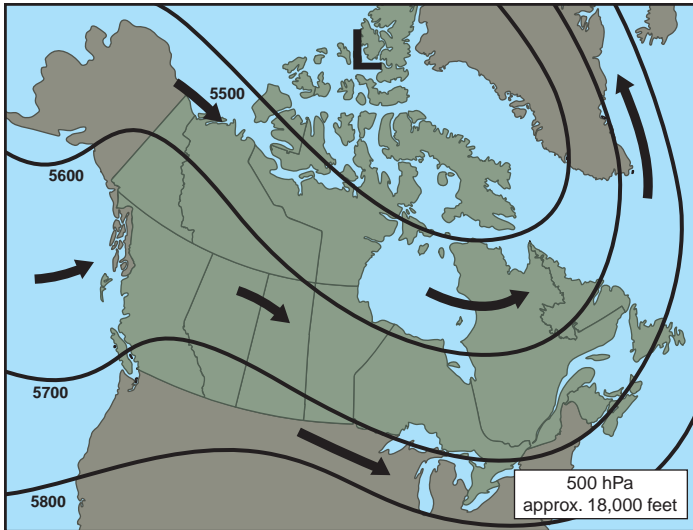


Fig. 3-7 - Mean summer upper winds

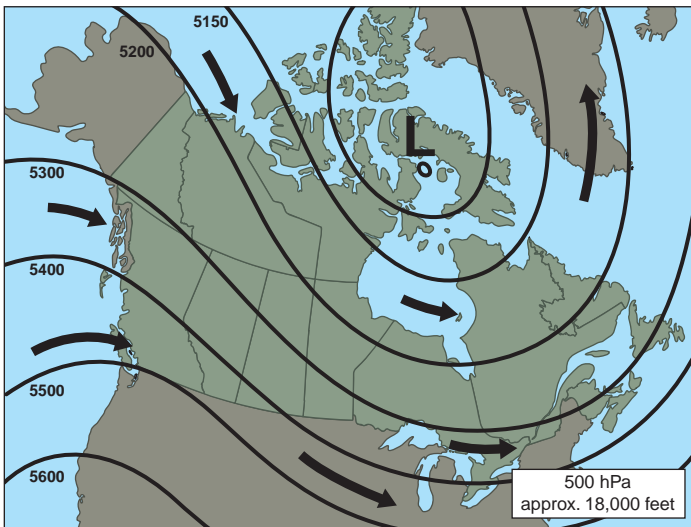


Fig. 3-8 - Mean winter upper winds

Across the GFACN35 domain, the mean flow is much stronger in winter than in summer. The flow in winter favours northwesterly and in summer favours 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.

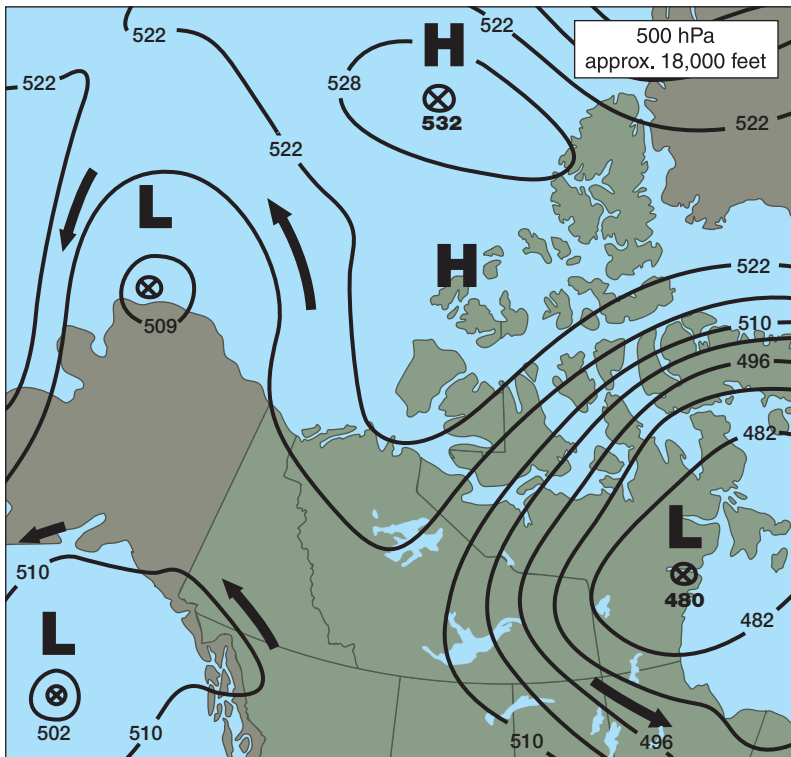


Fig. 3-9 - Upper flow 25 January 2002

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 south-westerly flow and the suggestion of an upper trough resides over central and southern Yukon.

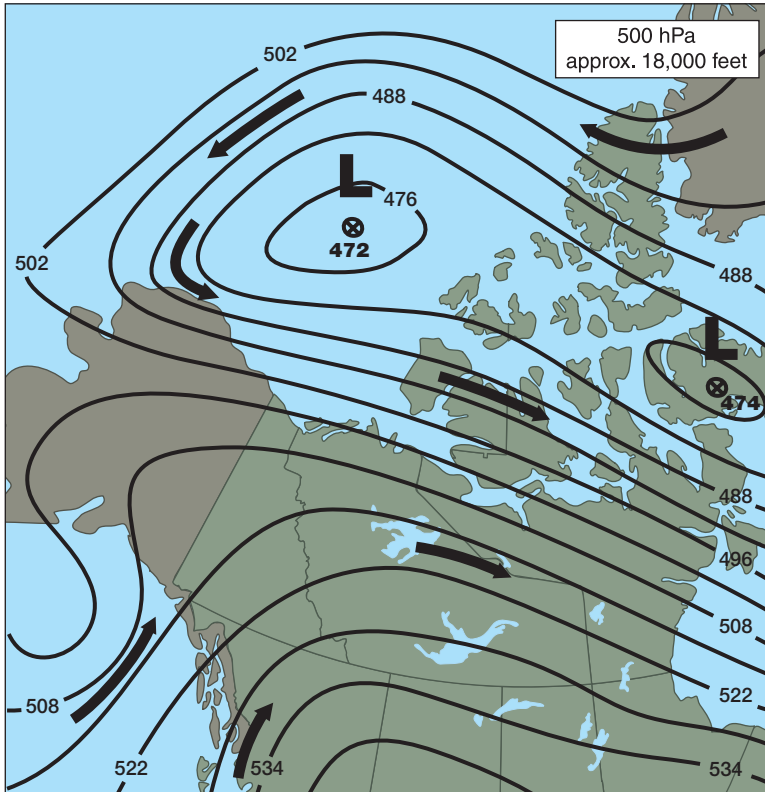


Fig. 3-10 - Upper flow 7 January 2002

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 status 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.

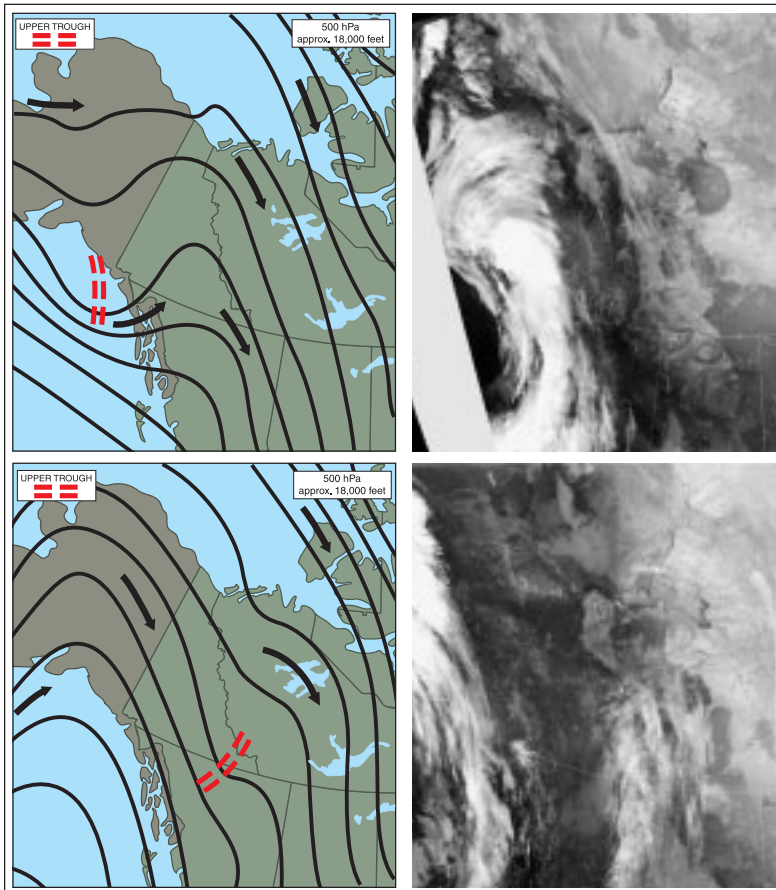


Fig 3-11 - 500 hPa charts and satellite imagery for 0000 UTC January 16 (top) and 0000 UTC January 17 (bottom) 2002

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.

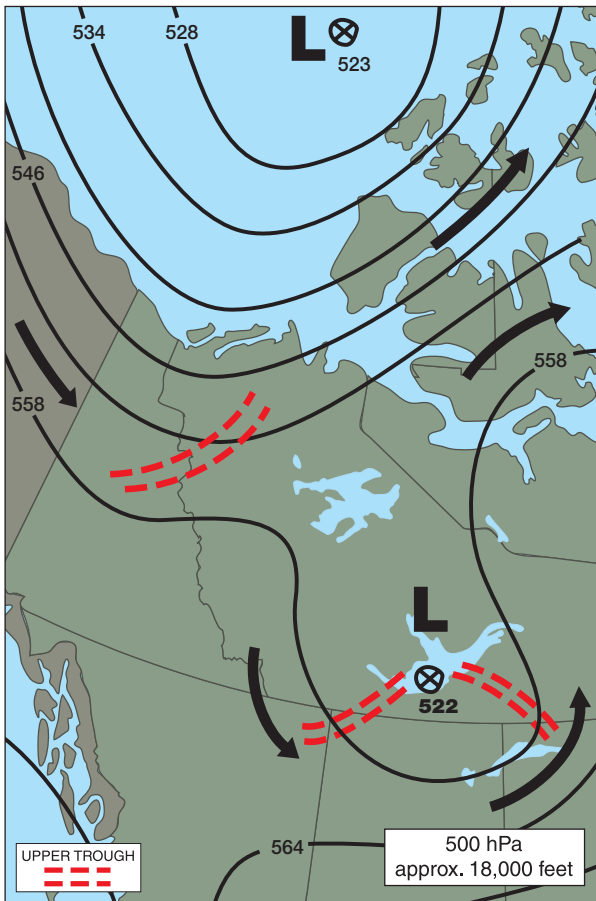


Fig. 3-12 - 500 hPa chart 0000 UTC 6 August 2001

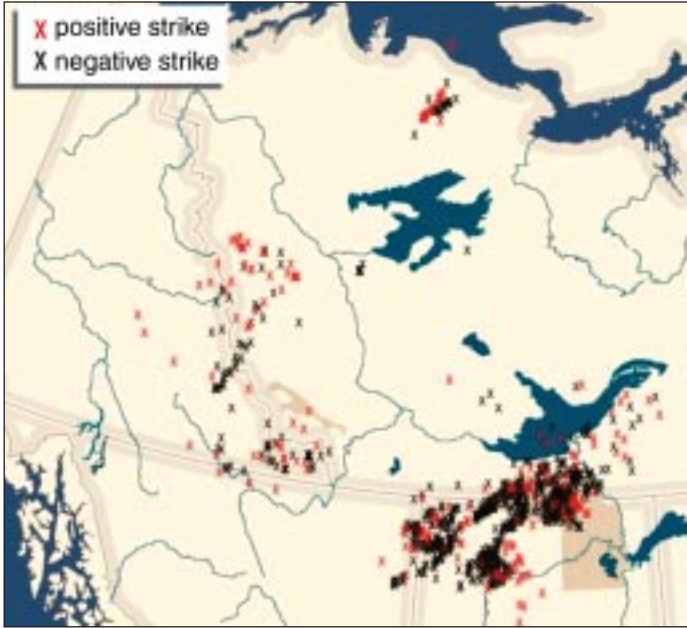


Fig. 3-13 - Cloud to ground lightning detected by Government of the Northwest Territories sensor array during the period 1200 UTC 05 August to 1200 UTC 6 August 2001.

credit: Department of Renewable Resources, Government of the Northwest Territories

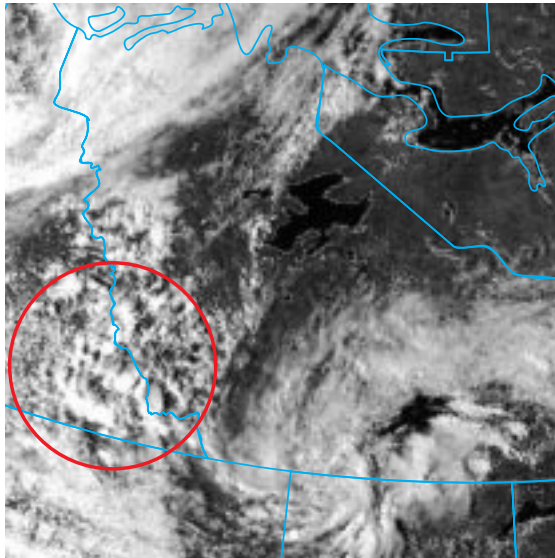


Photo 3-4 - Visual satellite photo 2329 UTC 5 August 2001
Note the popcorn-like cloud in the vicinity of the Yukon and Northwest Territories border.

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, stratocumulus, 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.

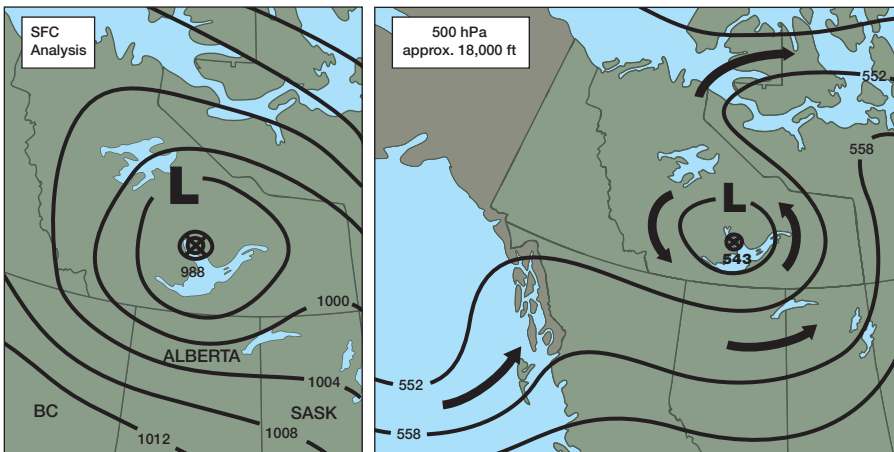


Fig. 3-14 - Intense surface low (left) under upper low (right), 0000 UTC 25 August 2001

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, re-develop, 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.

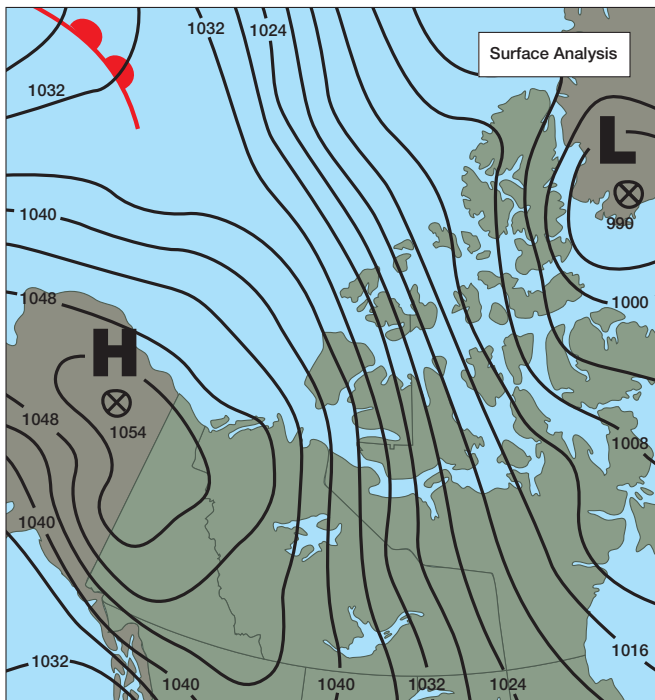


Fig. 3-15 - Surface pattern favouring strong northwest winds and blowing snow across eastern sections of GFACN35 domain, surface analysis 1800 UTC 5 March 2002

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.

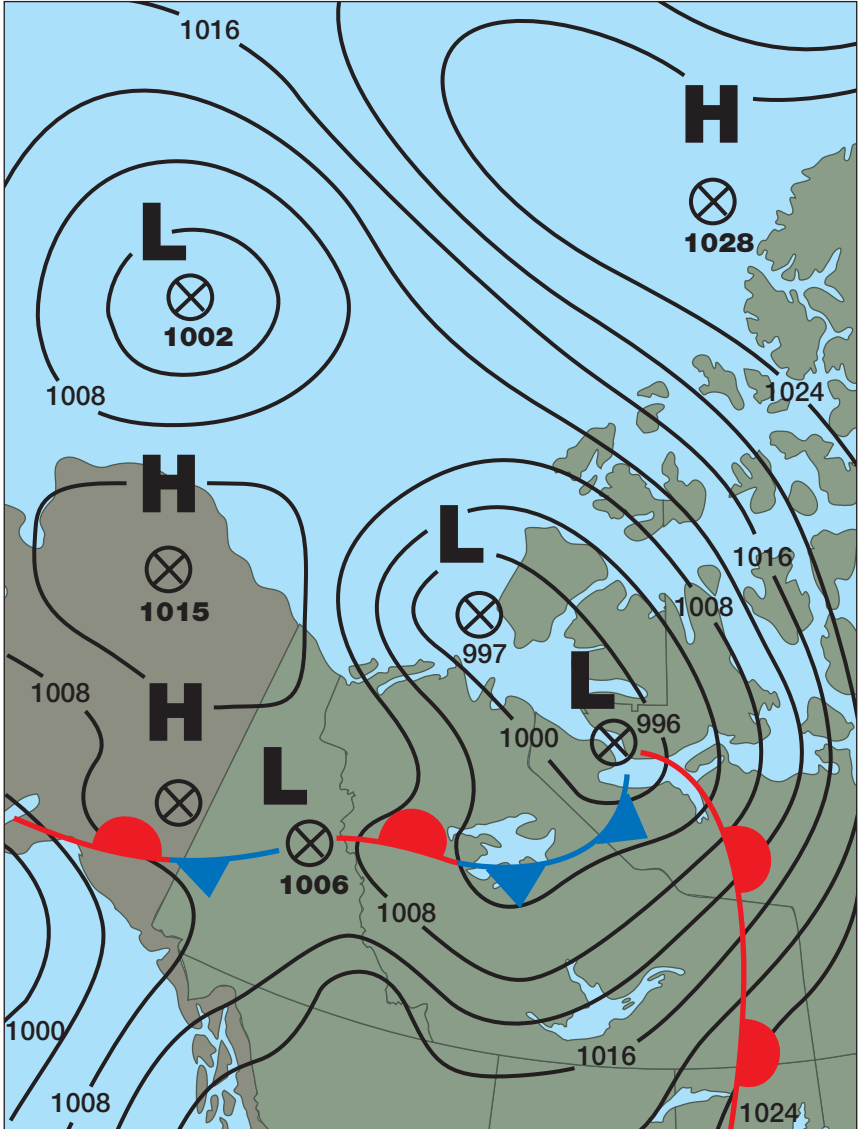


Fig. 3-16 - Strong winds and blowing snow east of Cambridge Bay. Note, at the same time, the strong winds and blowing snow over the Beaufort Sea 1800 UTC 25 December 2001

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.

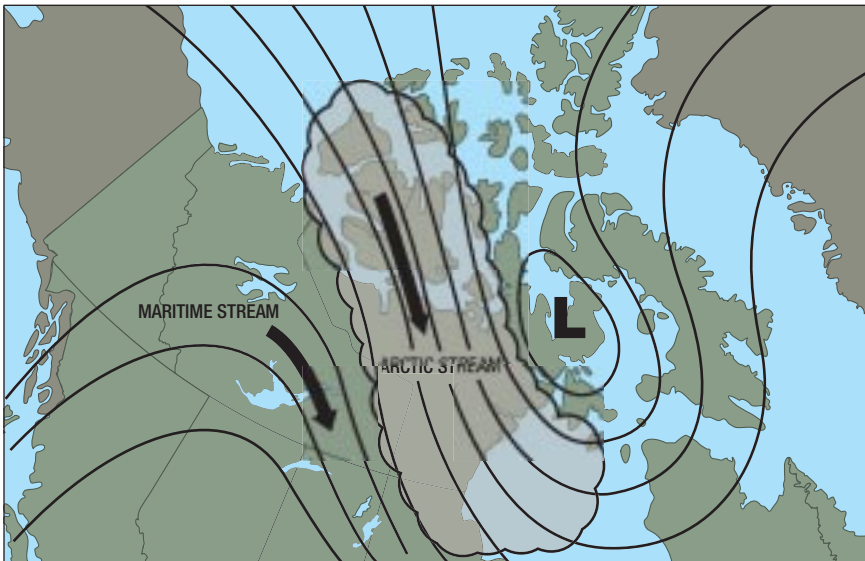


Fig. 3-17 - Pattern 1, spring thaw to early fall upper wind pattern and associated stratiform cloud area.

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.

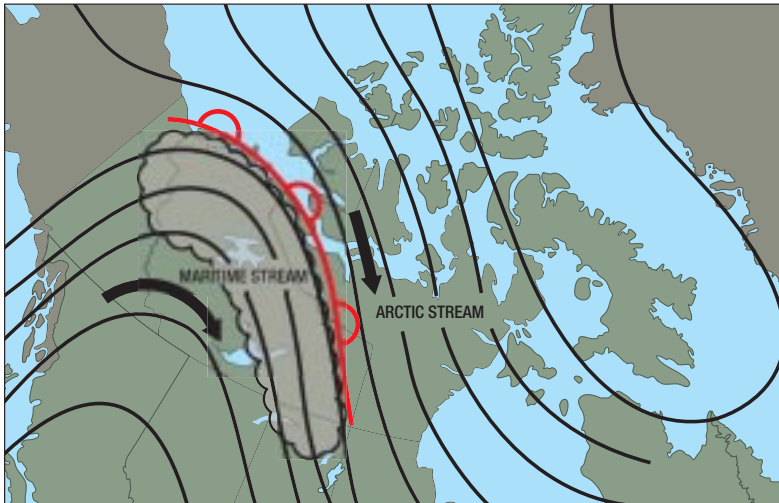


Fig. 3-18 - Pattern 2, Fall, winter, and early spring upper wind pattern and associated stratiform cloud area

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.

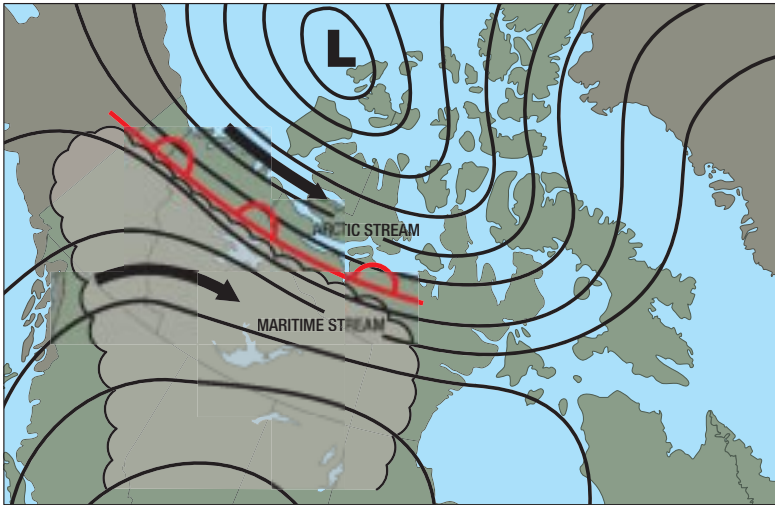


Fig. 3-19 - Pattern 3, Fall, winter, and early spring upper wind pattern and associated stratiform cloud area

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.

Table 3: Symbols Used in this Manual

	<p>Fog Symbol (3 horizontal lines) This standard symbol for fog indicates areas where fog is frequently observed.</p>
	<p>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.</p>
	<p>Icing symbol (2 vertical lines through a half circle) This standard symbol for icing indicate areas where significant icing is relatively common.</p>
	<p>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.</p>
	<p>Turbulence symbol This standard symbol for turbulence is also used to indicate areas known for significant windshear, as well as potentially hazardous downdrafts.</p>
	<p>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.</p>
	<p>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.</p>
	<p>Snow symbol (asterisk) This standard symbol for snow shows areas prone to very heavy snowfall.</p>
	<p>Thunderstorm symbol (half circle with anvil top) This standard symbol for cumulonimbus (CB) cloud is used to denote areas prone to thunderstorm activity.</p>
	<p>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.</p>
	<p>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.</p>

Chapter 4

Seasonal Weather and Local Effects

Northern Yukon including the Yukon Coast and Herschel Island



Map 4-1 - Topographical overview of the GFACN35 Domain

This chapter is devoted to local weather hazards and effects observed in the GFACN35 area of responsibility. After extensive discussions with local pilots, dispatchers, Flight Service Specialists, National Park Wardens and MSC personnel, 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. In other cases, the weather phenomena are better described in words. Table 3, shown previously and at the back of the book, provides a legend for the various symbols used throughout the local weather sections.

The chapter first looks at the Yukon, section by section, and then at the Northwest Territories and Western Nunavut, first overall, and then section by section.

The Yukon North Coast



Map 4-2 - The Yukon North Coast

The Yukon North Coast, commonly referred to as the “Arctic Slope”, is a 6 to 12-mile wide, gently sloping, treeless coastal plain that separates the rolling foothills of the Richardson and British Mountains from the Beaufort Sea. It is almost flat, ranging in elevation from sea level to about 1,000 feet ASL, with no major hills extending as far as the coast. Residents from communities in the Mackenzie River Delta maintain seasonal hunting and fishing camps along the coast but for the most part it is uninhabited. With the decommissioning of former DEW line sites at Komakuk Beach and Shingle Point, the nearest permanent Yukon settlement is Old Crow.

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. On a yearly average, the permanent pack ice lies about 50 n. miles north of Herschel Island, drifting in a prevailing clockwise current called the Beaufort Gyre. However, depending on winds and season, the pack ice will press right into the coastline.

That being said, the Yukon Coast, including Herschel Island, is generally ice free from early July to late September. Float planes often frequent the area at this time, bringing tourists to view the variety of birds and spectacular burst of colour that the tundra flowers develop during the short summer season. The coast is often shrouded in fog, particularly in the late summer, for periods ranging from hours to days.

Due to the treeless and relatively flat surface of the coastal plain and the rising terrain just a short distance inland, surface winds tend to blow parallel the coastline most of the year.

(a) Summer

The typical summer pattern has a strong Pacific High, extending northward out of the Gulf of Alaska, and a weak trough of low pressure, extending from Siberia through the northern Bering Sea to northwest Alaska. The Arctic front shifts northward, (tending to coincide with the tree line), residing along the northern slopes of the British Mountains.

The Arctic air to the north of this front is highly modified during the long daylight hours of spring and summer. While the Arctic air does become shallower, warmer and more moist, it still tends to remain convectively stable. This stability confines the moisture near the surface, generating low stratus and fog that lingers offshore and hugs the coastline. As a result, poor flying conditions due to low ceilings and poor visibility occur more frequently during the summer than winter. Onshore breezes carry this low cloud and fog inland where it is warmed by the ground and undergoes convective mixing. Frequently, this will result in good visibility a few miles inland from the coast.

There is very little precipitation over this area, some 200 millimetres annually. Most of this falls as rain, during a short month and half summer season that bridges July and early August, and very little falls as snow throughout the long winter.

Thunderstorms, even in summer, are rare on the north coast and incidents of hail have not been recorded at either Shingle Point or Komakuk Beach weather stations.

While some of the highest mean wind speeds are found here in the winter, significant winds blow across the Arctic slope throughout the summer, making this the Yukon's windiest region. The prevailing direction is out of the northwest. Local wind extremes are known to occur in both the Blow and Babbage River Valleys. Outflow winds in these areas often extend across the coastal plain.

(b) Winter

With the approach of winter, a major area of low pressure begins to develop and intensify over the Aleutians and elongates into the Gulf of Alaska. At the same time, a broad cold high pressure area begins to develop and dominate Siberia with a ridge extending eastward into the Beaufort Sea. By mid-winter, a major area of high pressure prevails over central Yukon and the Mackenzie Mountains.

Arctic air forms over northern Yukon in winter as a result of intense radiation cooling and gradually spreads southward, resulting in strong inversions. During the fall and early winter, a shallow moist surface layer persists in most valleys due to evapo-

ration from open lakes and rivers, but this moisture slowly diminishes as these water bodies freeze over. By January and February, the resulting airmass has almost negligible water content and is at its coldest and deepest, with temperatures at times plunging to less than -52°C .

An active winter storm track across the Bering Sea to the Beaufort Sea will occasionally bring milder temperatures to the area. With each storm comes very strong southwest winds and occasional blizzard conditions, as the systems track eastward along the coast. Under these conditions the Babbage River Valley (through the British Mountains) and the Blow River Valley (along the northeastern edge of the Richardson Mountains, just to the east of Shingle Point) develop extremely strong outflow winds. The combined effect of katabatic and gradient flows with funnelling contribute to outflow winds through these valleys that can exceed 60 knots, generating severe mechanical turbulence. Naturally, this combination of strong winds and snow can result in blizzard conditions extending across the width of the coastal plain.

The coastal area receives the bulk of its snowfall in October and has the longest snowfall season; however, it has the least annual snowfall amount of any region within the Yukon.

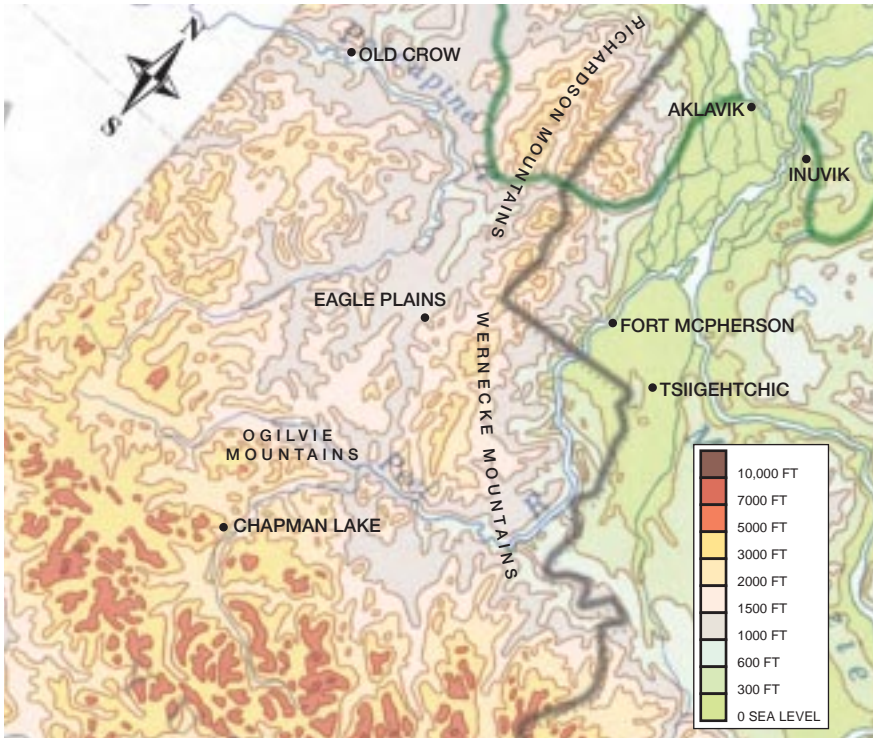
(c) Local Effects

For most Yukon regions, the occurrence of fog and low cloud peaks in the fall and rises again to a lesser extent in the spring, showing a minima in the drier periods of summer and after freeze up in winter. Along the Arctic coast, the occurrence of fog and low cloud is just as often associated with wind direction, even more so during the summer when retreating sea ice exposes broad expanses of cold open water. Both Komakuk Beach and Shingle Point have a marked tendency toward scattered cloud and good visibility, with offshore winds from the east through southwest, and with calm winds during winter. The occurrence and persistence of poor visibility and low ceilings increases dramatically with winds from the west through northeast.

Throughout the winter months, low ceilings and poor visibility often develop in association with strong winds, as a result of snow and blowing snow being swept onshore from the frozen Beaufort Sea to the north. While this area experiences frequent periods of blowing snow, the most severe blizzards are associated with local outflow winds along the Blow River and Babbage River Valleys.

Pilots seldom report encountering much more than light to moderate convective or mechanical turbulence along the flat expanse of the Yukon coast, even during the height of the short northern summer. However, local moderate to severe mechanical and shear turbulence should be expected in the vicinity of strong outflow winds, through mountain valleys. In the case of the Blow and Babbage River Valleys, the area of turbulence may extend northward across the coastal plain through a depth of several thousand feet.

Northern Yukon including the Porcupine - Peel River Basins



Map 4-3 - Northern Yukon including the Porcupine - Peel River Basins

The Porcupine - Peel River Basin area is comprised of a combination of plains, hills and plateaux bounded by the Ogilvie and Wernecke Mountains to the south, the British Mountains to the north, and the Richardson Mountains to the east. Several river valleys cut through these boundaries: the Porcupine River in the west, the Blow River through the northern mountains, and the Peel River through the Richardson Mountains to the east. The central area consists of fairly level terrain giving rise to names like Old Crow Flats and Eagle Plains. The climate of this region is unique from that of the northern coast and the south.

(a) Summer

Summers are short, confined by the long winter to the period between July and August. The strong temperature inversions characteristic of winter begin to disappear by May, allowing the river valleys throughout the basin to warm. However, the surrounding mountain areas remain cool. Spring and summer weather shows tremendous variability.

With the north's long daylight hours, fair weather can bring warm temperatures that can equal temperatures found much farther south. However, the Arctic air is

never that far away and when it invades, all too frequently during the summer, conditions will change suddenly to showery, windy and cool.

The Ogilvie Mountains to the south are effective in blocking much of the moisture brought to southern Yukon by Pacific systems. As a result, the Porcupine and Peel River areas are dry, receiving only 200 to 300 millimetres of precipitation annually. Most of that moisture falls in the summer as a result of light convective showers.

Thunderstorms can bring heavier precipitation, but develop infrequently across the region, and rarely occur outside of the months of June, July and August.

(b) Winter

The winters are long and cold, lasting from near mid October when freeze up occurs until May when the snow melts and the ice comes off the lakes and rivers. Most of the annual snowfall occurs in the fall and early winter, with a secondary maximum in May. Snowfall amounts are greater than those on the north coast, but in general the winters are dry. Less than 10 centimetres of snowfall accumulates per month between January and April.

By November, the Arctic inversion becomes well established and the basin area begins to experience lower mean temperatures than the surrounding mountain region. With cold air continually draining into the basin and a net loss of radiation due to long, often clear and calm winter nights, the surface temperatures can become bitterly cold, at times dropping below minus 50°C.

Sheltered by surrounding mountains, winter storms arriving from the Gulf of Alaska or the Arctic coast are weak and the lighter winds associated with these systems generally fail to scour out cold arctic air that pools on the basin floor. Old Crow, for example, experiences calm winds almost 50 percent of the time throughout the months of December, January and February.

Spring break up occurs in late March or April and, while flurries may occur at any time of the year, the terrain at lower elevations is usually free of snow by June.

(c) Local Effects

Old Crow - Old Crow Flats

Old Crow, on the Porcupine River, is the most northerly permanent settlement in the Yukon. With no road access and a location over 200 miles from the Dempster Highway, the community is only accessible by air year-round but is accessible by water in the summer and snowmobile or dogsled in the winter.

Fog or low cloud is common throughout the Porcupine and Peel River Basins, beginning in the late summer and often continues throughout the fall, when moisture

is freely available prior to freeze up. After freeze up, large arctic highs can bring periods of clear skies, very cold temperatures and flying conditions of unlimited visibility and “absolutely smooth” flight.

When fog does develop, it is usually in the early morning hours, often restricting aircraft operations within a few hours of sunrise then dissipating by mid day. After freeze up, fog or ice fog generally does not occur frequently outside of settlements due to the lack of moisture in the very cold air. Fog, forming from moisture and condensation nuclei released by household heating and vehicles including aircraft, will sometimes linger in the vicinity of Old Crow, while the surrounding area and the remainder of the region may be clear. Once formed, fog can become very persistent in winter due to Old Crow’s frequent light or calm winds and strong arctic inversions.



Photo 4-1 - View of Old Crow Airport looking westward credit: Unknown

Light to moderate convective turbulence is common across the region in the summer, especially during the afternoon and evening, the result of uneven surface heating of a varied terrain mix of low hills and valleys, marshes, lakes and rivers. Thunderstorms are generally less intense and arise less frequently than in the south. Small lines of thunderstorms may accompany the movement of cold fronts.

Pilots caution that fronts can move rapidly across the low open terrain of these basins. Some related stories of uncomfortable races against rapidly deteriorating conditions to make their way through passes along the Dempster Highway, ahead of the snow squalls.

The Mountain Passes Eagle Plains - Yukon / Northwest Territories Border

Commonly used by pilots flying to and from Inuvik, this route follows the Dempster Highway, north of Eagle Plains, through the Richardson Mountains at “Rat Pass” near the Yukon / Northwest Territory Border.

As well as being areas prone to low ceilings and poor visibility, the wind through this pass can be strong and turbulent. Very few weather reports come out of this sparsely populated area; however, pilots can gain an indication of winds and turbulence by looking at the strength of the pressure gradient across the region. A strong east-west pressure gradient across the Richardson Mountains should signal caution for turbulent conditions through Rat Pass, which is especially subject to strong easterly winds.



Photo 4-2 - Looking southeastward from the NWT border credit: Greg Pearce
along the Dempster Highway



Photo 4-3 - North Fork Pass (Km 82 (near Dawson) on the Dempster Highway) looking northeastwards towards Tombstone Mountain in the Ogilvies.

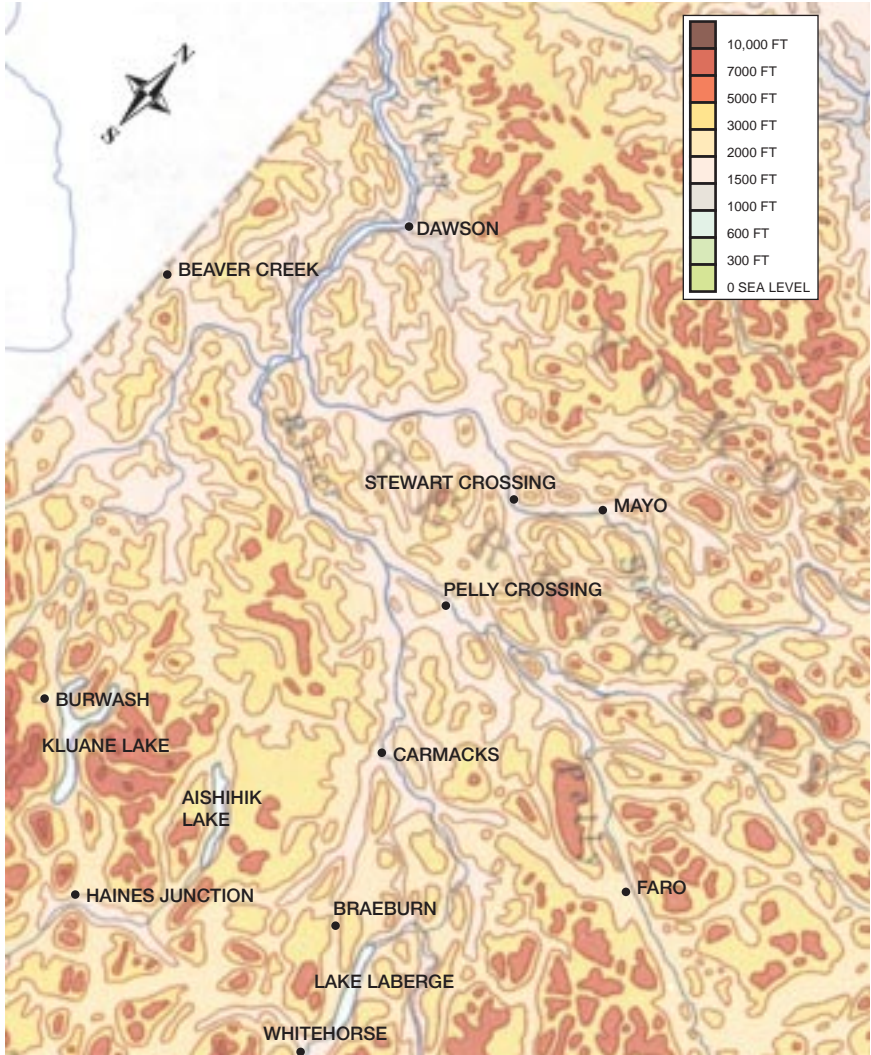
credit: Greg Pearce

Sapper Hill - Chapman Lake - Blackstone River - Robert Service Creek

Again, this is a sparsely populated area with few weather reports. A strong north-south pressure gradient across the Ogilvie Mountains signals turbulent conditions through passes. Between Sapper Hill and Chapman Lake, the terrain gradually rises with surrounding peaks to near 6,000 feet ASL. This higher terrain, in addition to channelling strong winds and generating frequent turbulence, is subject to low ceilings and poor visibility.

Between the Blackstone River and Robert Service Creek, the terrain rises again with spectacular surrounding peaks, including Tombstone Mountain rising to elevations in excess of 7,000 feet ASL. This area can often be a bottleneck of low cloud and turbulent, terrain channelled winds.

The Central Yukon River Basin



Map 4-4 - The Central Yukon River Basin

The central Yukon River Basin, lower in elevation and removed from the effects of the Gulf of Alaska and St Elias Mountains, has several of its own unique climatological characteristics.

a) Summer

Summers, defined as beginning when mean daily temperatures rise above 10 degrees and ending when mean temperatures fall below zero, are considerably longer than those further north. Summer begins in mid April and ends around mid October

and, during this period, offers some of the best flying weather. Warm summers are typical and at times they can be hot with maximums as high as 36°C recorded at Mayo.

The region sees more precipitation than the north or southwest but is drier than the Liard Basin to the southeast. Most of the annual 300 to 400 millimetres of precipitation falls in the summer as showers.

Summer thunderstorms are common across the region. Dry thunderstorms are often identified as the cause of wildfires. Smoke from large fires can significantly reduce visibility over broad areas and extend downwind for tens to hundreds of n. miles. Dry thunderstorms tend to occur after dry spells as the first surge of cold air aloft breaks down a persistent upper ridge. Wet thunderstorms, those associated with heavier precipitation, often accompany the passage of cold lows. Thunderstorms occur more frequently over the higher terrain elevations and are also most numerous between 1500 and 1800 LST.

(b) Winter

Winters are shorter than in the north, beginning about mid October, when lakes begin to freeze, and lasting until mid April when snow retreats and ice melts from the areas lakes and rivers. Most snowfall occurs in the fall and early winter and, after March, snowfall accumulations drop rapidly.

Well-organized storms, arriving from the Gulf of Alaska or the Arctic coast, commonly skirt this region, especially in the winter when the anticyclonic circulation of arctic highs dominates the interior. With few migratory low pressure systems and their associated pressure gradients, winter winds tend to be light. Dawson, for example, experiences calm winds over 79 percent of the time throughout the months of December, January and February.

In the fall, a combination of light or calm winds, falling temperatures and readily available moisture from the open water of lakes and rivers gives rise to persistent areas of fog. After freeze up the incidents of fog fall rapidly.

In winter, strong inversions are common and the lower basin areas often see the coldest temperatures, while at higher elevations conditions can be much milder. As the cold arctic air becomes well established, some extremely cold temperatures can develop as witnessed by a bone chilling record of -63°C at Snag.

Spring break-up generally begins in April and, while flurries may occur from time to time, lower elevations are usually free of snow in May.



Photo 4-4 - Carmacks looking northward along the Yukon River credit: Unknown

(c) Local Effects

Carmacks - Pelly Crossing - Dawson (Klondike Highway Route)

The commonly used route between Carmacks and Dawson follows the Klondike Highway, which parallels the Yukon River, from Carmacks to Minto, where it veers northward toward a small community and regional airstrip at Pelly Crossing. From there, the route continues northward to Stewart Crossing and follows the Stewart River, northwestward toward another small seasonally maintained airstrip at McQuesten. From McQuesten, the route leaves the Stewart River and presses northwestward to Dawson.

Due to the fact that this route follows low level terrain afforded by broad river valleys, it generally offers fair flying conditions. Typical of many areas of the Yukon, strong cross valley winds tend to result in turbulence to the lee of higher terrain. Turbulence is generally most pronounced under a strong southwest flow to the lee of the mountains between Carmacks and Minto, as well as between Pelly Crossing and Stewart Crossing.

The weather reported at Dawson and Mayo is a fairly good indicator of what can be expected along this route. During the winter, strong shallow temperature inversions of several degrees Celsius per hundred feet are common in this area. Developing in the fall and continuing throughout the winter, these inversions trap moisture in the lower elevations and often result in areas of fog or low stratus. This is most pronounced over and around the open water of numerous lakes and rivers prior to

freeze up, which usually takes place between late November and early December. Pilots have pointed out that as a general rule, if fog and low stratus has lifted out of Mayo and Dawson, the rest of the route is likely to be open. However, low stratus will periodically persist a while longer over the higher terrain between Pelly Crossing and Stewart Crossing.



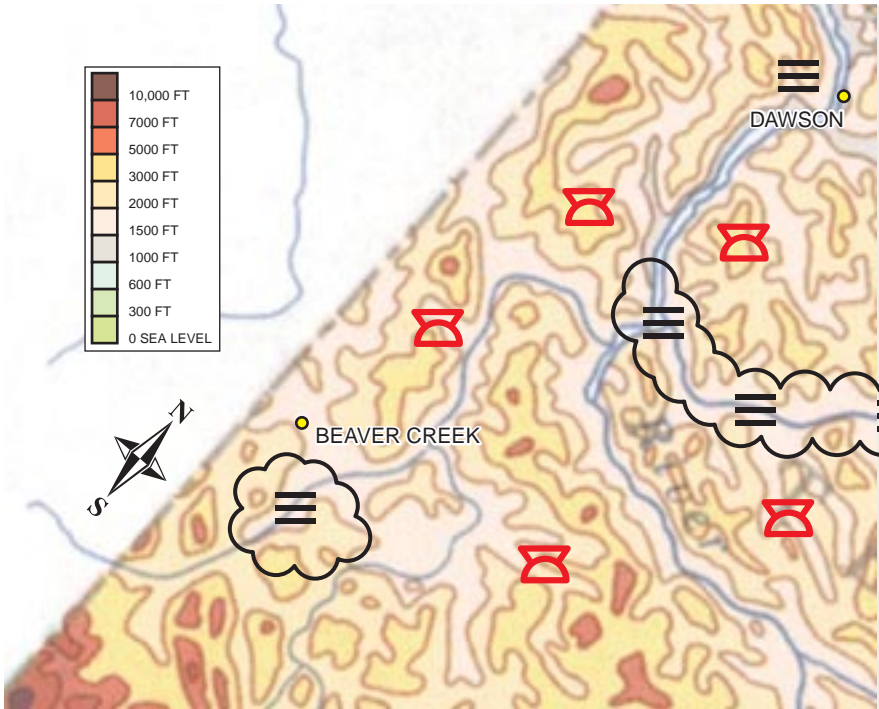
Photo 4-5 - The North Klondike River Valley meets the Klondike River Valley in the the Tintina Trench (just southeast of Dawson). In the background are the Ogilvie Mountains. credit: Greg Pearce

Thunderstorms are common throughout this area during the summer months. They occur most frequently along the mountainous upslope terrain to the east of the route. Convective cloud and thunderstorms will often persist well into the evening due to the long hours of sunshine. Pilots have cautioned that while convective turbulence will usually diminish along the route in the evening, strong but localized winds can sometimes develop from some of the smaller side valleys giving unexpected turbulence and directional shears.

When weather is fair, the Yukon River Valley, which continues northwest from Minto, is sometimes used by local pilots as an alternate route into Dawson. Within this scenic wilderness area, however, there are few roads and no maintained airports or aviation weather reporting stations. The Yukon River Valley narrows as it winds along the northern edge of the Dawson Range, from about 30 n. miles northwest of Minto to the confluence of the Stewart River. Ragged stratus, showers or snow squalls will at times block this section of the route, especially under a moist south or south-east flow; however, the remainder of the route will often remain open.

Fog and low stratus tends to develop in the fall and early winter, which is typical of most of the region prior to freeze up in late November or early December. The worst area for fog is described by pilots as that along the Yukon River, between the confluence of the White and Stewart Rivers. Fog will often persist in this area well after it has cleared in Dawson, Mayo and Beaver Creek.

Beaver Creek - Dawson



Map 4-5 - Beaver Creek - Dawson

This route follows the broad valleys and low terrain along the White River, around the Dawson Mountains from Snag to the Yukon River, then northward along the Yukon River to Dawson.

Weather at Dawson and Beaver Creek is generally representative of what can be expected along this route; however, lower ceilings and areas of fog will sometimes persist along the Yukon River Valley between its junction with the White and Stewart Rivers.

Thunderstorms often occur across this region throughout the summer and convective turbulence arising from daytime heating can give a jarring flight along the route on warm summer afternoons.

Stewart Crossing - Mayo

The flying conditions along this thirty-mile route through the Stewart River valley are not significantly different from those encountered along the Carmacks to Dawson route. Weather is fairly well represented by reports out of Mayo.

Under a strong northwest flow, pilots will often report turbulence to the lee of the 4 thousand foot hills northwest of the Mayo airport.

During the early morning, fog tends to form along the Stewart River, especially in the fall. If fog is reported at Mayo in the morning, it's likely to be present along this route but will usually lift before mid day.

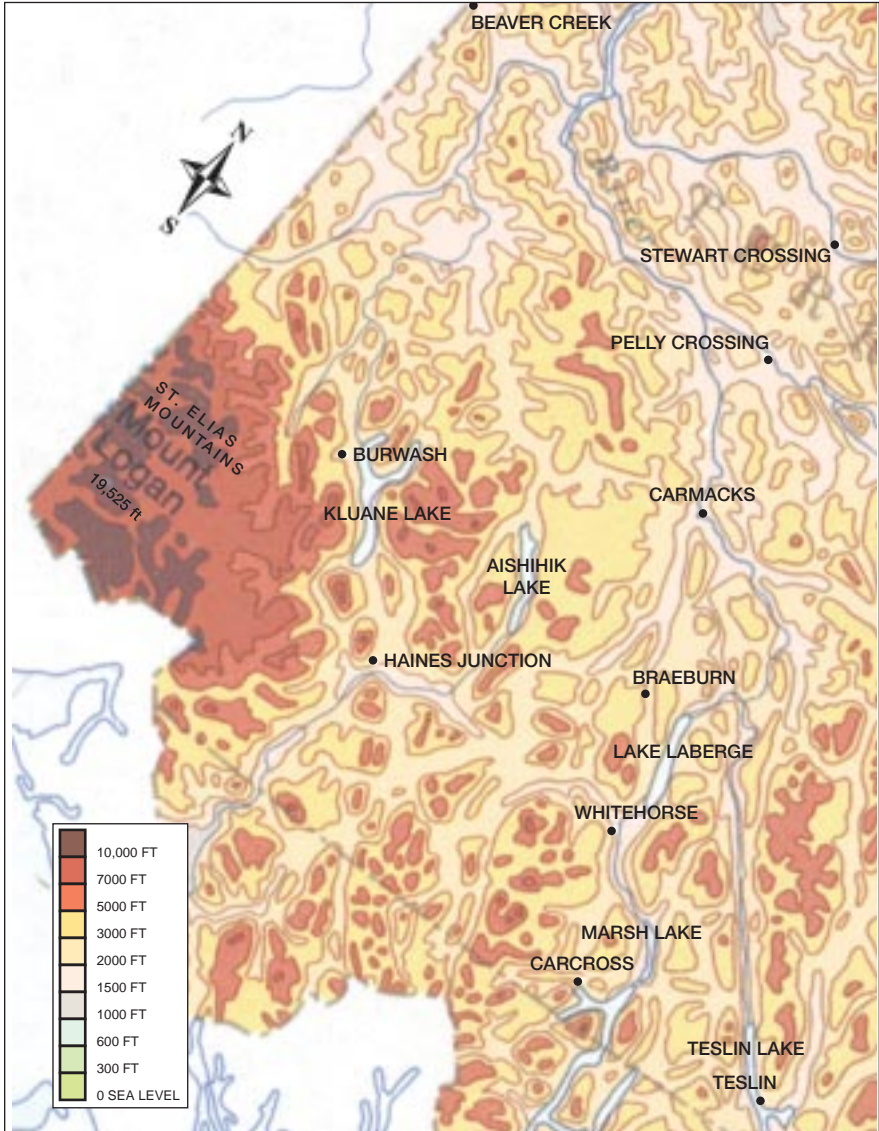
Low cloud will often linger over the higher terrain to either side of the Mayo River north of the airport, a route commonly used to reach Mayo Lake.

Carmacks - Faro

This route follows the Robert Campbell Highway through the east-to-west oriented Little Salmon River Valley. While the weather at Faro is generally indicative of what can be expected along this route, fog and low cloud will at times linger in the vicinity of Little Salmon Lake. This occurs more often in the fall when the lake is open and far less frequently after freeze up. The lake is exposed to the east and west and can become very rough with strong easterly or westerly winds. Strong southerly winds will generate a fair amount of turbulence to the lee of higher terrain from Little Salmon Lake west to Carmacks, while east to Faro the route tends to be much less turbulent.

Surface winds at Faro tend to be strongly channelled along the length of the Pelly River Valley, which is oriented northwest through southeast. While west or southwest winds may be present at or just below mountain top level, equally strong surface winds channelled out of the northwest or southeast may be present within the valley. This results in occasional significant shear turbulence that has been noted by pilots on approach into the Faro airport.

Southwest Yukon including the St. Elias and Coast Mountains



Map 4-6 - Southwest Yukon including the St. Elias and Coast Mountains

Southwest Yukon forms a vast area encompassing the towering St. Elias Mountains and the upper section of the Yukon River Basin.

The St. Elias Mountains block is a major orographic barrier between the Pacific Ocean and the Yukon interior. The climate of these mountains represents a transition from wet coastal maritime along the windward western slopes to the dry continental

interior east of these jagged peaks. Extensive networks of glaciers nestle in depressions throughout the mountains' cold, high elevations and, due to the storminess of the Gulf of Alaska, this is one of the windiest locations in Yukon. While the sheer majestic beauty of this range can be magnificent, the weather here is unforgiving and pilots are wise to view it with extreme caution.

The Upper Yukon Basin, a relatively high elevation plateau lined with deep river valleys, lies between the St. Elias Mountains and the Cassiar-Pelly Mountains to the east. It is one of the windiest areas in Yukon, short of the St. Elias Mountains and the Yukon's northern coast. Due to the rain shadow effect of the mountains, the climate is continental, showing significant temperature variation throughout the seasons and annual precipitation of only 200 to 300 millimetres per year.

a) Summer

Throughout the spring and summer, Pacific storms arriving from the Gulf of Alaska become weaker than those in the winter. The main storm track shifts across northern British Columbia and lows tend to weaken on the coast, then re-develop over the Peace River region east of the Rocky Mountains.

Southwest Yukon experiences a relatively short, dry and sunny spring, usually lasting from mid April through mid May. The driest areas are in the vicinity of Carcross and Kluane Lake.

At this northern latitude, hours of daylight increase rapidly and with that comes warmer temperatures. Summer, defined as beginning when mean daily temperatures rise above 10 degrees and ending when mean temperatures fall below zero, arrives at the lower valley elevations in mid May and is gone in September. The high elevation terrain of the St. Elias range, to the west-southwest of Haines Junction, retains winter like temperatures throughout the year. This mountain area can rapidly close in with cloud, strong winds and even heavy snowfall, at times, in mid summer.

Winds, while lighter than in the winter, are a persistent and notable feature throughout southwest Yukon. The deep river valleys oriented northwest through southeast, as is the case with Whitehorse, often see the strongest and most persistent winds. Winds, interacting with the regions rugged terrain, often lead to areas of mechanical or lee turbulence.

Summer thunderstorms are common but tend to occur less often than in the central Yukon basin. They develop more frequently over the higher terrain elevations and are also most numerous between about 1500 and 1800 LST.

The combination of dryness, winds and warmer temperatures greatly reduces the occurrence of low ceilings or poor visibility in the summer. As a result, summer brings some of the region's best flying weather.

(b) Winter

With the arrival of fall and continuing into the winter, the Gulf of Alaska starts churning out a steady stream of low pressure systems. Many of these systems track across northern British Columbia and southern Yukon. At times, western slopes and passes of the coastal mountains and the St. Elias Mountains are socked in with cloud and heavy precipitation. At the same time, southwest Yukon, sheltered to the lee of these ranges, often misses much of the initial brunt of a storm. Once the low's centre breaches the interior, however, clouds and moisture wrapping around the low from the south and southeast can cause conditions across the region to deteriorate rapidly.

Southwest Yukon experiences some of its strongest winds in the winter months. Whitehorse is the most consistently windy location; however, Burwash generally records some of the highest peak wind gusts.

While less prevalent and less persistent than in the central Yukon basin or the Liard Basin to the east, fall is also southwest Yukon's season for fog. Fog will often develop within a day or two following the passage of a frontal system as winds becoming light or calm, skies clear and temperatures fall. During the fall, moisture for the formation of fog is freely available from the comparatively warm open water of lakes and rivers. After freeze up the incidents of fog fall rapidly.

The southwest experiences a shorter winter than the rest of Yukon. Temperatures can become bitterly cold but long cold spells are not as common as in the central and northern areas, being more frequently broken by intrusions of warmer Pacific air masses.

The development of cold arctic highs can bring occasional periods of fine flying weather throughout the winter. Unlike fair weather summer flying, which is often accompanied by convective turbulence, winter domes of clear, cold and dry arctic air frequently offer smooth flying. Unfortunately the cold temperatures can also bring persistent ice fog which can hamper flight operations.

(c) Local Effects

Whitehorse - Haines Junction



Map 4-7 - Whitehorse - Haines Junction

This frequently used common air route from Whitehorse to Haines Junction follows the Alaska Highway through the very wide, relatively low, east - west oriented Takhini and Dezadeash River Valleys.

This route presents few aviation weather hazards with the exception of significant turbulence developing when strong southerly winds blow across the valley. Turbulence is often most pronounced to the lee of the Dezadeash Mountains, between Champagne and Pine Lake. With good ceilings and visibility, pilots will occasionally shorten the Whitehorse - Haines Junction route somewhat by flying through the Ibx River Valley and over the higher terrain to the west of the Whitehorse Airport; however, this route is also subject to significant turbulence with strong southerly winds. On windy days, expect turbulence with approaches and departures from Haines Junction airport and Pine Lake.

Haines Junction - Burwash



Map 4-8 - Haines Junction - Burwash

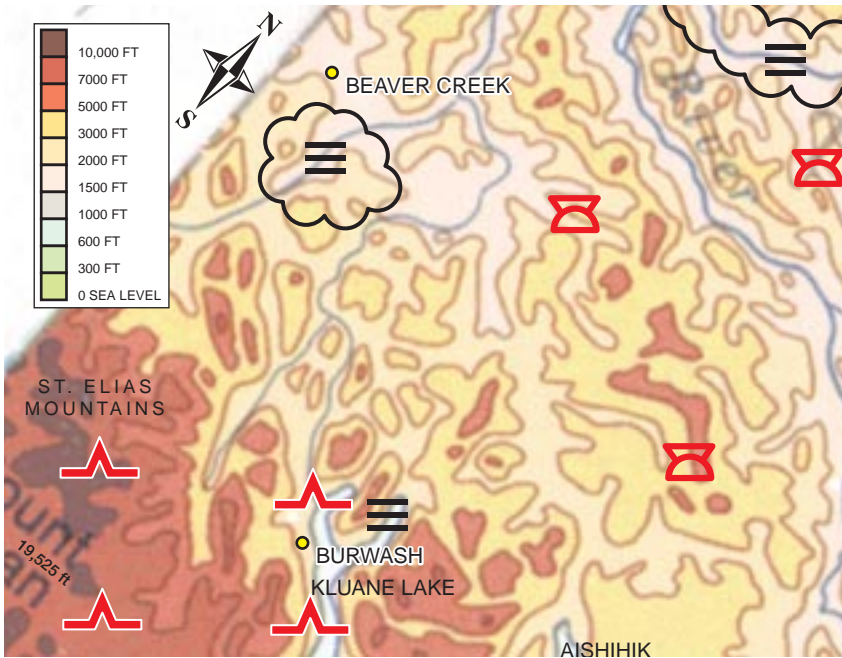
From Haines Junction through Burwash the route follows the Alaska Highway along the northwest - southeast oriented Shakwak Trench.

The worst weather along this route typically occurs over a section of rising terrain known as the Bear Summit, located about 10 n. miles northwest of Haines Junction. The summit area is notorious for low cloud and poor visibility, though there may be no indication of poor weather at either Haines Junction or Burwash.

Strong winds and turbulence are common in the vicinity of Kluane Lake and Burwash airport. Kluane Lake, is known as one of the windiest lakes in Yukon. The worst turbulence occurs along the western side of the lake to the lee of the Donjek Mountains (also referred to as the Front Ranges of the St. Elias Mountains). This area of turbulence can often be avoided by flying the centre of the lake or along the eastern shoreline.

To the southwest of this route lie the tallest mountain ranges and some of the most extensive ice fields on the continent. These ice fields feed into glacier filled valleys, which fall through tremendous elevation, melting and feeding the Donjek, Slims, Dusty and Alesk Rivers. Channelling of strong glacial winds through these valleys can generate severe turbulence. Pilots have reported winds raising clouds of glacial silt and dust to more than 8 thousand feet along the lower sections of the Slims and Dusty River areas.

Burwash - Beaver Creek - Alaskan Border

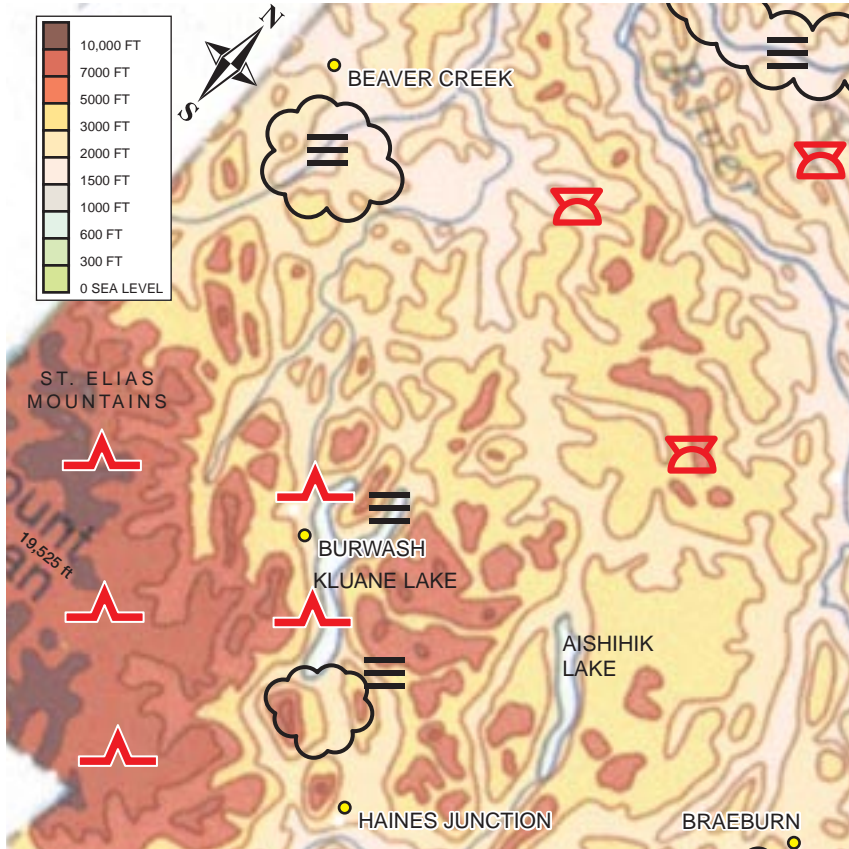


Map 4-9 - Burwash - Beaver Creek - Alaskan Border

This section of the route follows the Alaska Highway through the northern end of the Shakwak Trench.

It is one of the driest areas in Yukon, and generally presents few aviation weather hazards other than winds and turbulence. When poor weather develops across this region, it is usually associated with a moist northwest flow, and ceilings and visibility will be at their worst in the area between the Donjek River and White River. Under these conditions, low cloud and precipitation will occasionally extend beyond this area to include Burwash and, less frequently, through to Haines Junction.

Haines Junction - Beaver Creek via Aishihik - Nisling River - White River

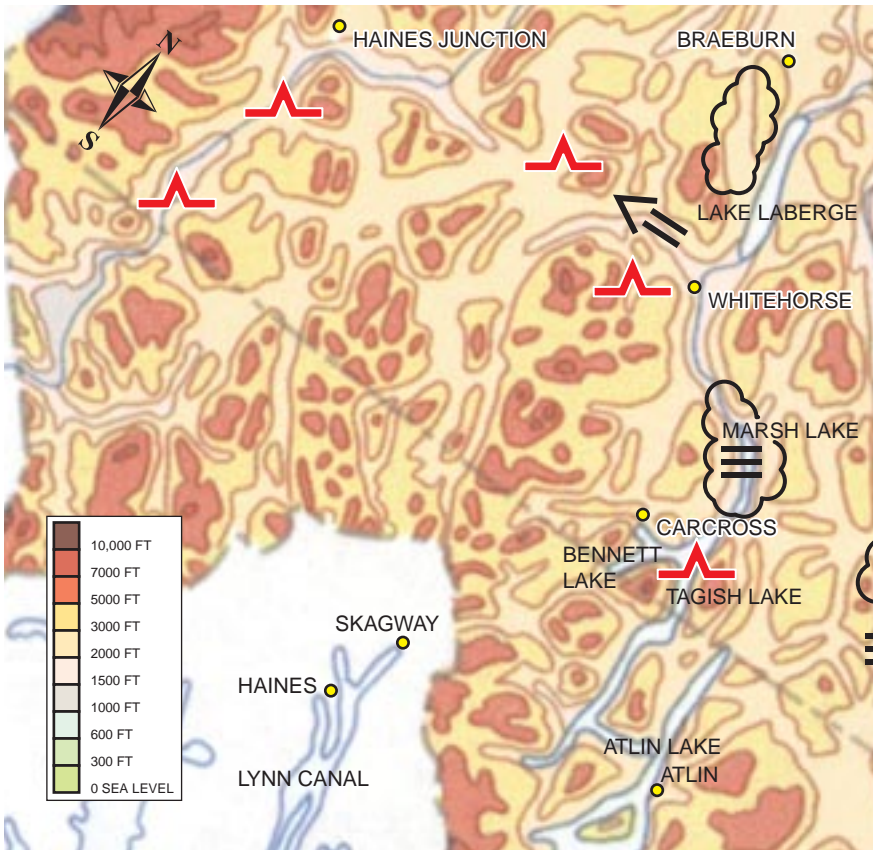


Map 4-10 - Haines Junction - Beaver Creek via Aishihik - Nisling River - White River

This route is sometimes used to avoid low ceilings and poor visibility along the Alaska Highway route over the Bear Summit. It follows the Aishihik River Valley northward from Haines Junction to Aishihik Lake. From there it goes northwestward along the Nisling River to the White River, then southwestward to Snag and Beaver Creek.

The south facing slopes of the Dawson Range, to the north of the Nisling River, are sites of frequent convective development. Thunderstorms often occur here throughout the summer, as witnessed by widespread areas burned by forest fires. Convective turbulence arising from daytime heating can give a jarring flight along this route on warm summer afternoons.

Haines Junction - Haines Alaska - Lynn Canal



Map 4-11 - Haines Junction - Haines Alaska - Lynn Canal

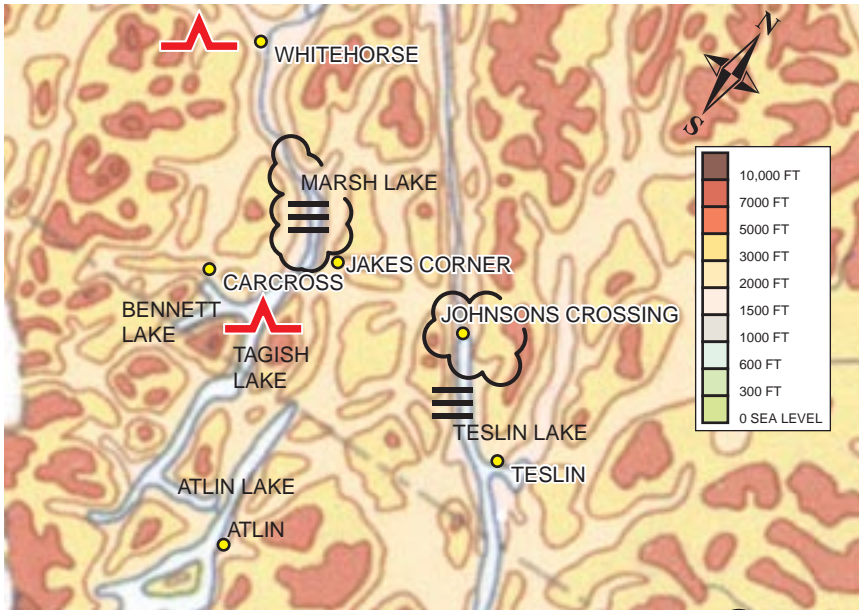
Following the Haines Road southward from Haines Junction to the U.S. border, this route continues on to Haines, Alaska at the northern end of the Lynn Canal.

A strong south or southwest flow aloft will often result in significant turbulence to the lee of the Dalton Mountain range (from just south of Haines Junction through to Klukshu, just south of Dezadeash Lake). South of Klukshu through to Mule Creek, the route is usually less turbulent.

Low ceilings and poor visibility often plague the section of the route south of Mule Creek, especially with a moist southerly upslope flow. Mule Creek through to Haines Junction will usually have much better conditions, except for turbulence. Even on relatively clear days, with good flying conditions being reported at both Haines Junction and Haines Alaska, low cloud and fog will often block the upper elevations of the Haines Road, within 10 n. miles of Pleasant Camp.

It should be noted that the Chilcat Pass along the Haines Highway, between Haines Junction, Yukon and Haines, Alaska, is subject to strong outflow winds and mechanical turbulence. This is most pronounced in winter with the pooling of extremely cold air over the Yukon interior and the approach of a vigorous low pressure centre along the Pacific Coast. The resulting winds driven by pressure gradient, katabatic and funnelling effects can reach speeds of 60 knots or more.

Whitehorse - Teslin



Map 4-12 - Whitehorse - Teslin

The commonly used air route follows Highway 1 across the northern end of Marsh Lake to Jakes Corner, then eastward through the pass to Johnsons Crossing and along the northeast side of Teslin Lake to Teslin.



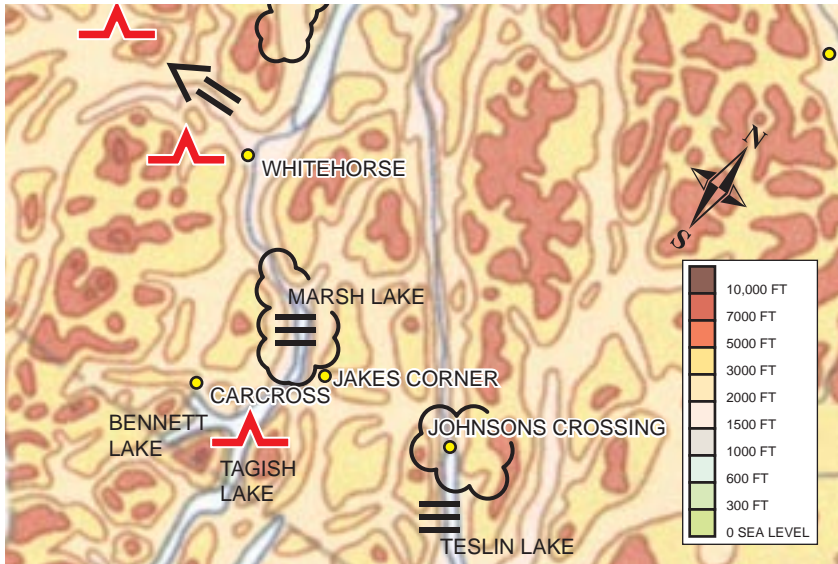
Photo 4-6 - Teslin Lake looking south

credit: Unknown

When the weather is good at Whitehorse, the broad Yukon River Valley from Whitehorse through to Jakes Corner generally presents few weather problems. Radiation fog, however, will sometimes develop and linger along the Yukon River and over Marsh Lake. This occurs more frequently in late summer and fall and will often continue to develop until winter freeze up.

Between Jakes Corner and Johnson Crossing the route narrows with rising terrain through the Summit Lake Pass. If low cloud is present at either Jakes Corner or Johnson Crossing, then the pass will often be socked in. A cross valley flow develops with strong southerly winds, resulting in significant turbulence along this section of the route. The weather at Teslin is usually fairly representative of conditions along the lake south of Johnson Crossing, however, the weather here can change quickly. Summer thunderstorms can generate sudden strong winds, deteriorating visibility in clouds and showers, and some very rough surface water conditions. In addition, fall and winter snow squalls can move rapidly down the lake reducing ceilings and visibility. Periods of cold weather following winter freeze up of the lakes generally result in good flying conditions.

Whitehorse - Carcross



Map 4-13 - Whitehorse - Carcross

This route follows the Yukon - Whitepass Railroad south-southeast from Whitehorse along the wide Yukon River Valley to Carcross.

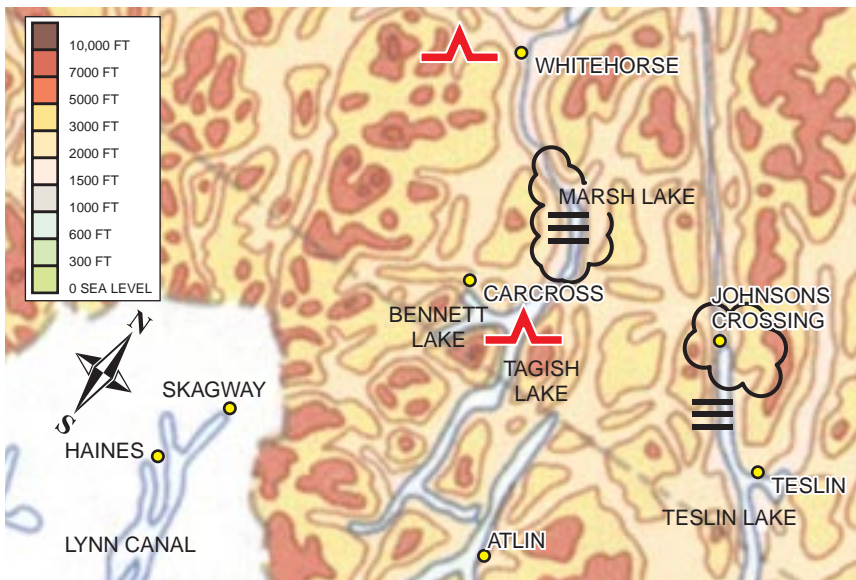
If there is good flying weather at both Whitehorse and Carcross, then conditions will generally be good along the route. Patchy morning radiation fog and low cloud are often seen over the numerous small lakes and along the rivers in the late summer and fall, but seldom persist throughout the day and are much less frequent after winter freeze up. Strong southerly and northerly winds are commonly channelled along the river valley but generally do not generate significant turbulence; however, a strong southwest flow will often result in frequent areas of turbulence to the lee of terrain along the west side of the valley.



Photo 4-7 - Carcross from Bennett Lake with Tagish Lake in background credit: Unknown

Carcross lies at the junction of two large valleys, surrounded by mountains rising 5 to 7,000 feet ASL and open to long fetches of water between Bennett and Tagish Lakes. Passage of frontal systems frequently bring shifting winds and rapidly changing weather.

Carcross - Skagway and Haines

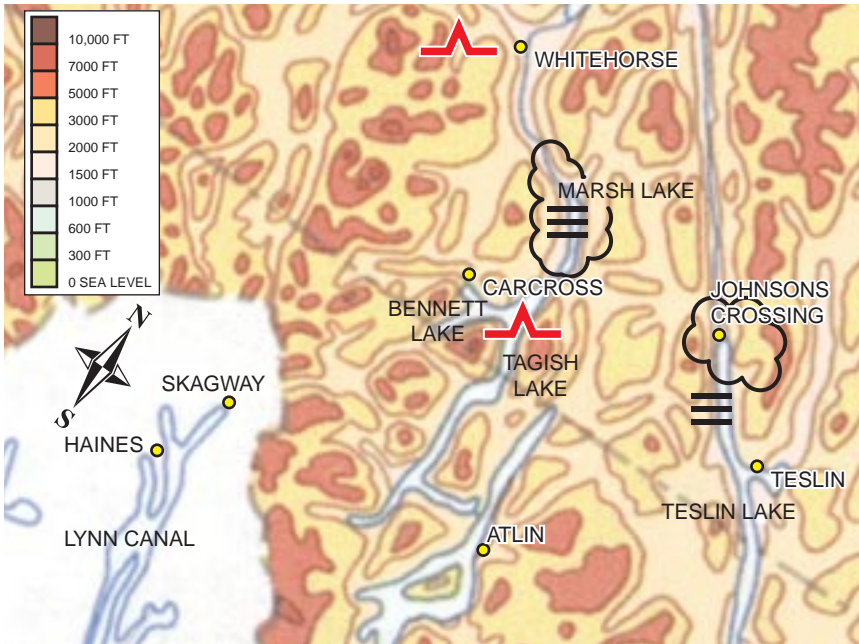


Map 4-14 - Carcross - Skagway and Haines

Poor ceilings and visibility across the mountainous upslope coastal terrain and high elevation pass between Skagway, Alaska and the British Columbia border often restrict the use of this very scenic route.

When weather permits, pilots will either follow the Yukon White Pass Railway from Carcross down the east side of Bennett Lake to Fraser, or get to the same point by following the highway along the west side of Tagish Lake and Tutshi Lake. From Fraser, the common flight route into Skagway is to follow the highway through White Pass (3,290 feet ASL). The weather across the pass, which is often blocked by low cloud, can close in quickly, while good flying conditions may continue to be reported at both Skagway and Carcross. Even when the pass is open, strong inflow or outflow winds can generate heavy turbulence and loss of altitude to the leeward side of the pass, due to subsidence.

Carcross - Atlin



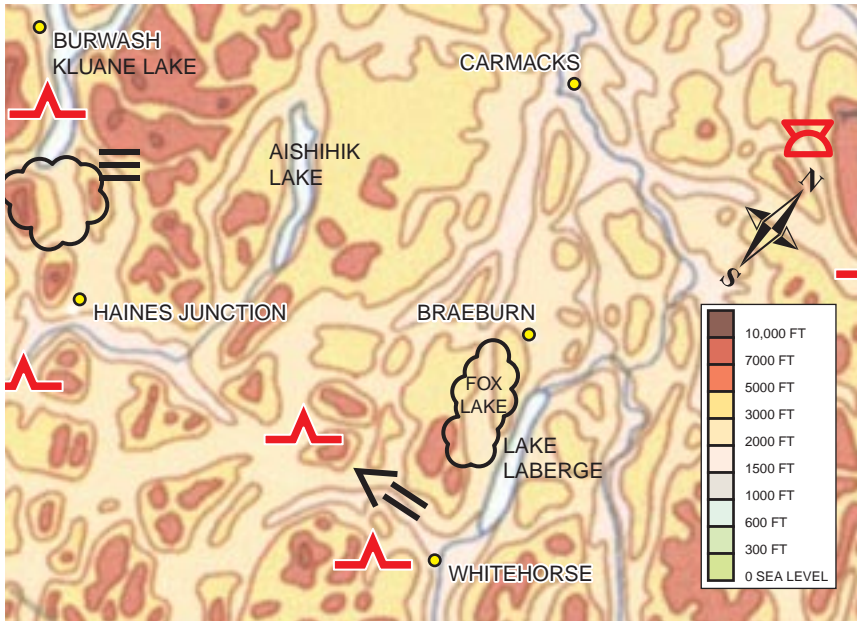
Map 4-15 - Carcross - Atlin

Pilots flying from Carcross to Atlin will usually follow Tagish Lake east to Taku Arm then south along Taku Arm to Talaha Bay. From Talaha Bay, they fly southeast across the low elevation pass near Jones Lake to Atlin Lake and follow the highway south, along Atlin Lake to Atlin.

While the weather at Carcross and Atlin will often give a good indication of general flying conditions for this route, rapidly moving systems and summer convective

storms can cause that weather to deteriorate quickly. The large lakes in this region are subject to strong winds and rough surface conditions. A strong southerly flow does not generally produce widespread turbulence, as many of the routes lie along north - south oriented lakes. However, a strong west or southwest, cross-valley flow will frequently result in areas of moderate turbulence to the lee of higher terrain, especially along the west side of Atlin Lake, near Atlin Mountain and Mt. Minto.

Whitehorse - Carmacks



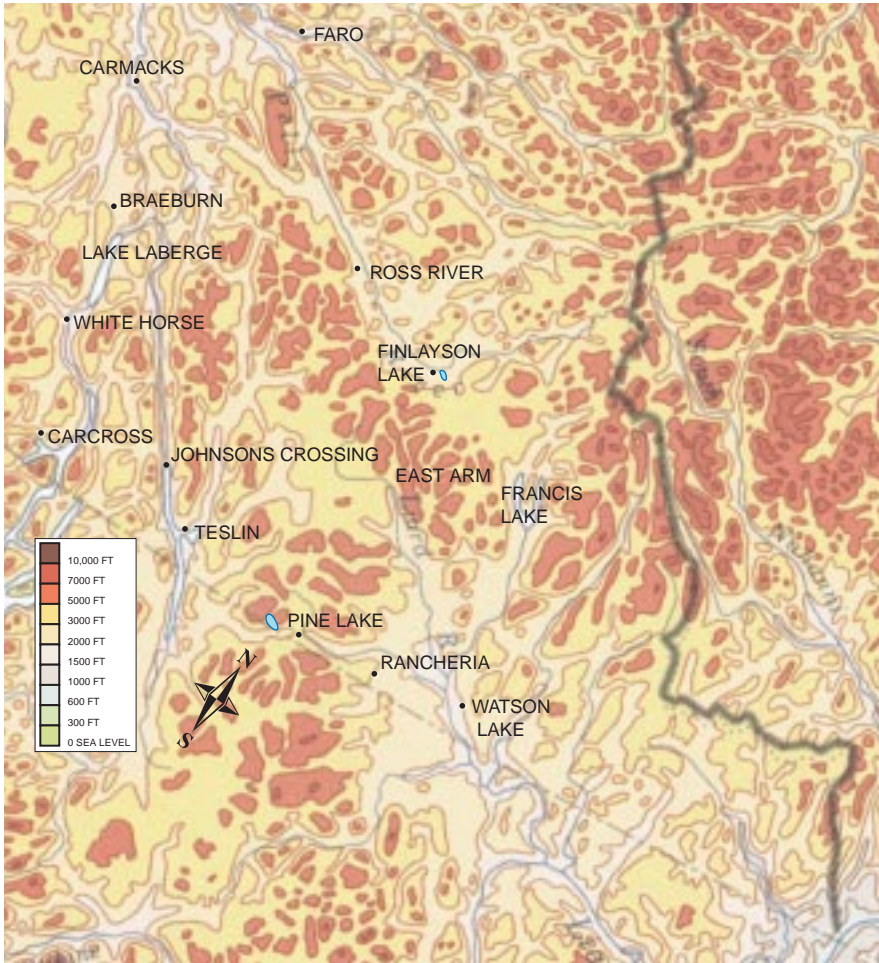
Map 4-16 - Whitehorse - Carmacks

This well used air route follows the Klondike Highway, just to the west of Lake Laberge and over Fox Lake, northwestward to Carmacks.

Strong southerly winds are common but tend to produce little significant turbulence, while southwest winds can produce significant turbulence to the lee of higher terrain, especially near Pilot Mountain and Flat Mountain (near the southern end of Lake Laberge). The weather at Whitehorse is generally representative of what can be expected along the route. Low cloud and fog, however, will sometimes develop and linger in the vicinity of Fox Lake, and moisture from Lake Laberge and the Yukon River will often generate considerable low cloud and fog throughout the late summer and fall, before freeze up.

To avoid low cloud blocking higher terrain along the Klondike Highway route in the vicinity of Fox Lake, pilots will at times follow the lower terrain along the Yukon River, northward from Lake Laberge to Carmacks.

Southeast Yukon including the Liard River Basin



Map 4-17 - The Laird River Basin

The greater part of Southeast Yukon is encompassed within the Liard River Basin, a broad low plateau covered in rolling forested hills open to the northern end of the Rocky Mountain Trench. The Liard River runs the along the length of the basin floor from northwest through southeast. While the floor of the basin ranges in elevation between 2,000 and 3,000 feet, mountains to the northeast and southwest rise to over 6,000 feet ASL. The principal airport in the region is located at Watson Lake.

a) Summer

During the summer the pacific storm track shifts across northern British Columbia. Low pressure systems, significantly weaker than their winter counterparts track eastward along the southern Yukon border, often re-developing over the Peace

River region east of the Rocky Mountains. The mild moist air masses that accompany these lows cause southeast Yukon summers to be long, warm and wet. More than half of the annual 400 to 600 millimetres of precipitation that occurs here falls as rain over the lower basin elevations during the summer.

Convective cloud often abounds throughout the summer and in association convective turbulence is common. Thunderstorm numbers peak in July but rarely occurring outside of May through September. Watson Lake reports an average of 11 days with thunderstorms per year, nearly double the average for most low elevation Yukon sites.

Surface winds tend to be light to moderate and are largely channelled by terrain. The prevailing direction is nearly evenly divided along the length of the basin, either from the northwest or southeast. Because of this, terrain induced mechanical turbulence tends to be very localized.

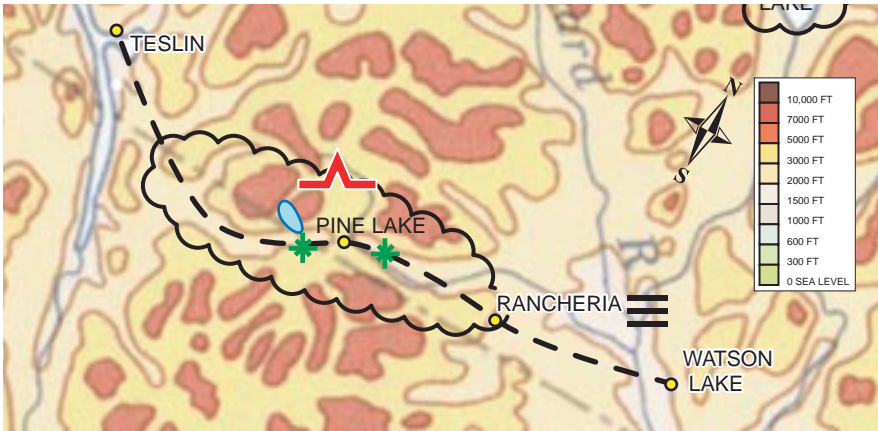
(b) Winter

With the onset of fall, the combined effect of falling temperatures, the regions propensity toward light or calm winds, and readily available moisture from the open water of lakes and rivers gives rise to frequent and often persistent areas of fog and low stratus. Watson Lake for example is one of the Yukon interiors foggiest airports. Only after freeze up do the incidents of fog fall rapidly.

Throughout the winter, the Gulf of Alaska begins churning out a steady stream of more vigorous low pressure systems. While the main winter storm track shifts south of the southern border, many of these systems track across northern British Columbia wrapping cloud and snowfall into southeast Yukon.

Over the lower elevations, a little under half of the annual precipitation falls as snow. During the winter months snow takes over from fog as the primary cause of low ceilings and poor visibility restricting aircraft operations.

Cold arctic highs can bring prolonged periods excellent flying conditions with clear skies and cold temperatures. However, strong shallow temperature inversions are common within the Liard River Basin. They can trap low level moisture in the cold still air beneath the inversion producing persistent areas of low stratus.

(c) Local Effects**Watson Lake - Teslin**

Map 4-18 - Watson Lake - Teslin

The air route between Teslin and Watson Lake follows the Alaska Highway along the British Columbia - Yukon border, crossing some relatively high terrain that is well known for its propensity for generating poor flying conditions. The pass elevations between Rancheria and Swift River are more than one thousand feet greater than that at Watson Lake or Teslin and considerably higher mountains lies on either of this corridor. Good flying weather may be reported at both airports while low cloud will often close the section around the pass. This same area is also prone to heavy snow, even in late summer or early autumn. As with many deeper lakes, low convective-type cloud can be a problem over Teslin and Watson Lakes in the autumn until freeze up. As with most Yukon flying, turbulence is often at its worst to the lee of higher mountain terrain, especially in the case of strong cross valley winds.



Photo 4-8 - Watson Lake on approach looking east.

credit: Unknown

Watson Lake - Faro



Map 4-19 - Watson Lake - Faro

This air route follows the Robert Campbell Highway along the lower elevation of Frances River Valley northward from Watson Lake to Frances Lake then turns north-westward toward Finlayson Lake where terrain gently rises to an elevation of just over 3,300 feet ASL. From Finlayson Lake the route continues northwestward falling in elevation along the Pelly River Valley to Faro.

The weather at Watson Lake and Faro is a fair indicator of weather along the route however there are a few areas more prone to problems with low cloud poor visibility and turbulence. Low cloud and fog will occasionally block the higher terrain in the vicinity of Finlayson Lake and conditions are generally at their worst with a moist southeast upslope flow.

This route follows the Robert Campbell highway and the Tintina Trench. The Tintina Trench is a narrow rain shadow area in the predominately southwesterly flow. In winter the Arctic front often lies near Faro in this flow. Faro is in the warm sector occasionally and on average warmer than Ross River and receives more precipitation. During summer cloud ceilings remain at 10,000-12,000 feet, but as a upper-level disturbances pass by they lower to 4,000-5,000 feet for a few hours of rain or showers.

Along moisture sources along the route watch for low cloud or fog to develop especially in late summer and autumn until freeze up occurs.

Turbulence, while generally not a problem, can be significant in the area of Ross River especially under a strong southwest flow. Turbulence will often be worst to the lee of the mountains along the southwest side of the valley and can be avoided by flying the northeast side of the valley in the vicinity of the Ross River airport.

*** Watson Lake - Rocky Mountain Trench - Fort Ware**

From Watson Lake southward, the terrain gradually rises and there is a higher frequency of low cloud. Pilots must exercise caution so as not to mistake the Gataga River Valley, for the Trench. Similarly, in flying north the Kechika River is often mistaken as the route to Watson Lake. The terrain continues to rise in elevation south to Sifton Pass, which is reputedly the worst spot along the Trench with frequent turbulence and cloud, often to the treetops.

*** Watson Lake - Fort Nelson**

This route follows the Alaska Highway southeastward, paralleling the Liard River. Weather along the route often bears little resemblance to that at surrounding weather stations however, if low cloud is present at Fort Nelson or at Watson Lake, the route is almost certainly closed.

The worst weather in terms of flow ceilings and poor visibility is typically encountered south of the Yukon border between Summit Lake and the pass west of Toad River. Fog is a common problem at Watson Lake especially in the fall and like Fort Nelson, which also lies in a hollow it is subject to more frequent and persistent periods of fog than the surrounding area.

** Weather for these routes is detailed in the book "The Weather of British Columbia Graphic Area Forecast 31"*

Weather of Northwest Territories and Western Nunavut

Weather by season

(a) Winter

For winter, the mean controlling pattern aloft is an upper ridge to the west over Alaska and Yukon, with northwest flow over the western arctic. At the surface, the mean pattern is a high pressure system that extends from the Northern Yukon through the Mackenzie Mountains and southeast into the Prairies. At this time, all water bodies are frozen over, although the pack ice over the Arctic ocean remains in constant motion, producing open leads in the shear zone where the pack borders motionless ice fastened to the land (fast ice).

Under these conditions, cold and generally dry air masses persist. Little significant cloud occurs due to the low moisture availability, and the cloud that forms is often very diffuse in nature. Ice crystal haze often occurs, particularly downstream of moisture sources and can produce marginal flying conditions. In very cold conditions, ice fog produced by human activities (fuel combustion, primarily) can be a problem in settlements and at airports, producing low ceilings and visibility which can be quite persistent under light winds.

Another weather concern that accompanies the “mean” condition occurs when low pressure systems to the east of the region - surface and aloft - strengthen or approach. This leads to strengthening northerly winds, blowing snow and possible blizzard conditions, mainly over areas to the east and north of the tree line. Here the surface wind speed and direction are strongly dependent on local topography, producing significant differences in winds and visibilities between sites.

At times, the predominant upper level ridge breaks down, or weakens, allowing a west or southwest flow from the Gulf of Alaska to spread east into southern portions of the area. This mild air overruns the cold surface layer, spreading cloud into the South Mackenzie. The mild air also lowers surface pressures which forces the “resident” high pressure centre northeast. A strengthening east to southeast pressure pattern develops although surface wind speeds are often not strong due to the stable cold air. In such cases, stronger winds may be present near the surface, and low level wind shear may be present. North and east of the treeline, winds are often stronger and blowing snow may be a problem.

Snowfall is often light, initially due to subsidence east of the mountains, but becomes more significant as low pressure centres develop in the Mackenzie Valley and move east.

Another variation of the mean pattern occurs when milder air takes a long route to the north of the upper ridge around northern Alaska, and then eastwards into the northwestern Mackenzie. At the surface, a narrow low pressure trough develops from northern Alaska to the Yukon coast, and into the lower Mackenzie valley. Eventually, a surface low pressure centre may form in this trough off the Yukon coast and move eastwards.

Due to the long trajectory from its source, this mild air is usually much drier than that taking a direct route from the Gulf of Alaska. Variable cloud amounts are present and precipitation is generally light. The major effect in this case is the often strong southerly and southeasterly flow generated to the east of the developing trough. In the Mackenzie Delta, surface winds are often not strong, but low level wind shear may be present. Further to the east, strong winds become more likely, particularly along the arctic coast from Franklin Bay to west of Kugluktuk, and over portions of Banks and Victoria Islands. Poor visibilities in blowing snow occur if snow cover is sufficient, and turbulence may be severe.

If a surface low forms and moves off southeastward, a strong rebuilding of the surface high from the Arctic Ocean into the Mackenzie can occur. This would bring a shift to strong northwest winds and blowing snow.

(b) Spring

Spring, the transition season, is marked by more frequent, prolonged and extensive intrusions of mild Pacific air. Strong air mass contrasts occur with concurrent strong low pressure systems.

With warmer air masses involved, snowfall amounts can be significant with lower ceilings and visibilities present. Freezing precipitation is a possibility. Ice begins to break up, over larger rivers mainly, with lakes retaining ice until late spring. Break up of sea ice usually does not begin until very late spring into early summer, but surface melting begins. Water bodies become a source of cool and moist air.

Strong north-south contrasts appear, with thunderstorms possible across the southern Yukon and southwestern NWT while, at the same time, a blizzard could be striking the Nunavut sections of the GFACN35 domain.

(c) Summer

For summer, the upper flow is much weaker than it was during winter and spring and is west-northwest on average. The mean surface pattern is also very weak with a flat low pressure area between Great Bear and Great Slave Lakes.

There is often a broad upper ridge from BC into Yukon with weak surface low over the Mackenzie Valley. Air masses are often convectively unstable over Mackenzie sections with some CB activity present most days July to mid August. These thundershowers commonly develop over higher terrain, particularly the eastern slopes of the Mackenzie Mountains and over the Horn Plateau and the Cameron Hills. Under weak upper level flows, convective cloud tends to remain stationary and subside in the evening as solar heating weakens. With strong westerly/southwesterly flows aloft, thundershowers may drift east or northeast before subsiding. Much of the Mackenzie Valley lies well to the west of its nominal mountain time zone, so maximum solar

heating occurs relatively late in the day, which means convection begins later in the afternoon than one might otherwise expect and tends to die out later in the evening.

When a dynamic feature, generally an upper trough embedded in the general flow, is moving through and aiding in generating vertical ascent along with cooler air aloft to maintain instability, thundershowers will often persist through the night into the following day and will move along with the feature. While most storms are inhibited by the cool surface of large lakes or the ocean, those with dynamic support can persist and even reform over these large lakes/the ocean. Major thunderstorm outbreaks occur when an upper ridge system breaks down as a strong trough moves through.

While severe thunderstorms with hail or tornadoes are rare north of 60, due largely to less moisture in the air than further south, they can occur. Such events usually occur after several days of southerly flows has spread moist air into the Mackenzie, then a trough aloft moves in and triggers convection.

The other main feature of summer weather relates to the melting of sea ice and the abundant low level moisture source of the tundra. Low stratus cloud and fog become ever-present over the ocean during the summer and frequently drift over coastal sites with onshore winds. Where winds are strong enough, and terrain is flat such as the Mackenzie Delta, this low cloud can spread well inland, particularly overnight when solar heating weakens even under the midnight sun. Low cloud and fog are also very common over the higher terrain north and east of Great Bear and Great Slave Lakes. This cloud is often very persistent over the height of land as flows from most directions have an upslope component.

(d) Fall

Fall is the period where a transition back to winter with strengthening westerly flow aloft occurs. The September mean surface pattern shows very weak flows, likely a result of migratory systems. October shows a weak high beginning to develop over the Mackenzie Mountains and a weak low pressure area over Amundsen Gulf, a thermal effect due to an open water heat source under increasingly cold air masses.

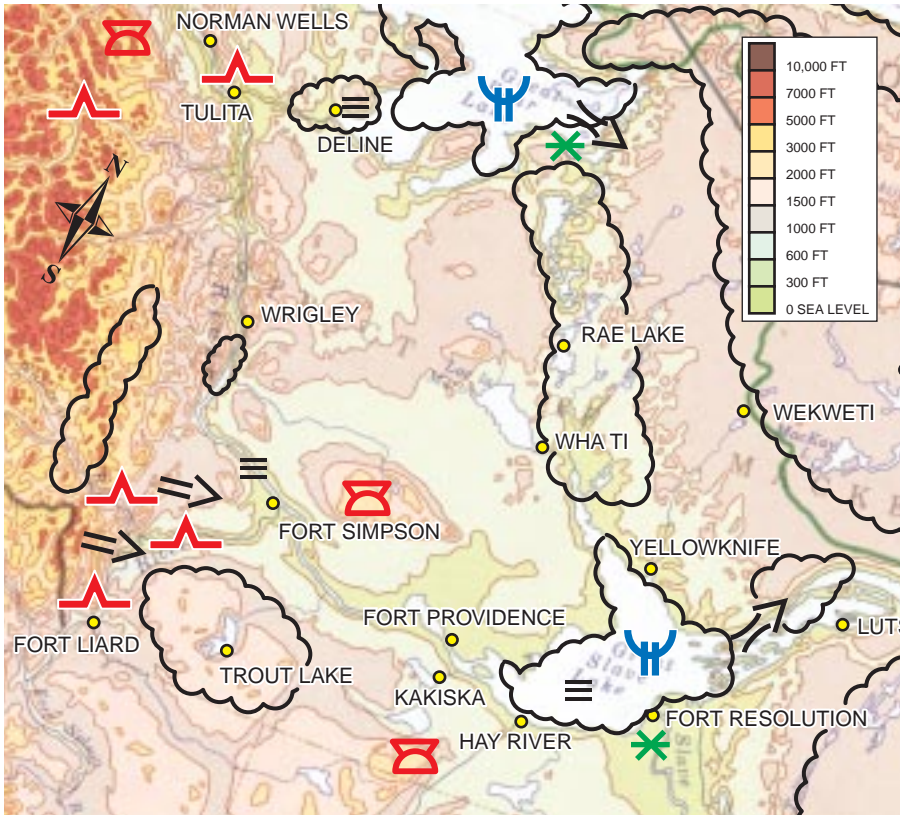
The fall tends to be a stormy season with maximum air mass contrasts. There are strong storms that develop over the Beaufort Sea with minimum ice cover and a feed of cold air giving strong low level instability. Over sea and in onshore flows, cloud bases tend to be higher - stratocumulus ceilings rather than stratus ceilings, and there is considerably less fog and, hence, visibility is generally much better than during summer, with snow showers being the main reduction to visibility until freeze-up.

Similarly, over and to lee of large inland lakes cold air crossing open water generates low cloud which can extend far downstream. For example, such cloud can extend from Great Bear to the north shore of Great Slave at times. Convective cloud embedded can produce heavy snow showers with poor ceilings and visibilities along with significant icing in cloud.

Earlier in the fall, lower cloud becomes more persistent due to less solar heating and areas of stratus and fog develop overnight and linger.

Weather by area

Fort Simpson, Wrigley, Jean Marie River, Fort Liard, Trout Lake



Map 4-20 - Fort Simpson, Wrigley, Jean Marie River, Fort Liard, Trout Lake

Disturbances from the Gulf of Alaska

Disturbances moving east or northeast from the Gulf of Alaska can appear lost on weather maps as they cross the Yukon. When the upper disturbance that is supporting the system nears the Mackenzie Valley, it can once again work on the system and fuel thickening cloud and generate precipitation. The upper disturbance also routinely leads to cyclogenesis (development of a low centre). The weather at Watson Lake, Yukon, and then the weather at Fort Liard can be indicators of weather headed Fort Simpson way.

The thickening of the cloud and onset of precipitation can be dramatic and can occur in less than an hour. Cloud ceilings that are altocumulus can quickly become

stratocumulus and locally stratus ceilings with reduced visibility in precipitation - rain in summer and snow in winter.

Thinning of cloud starts once the upper disturbance has passed. At the same time, the new surface low moves away (generally toward the east) and northwesterly winds envelope the Mackenzie Valley, while northeasterly winds envelope the Liard Valley. Clearing can be slower from Wrigley north than in the Simpson, Liard and Nahanni areas, as northwesterly winds are upslope winds for the Wrigley area. The surge of cold air southward along the Mackenzie can be dramatic resulting in locally strong, gusty northwest surface winds giving low level mechanical turbulence.

Winter warmth but strong gusty winds and low level turbulence and maybe freezing rain

In winter, a southwesterly flow aloft can bring very warm air to the area that settles onto the surface. In December 1999, for example, a Chinook took Fort Simpson's temperature from minus teens on the 22nd to plus 14°C on the 23rd. Plus temperatures then lingered into the 24th. Christmas Day temperatures were as low as minus 18°C and by the last day of the month/year were as low as minus 39°C. The warmth is often accompanied by strong, gusty surface winds. "Chinook" winds up to 100 knots are cited for Little Doctor Lake (61°53'N 123°16'W). Freezing precipitation is possible with these intrusions of warm air. However, the southwesterly flows aloft associated with the systems are usually dry which precludes precipitation. Chinooks are relatively common in the Fort Liard area.

Turbulence

Deadmen Valley - There can be significant low level turbulence along the Deadmen Valley (61° 19'N 124°35'W).

Liard Range - Within 10 to 15 miles east of the Liard Range, there can be low level mechanical turbulence when the flow aloft is westerly or southwesterly. There can also be some lee wave turbulence.

Nahanni Butte - Swan Point, located on the Liard River about 10 miles downstream of Nahanni Butte, is an area where one can experience severe mechanical turbulence.

Fort Liard - There can be mechanical turbulence below 500 feet AGL in the Fort Liard area.

Wrigley - Ridges to the northeast through east to southeast of Wrigley are prone to low level mechanical turbulence with northwest winds.

Low cloud and fog

Morning fog at Virginia Falls and Rabbit Kettle Lake - From mid August until freeze-up, fog often develops overnight and lingers until mid day.

Stratus in the Nahanni - During the fall, the Nahanni River Valley is often filled with cloud. During the winter, skies are generally clear over the Nahanni River Valley, but the valley can, on occasion, fill in with stratus and stratocumulus.

Fort Simpson to Trout Lake - The terrain rises as one flies from Fort Simpson to Trout Lake. Cloud height above ground often correspondingly decreases. For example, when flying from Fort Simpson to Trout Lake, cloud heights of 1,500 feet ASL at Fort Simpson can lower into the trees 40 n. miles south of Fort Simpson.

Along the Mackenzie - The spring break-up period, like the fall freeze-up period, can bring periods of low cloud and fog. The difference is that the increased sunlight through the break-up period makes the low cloud slower to develop and quicker to burn off. Pilots cite an area on the Mackenzie River between about 25 and 35 miles south of Wrigley as being vulnerable to low cloud and fog during break-up and freeze-up.

Prevailing winds versus runway orientation

At Trout Lake, southwest winds prevail but the runway orientation is the same as that of Fort Simpson (13/31) where northwest and southeast winds prevail.

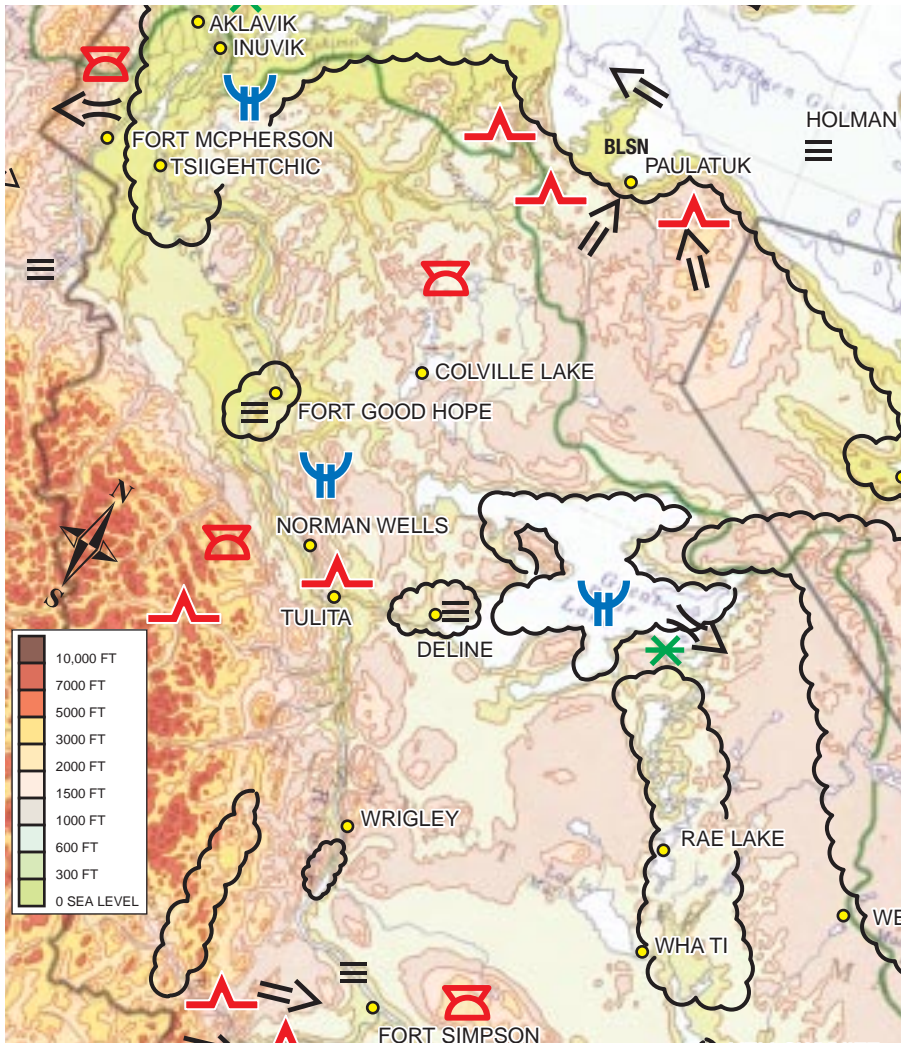
Thundershowers

Thundershowers can be found anywhere in the area. The thundershower season is generally from the end of May to about mid August.

Horn Plateau and Cameron Hills - In addition to convective cloud caused by daytime heating, orographic lift on the Horn Plateau and the Cameron Hills helps produce towering cumulus and cumulonimbus.

Nahanni Valley - During the summer, when a system is approaching from the west or southwest, a wall of cloud with embedded showers and thundershowers will often develop. This wall will develop by midday along about 125°W longitude and stretch from about 61°N to about 63°N.

Norman Wells, Tulita, Deline, Fort Good Hope, Colville Lake



Map 4-21 - Norman Wells, Tulita, Deline, Fort Good Hope, Colville Lake

Favoured areas for low cloud and/or fog

Scented Grass Hills - When flying from Norman Wells to Great Bear Lake the Scented Grass Hills area is a favored location for low cloud.

Mackenzie River and Great Bear Lake - Along the Mackenzie River and over Great Bear Lake, the spring break-up period, like the fall freeze-up period, can bring periods of low cloud and fog. The difference is that the increased periods of sunlight through the break-up period makes the low cloud slower to develop and quicker to

burn off. However, in spring, a southerly flow of warm moist air over the ice-covered Great Bear Lake is a recipe for fog. In fall, there can be significant icing in this cloud.

Southwest of Fort Good Hope - Pilots cite an area from about 7 miles southwest of Fort Good Hope to about 5 miles north of Fort Good Hope as an area where low cloud and fog sits. The pilots note that the cloud and fog is reluctant to move into the airport.

Mouth of Great Bear River/Mackenzie River about 60 miles northwest of Norman Wells open through the winter - The Great Bear River, at its mouth out of Great Bear Lake, and the Mackenzie River, about 60 miles northwest of Norman Wells (river at about 65° 40'N), are both prone to staying open through the winter. Thus, they are both a source of low level moisture and, hence, ice fog through the winter.

Brckett Lake and Lac Belot - Brckett Lake (65°13'N 125° 20'W) is slow to freeze over and is a potential source of low cloud and/or fog after other lakes in the area have frozen over. Lac Belot (66° 53'N 126° 16'W) routinely stays open about one month longer than Colville Lake and is a potential source for low cloud and/or fog for the community of Colville Lake.

Fall snow showers/streamers

Off Great Bear Lake - Prior to freeze-up, in the fall, a northwesterly flow across Great Bear Lake, which is still unfrozen, can result in snow showers streaming off the lake, in some cases reaching inland to communities such as Rae Lake and Wha Ti. Tops of the cloud producing the steamers/the snow can be deceptively low.

Icing/ Windshield obstruction during fall into winter

Once or twice a year (fall into winter), there is significant icing both in and below cloud. The icing can coat not only surfaces affecting aircraft lift but also the aircraft windshield thereby affecting visibility from the cockpit. The cloud itself need not be thick. Stratus bases and stratocumulus tops as low as 3,000 to 4,000 feet have been associated with such events. Virga-like protrusions below the cloud have been observed giving icing and lowered visibility conditions while flying through them. Temperatures as low as -35° Celsius have been reported while encountering this icing.

Turbulence

Bear Rock - Bear Rock, about 33 miles southeast of Norman Wells or about 5 miles north of Tulita, is a favored location with northwesterly winds for moderate to severe mechanical turbulence below 2,000 feet AGL. Along the Canol Road and pipeline route, low level mechanical turbulence was cited for the area about 64°20'N 128° 15'W. Within about 5 to 10 miles northwest of Norman Wells, a strong north-

westerly flow above 500 feet can on occasion be a much lighter flow at the surface. This results in a noticeable low level wind shear.

Rotor Cloud on mountains west of Norman Wells - With a southwesterly flow aloft and the parallel alignment of the mountains / valleys, rotor clouds have been observed on the mountains to the west of Norman Wells. The rotors are reported to be, on occasion, worse near the crest of the mountains.

Winds

Great Bear Lake - During summer, due to the combination of the pressure gradient and an induced lake breeze, the orientation of the terrain can result in some tricky wind scenarios, where light winds and strong winds exist short distances apart. Both Cameron Bay (66°04'N 117°52'W) and Port Radium area are vulnerable to winds that vary both in speed and direction across very short distances. An added element in this area is terrain which leaps to heights of 1,000 feet above lake level.

Thundershowers

Thundershowers can be found anywhere in the area. The thundershower season is generally June to about mid August. There are some favoured areas for thundershower development. In the Norman Wells area, thundershowers favor the west side of the river and tend to stay on these mountains, or at least on the west side of the Mackenzie River.

Inuvik, Aklavik, Fort McPherson, Tsiightchic, Tuktoyaktuk, Paulatuk, Sachs Harbour and Holman



Map 4-22 - Inuvik, Aklavik, Fort McPherson, Tsiightchic, Tuktoyaktuk, Paulatuk, Sachs Harbour and Holman

Low cloud and fog through the open water season

In light wind regimes, there is routinely extensive low cloud and areas of fog across the open water areas of Mackenzie Bay, the Beaufort Sea, and Amundsen Gulf and the waterway to Cambridge Bay and beyond. The low cloud and fog routinely push inland with onshore flows.

“Burst of Beaufort” inland across Delta

In a recurring scenario, a low pressure system evolves over the Delta or in Mackenzie Bay and then moves off eastward. Ahead of the developing system, easterly to southeasterly winds move warm, dry air offshore from the mainland giving clear skies to the marine area. However, in the wake of the low, the wind comes around to northwesterly causing a cold front to evolve in the lowest levels, behind which the air temperatures falls to meet the dewpoint. A “burst of Beaufort” pushes

inland (the term “burst of Beaufort” was coined by forecasters to describe the low cloud, fog, and falling temperatures that came with the northwest winds in the wake of low passage across the Delta, Mackenzie Bay or southern Beaufort). The low cloud and fog move rapidly southward and can immediately blanket the coastal areas. The flat terrain of the Delta and the Mackenzie River Basin pose no barrier. Aklavik is routinely first to experience the low cloud and fog followed by Inuvik town and shortly afterward Inuvik airport. Tsiigehtic and Tuktoyaktuk are next. The low cloud and fog often move close to - but do not always make it to - Fort McPherson. Rather, depending on the nature of the northwesterly flow, the low cloud and fog may proceed along the Mackenzie Valley.

The time of day and season play a significant role in the arrival of the low cloud and fog, and how long it lingers. Along with the wind regime, they also play a role in how far south the low cloud and or fog can push. The time between the shift to northwesterly winds and the arrival of low cloud and fog is shortened when the northwesterlies arrive overnight, and lengthened when the northwesterlies arrive in the late afternoon or early evening. The low cloud and fog will also linger longer late August and early September than it will in July or early August. It takes easterly to southeasterly winds to flush the low cloud and fog.

Snow streamers and visibility during fall

In September and October, prior to freeze-up, the air in the northwesterly flow off the ice and passing over the waters of Mackenzie Bay and Amundsen Gulf is much colder than the water. The heat and moisture feed result in snow streamers. In early September, the precipitation can be rain on the coast (Tuktoyaktuk) which changes to snow further inland (Inuvik). Visibility in the snow streamers when they hit the coast and push inland can be very low.

Strong surface and/or low level winds

Blow River, Shingle Point and into Mackenzie Bay - Winds at Shingle Point manifest the strong low level southwest winds that frequent the Blow River when weather systems are approaching from the southwest. The strong southwest winds extend out a few miles out into Mackenzie Bay and can be of gale (34 knot) strength. These strong southwest winds are a local effect and the wind regime elsewhere across Mackenzie Bay fit the pressure pattern. Such winds can occur anytime during the year.

North Yukon Coast, across the Delta to about 25 miles east of Inuvik - Routinely, when a low pressure system is departing and a ridge is building from the northwest into northern Yukon, a band of strong northwest winds develops along the north Yukon Coast and sweeps southeast into the Delta.

On occasion, in addition to the strong surface winds, a band of strong northwest winds can develop between about 150 and 500 feet AGL across northern coastal

Yukon and shoot across the Delta to end about 25 miles east of Inuvik. The winds on the upper air sounding that is done at Inuvik may not catch this band of strong winds.

Passes west of Fort McPherson - Just as weather systems approaching from the southwest can trigger strong southwest winds along the Blow River and out into Mackenzie Bay, they can, during winter, trigger strong easterly winds across the mountain passes to the west of Fort McPherson. At the automatic weather station located at Rock River, Yukon (66° 59'N 136° 12'W; elevation 2,362 feet ASL), easterly wind of 50 gusting 60 knots is common during these events.

Winds, turbulence, and blowing snow

Arctic Coast from Horton River to Paulatuk to east of Clinton Point - With moderate to strong generally southerly to southeasterly flow, the winds along the Arctic coast, from the mouth of the Horton River to Paulatuk to Clinton Point (69° 13'N 118° 38'W), are “variable” and locally strong or very strong. The phenomena is a year-round event and occurs when an upper warm front moves north of the coast, resulting in lowering of the inversion. During the winter, locally strong winds give blowing snow and low level turbulence which can be severe. The Paulatuk community/airport reside in this zone of “variable winds”. A localized wind system develops over the Melville Hills (69°15'N 122°00'W) beneath a winter inversion. Associated pressure jumps cause abrupt and sometimes-violent changes in surface wind characteristics and severe turbulence in the lowest levels of the troposphere. The ‘core’ of the strong winds is close to Langton Bay and the strong winds can, but do not always, reach Paulatuk. Triggers for these “local” winds that the forecasters look for are pressure falls north of Paulatuk and warm air aloft/warming aloft over Paulatuk. During the events, winds can jump to values in the 40’s gusting to the 50’s with PIREPs reflecting moderate to severe turbulence in the low levels and severe wind shear below 1,000 feet AGL. When there is snow on the ground, visibility in these events is routinely near zero.

Blowing snow

Mackenzie Delta - The combination of no trees and strong winds makes the coastal area of the Delta and the frozen channels of the Mackenzie Delta vulnerable to reduced visibility in blowing snow, during both strong easterly and strong north-westerly wind events.

Thundershowers

Although not as common, thundershowers can occur anywhere on the mainland, June and July into August. Thundershowers like to form on the mountains to the west of the Delta and drift east. Thundershowers are rare offshore but have been reported. Thundershowers occur on Banks and Victoria Islands but very infrequently.

Smoke all year

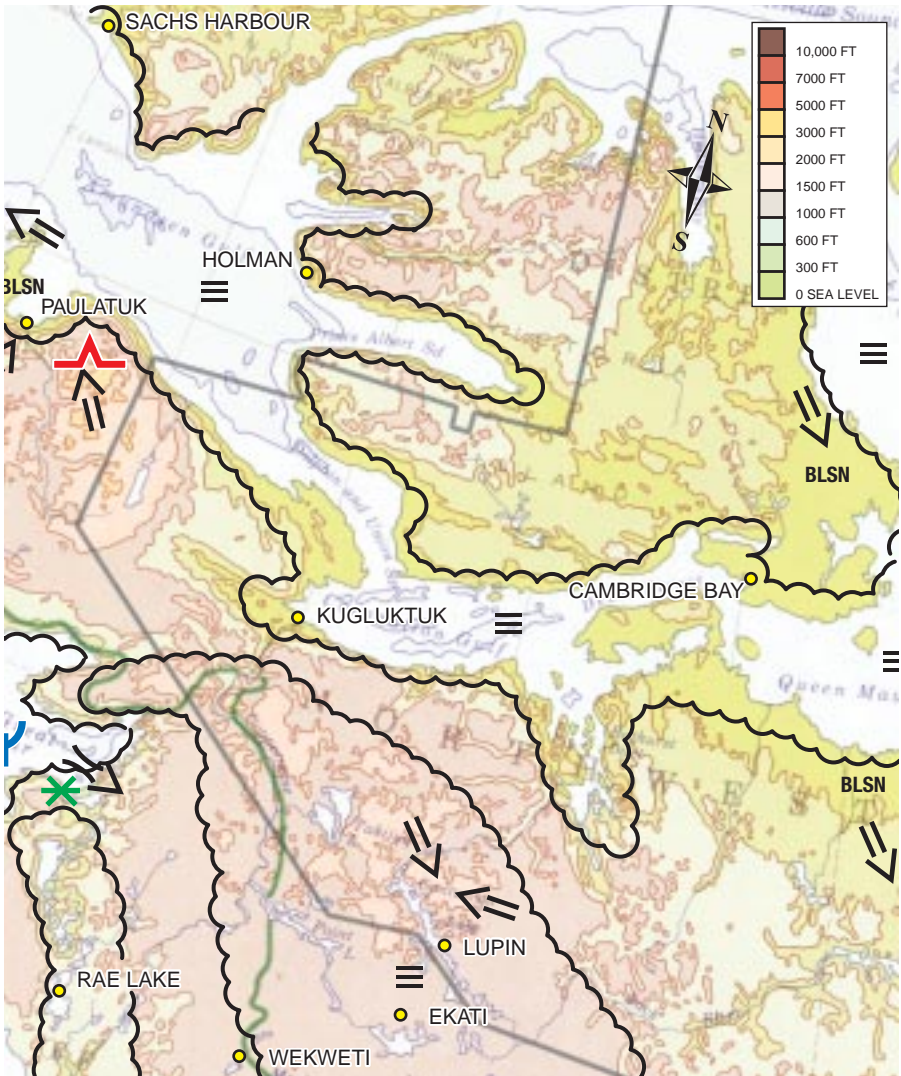
Located on the west coast of Franklin Bay, the Smoking Hills contain extensive deposits of magnesium, sulphur and low-grade coal. When exposed to oxygen, the Smoking Hills appear to spontaneously combust. Fanned by winds, they smoulder constantly.



Photo 4-9 -Smoking Hills

credit: Government of the Northwest
Territories web site

Kugluktuk and Cambridge Bay



Map 4-23 - Kugluktuk and Cambridge Bay

Low Cloud and/or fog

If one ignores blowing snow, winter is the season of limited cloud across this area. Spring brings low cloud and ice fog to areas adjacent to the sea. During the summer, in light wind regimes, low cloud and fog from open water sea areas often penetrate only a few miles inland. In the Cambridge Bay area, for example, pilots cite the low cloud penetrating 2 to 3 miles inland before breaking up, due to the land and water inland being several degrees warmer than the source area over the sea. Later in

the summer, when the snow and ice are largely melted from the land but areas of sea ice are still present, fog and low cloud are generally limited to areas where sea ice persists. Inland, summer tundra ponds are a moisture source for low cloud and fog during the cooler overnight and early morning hours. Pilots in the area state that fog can occur with strong winds and cite instances of fog with 30 knots.

The land across eastern Victoria Island and sections of the mainland to the southeast of Cambridge Bay has little geographic relief. During the summer and fall, northwesterly flows can bring low cloud across these areas. At Kugluktuk, northeast winds during the summer and fall can bring stratus inland. In summer, such northeast winds can be a sea breeze.

Aircraft Icing

Weather systems in this area - usually during the spring or fall - can, once or twice a year, have icing up to 7 to 9 thousand feet ASL. During the fall, low cloud can give icing. Snow grains are common in the area, an indication of icing aloft. During the typical early summer, when melted snow feeds moisture into the air and also during late fall, when large bodies of open water feed moisture and heat into cold unstable airmass, convective clouds based at a few hundred feet and only a few thousand feet thick are responsible for most of the snow pellet showers.

Blowing snow and strong winds

The northeastern section of this area including Cambridge Bay is part of the northwest to southeast corridor that routinely experiences strong winds and blizzard conditions from after freeze-up until the spring melt period. On occasion, low pressure systems moving east from the Mackenzie will bring both a fresh snowfall and strong easterly winds and generate blizzard conditions.

At Cambridge Bay, there are on average 11 events a year where the visibility is reported as one half mile or less, for a period of 6 hours or more. Kugluktuk experiences 4 to 5 such events a year, usually associated with strong northwesterly winds. In contrast, Baker Lake is the blizzard capital of Canada and posts on average 21 events a year.

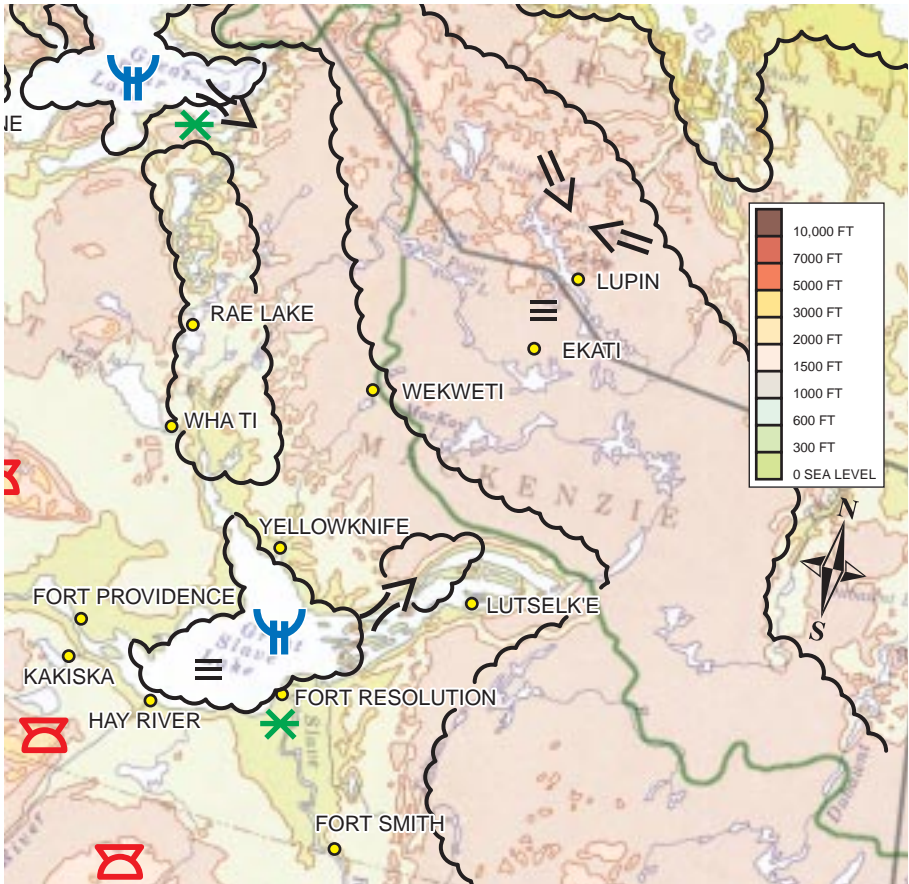
Spring storms

Common in spring, low pressure systems moving rapidly east or northeast from the Mackenzie can give a dangerous mix of weather through a short period of time. A sunny spring day can quickly evolve into a blizzard. With the arrival of cloud from the approaching low comes wet snow or rain. With passage of the low, cold northwest winds, falling snow and blowing snow take over.

Thundershowers

Thundershowers are rare north of the mainland but they do occur. There is a little more thundershower activity on the mainland. Thundershower season is generally from July to early August but can linger into early September. Albeit extremely rare, thundershowers have been observed as early as April at Cambridge Bay.

Yellowknife, Hay River, Fort Resolution, Fort Smith, Lutselk'e, Fort Providence, Kakiska, Wha Ti, Rae Lakes, Lupin, Ekati



Map 4-24 - Yellowknife, Hay River, Fort Resolution, Fort Smith, Lutselk'e, Fort Providence, Kakiska, Wha Ti, Rae Lakes, Lupin, Ekati

Low cloud

Late summer and through the fall around open lakes - Until freeze-up is complete, open water areas - and Great Slave Lake is a big one - are a heat and moisture source. Over the water, low cloud dominates. Cloud ceilings generally lower as the cloud comes onshore and as the terrain below the cloud rises. A look at the map

shows the terrain to the northeast of Yellowknife rising. A stratus ceiling around the lake readily becomes cloud to the deck northeast of Yellowknife, while stratocumulus over the lake becomes stratus east and northeast of Yellowknife.

Corridor of stratus between Great Slave and Great Bear - During spring and fall, a corridor of stratus and fog develops overnight and lingers between Great Slave Lake and Great Bear Lake. The lingering is longer in the fall than it is during the spring. However, in the spring when the low level flow is southerly, the stratus and fog can be as reluctant to lift as it is during the fall. Freezing drizzle below the cloud and icing in cloud is a concern. Cloud ceilings in this cloud are routinely lower than the cloud ceiling at Yellowknife. For example, if Yellowknife has a ceiling of 500 feet, then the ceiling 20 miles north of Yellowknife can be 100 feet.

McLeod Bay northeast - McLeod Bay, northeast of Great Slave Lake, is slow to freeze over and is a potential source of low cloud and/or fog after other parts of the lake have frozen over.

Fall snow showers/streamers

Off Great Slave Lake - Prior to freeze-up, in the fall, a northwesterly flow across an open Great Slave Lake can result in snow showers /steamers flowing off the lake across the south shore of the lake and inland. These streamers can on occasion reach inland to Fort Smith. Tops of the cloud producing the snow can be deceptively low.

Low cloud, poor visibility, wind, blowing snow

The higher terrain northeast of Yellowknife is treeless and vulnerable to strong easterly winds, as weather systems approach the Mackenzie, and to strong northwesterly winds once the system has moved to the east. The combination of a building ridge along the Mackenzie and the presence of a deep low over Nunavut will also produce strong winds. The Ekati and Lupin areas are blizzard prone during the winter.

The Ekati and Lupin sites are also particularly vulnerable to low ceilings and visibility conditions in the fall. Pilots advise that the runway at Ekati sits in a bit of a bowl which can trap low cloud and fog at Ekati, while surrounding weather is favorable.

Icing

The cloud over Great Slave Lake during both break-up and freeze-up period gives icing. The icing typically occurs in cloud between 2,500 and 5,500 feet ASL.

Winter ice fog

When temperatures plunge to about -35°C and lower, ice fog develops over the city and can drift, or develop, over the airport reducing visibility.

Winds

During summer, the combination of the pressure gradient, an induced lake breeze and the orientation of the terrain can result in some tricky wind scenarios where light winds and strong winds exist short distances apart. The northeast arm of Great Slave Lake has locations where this mix comes together. Taltheilei Narrows is one such location cited by pilots.

Thundershowers

Thundershowers can occur anywhere in the area April into September. The “prime” period for thundershowers is June to about mid August.

Caribou Mountains / Cameron Hills - In addition to convective cloud caused by daytime heating, orographic lift on the Caribou Mountains (south of Hay River in northern Alberta) and the Cameron Hills, that extend northeast from Alberta, helps produce towering cumulus and cumulonimbus clouds in the Hay River area.

Horn Plateau - The Horn Plateau is a favorite area for daytime heating and orographic lift to join to generate thundershowers.

East to northeast of Yellowknife - Thundershowers favor an area between 70 and 100 miles east of Yellowknife. Cloud bases of thundershowers often lower as they move east from the Yellowknife area.

Chapter 5

Airport Climatology for the Yukon

Dawson

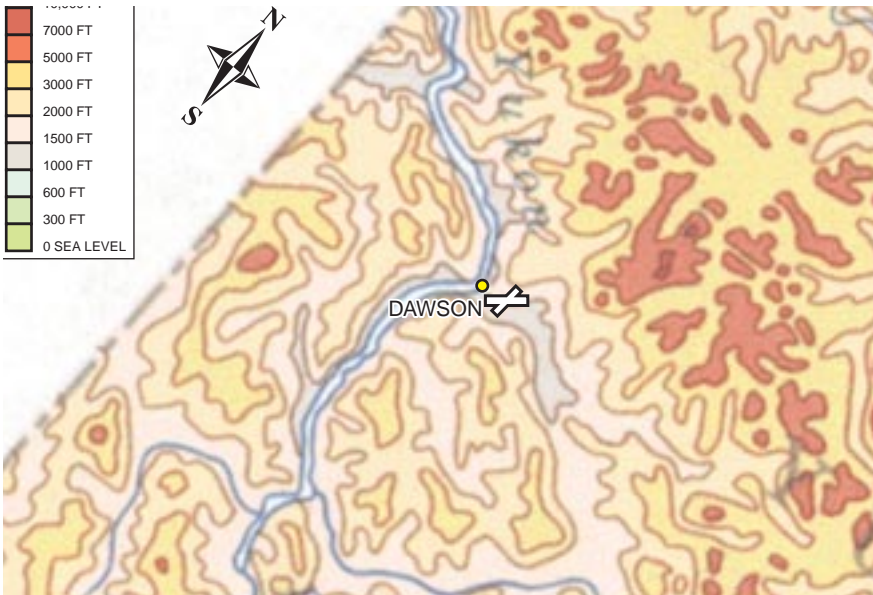
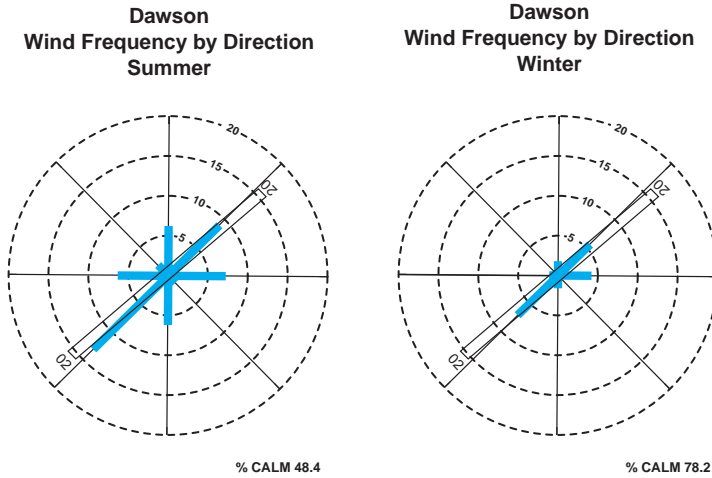


Photo 5-1 - Dawson Airport looking southwest

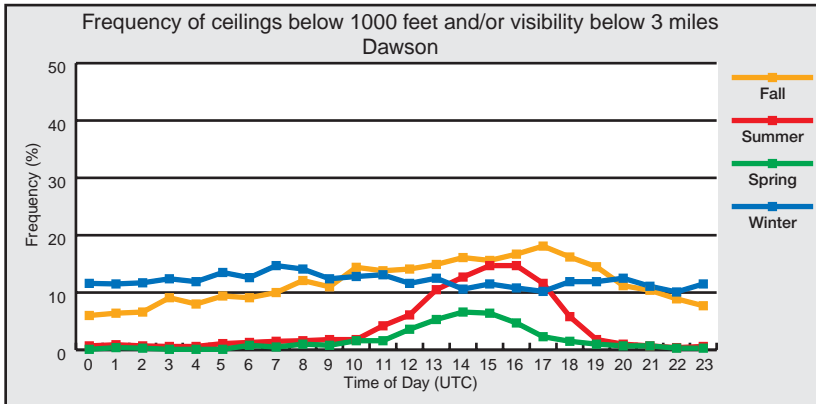
Dawson Airport is located in west-central Yukon on the relatively flat floor of the Klondike River Valley, about 8 n. miles east of its confluence with the Yukon River and the City centre. Lying just to the south of the Klondike River and highway, the airport is surrounded by flat areas of grass, scrub trees and sand-gravel marshes. Mountain peaks and ridges with elevations of over 6,000 feet ASL extend along the

north side of the valley at a distance of about 20 miles. A line of hills parallels the runway approximately one mile to the southwest, then rises fairly abruptly to heights of over 600 feet. Pilots have commented on the fact that, when approaching from the south or southeast at low elevation, the runway is not clearly visible at any significant distance due to this line of hills. In addition, high terrain encroaches takeoff and landing paths approximately two nautical miles from either end of the runway.



The airport rarely has strong winds and, in fact, calm winds prevail about 54 percent of the time during the summer months and over 78 percent of the time in winter. Channelled by the river valleys and surrounding mountains, winds out of the west through southwest and east through northeast are dominant both in summer and winter. North and northwest winds, as well as those out of the south and southeast, are usually much lighter and only develop about 4 percent of the time. Due to terrain effects, a strong southeast flow above the ridgeline will sometimes result in light surface winds converging on the airport from both ends of the runway. It has been noted that, at these times, there can be significant directional shear and often turbulence reported within a thousand feet of the runway surface. In contrast, the prevailing winds flowing along the length of the valley, from west-southwest and east-northeast, tend to be less turbulent.

In general, good flying weather can be expected from late winter through spring and early summer. During the winter, scattered cloud cover appears about 40 percent of the time and about 30 percent of the time in summer. While scattered cloud continues to appear about 30 percent of the time in the fall and 40 percent of the time in the winter, Dawson has one of the highest occurrences of low ceiling and poor visibility throughout the late summer, fall and early winter. Fog is the single greatest contributing factor, averaging 20 days per year, making Dawson the foggiest airport south of Komakuk Beach and Shingle Point, on Yukon's northern coast.



Fog begins to develop more frequently in late July and its occurrence increases to a peak by late August, due to the contribution of light winds, falling temperatures and moisture from the comparatively warm open waters of the Klondike and Yukon Rivers. Throughout the late summer and early fall, fog will generally form in the early morning hours and, with daytime heating, gradually erode away by mid day. This diurnal effect is depicted by the mid-morning (1800 UTC) summer peak in low ceiling and visibility that appears in the graph. As the hours of daytime heating shorten throughout the fall, fog becomes more persistent and the diurnal peak in low ceiling and visibility flattens out. After freeze up, the primary source of moisture needed to produce fog is gone and its occurrence drops dramatically. Low cloud and snow, which starts and stops independently of time of day, gradually displaces fog as the primary cause of ceiling and visibility restrictions on aircraft operations at Dawson, during the winter.

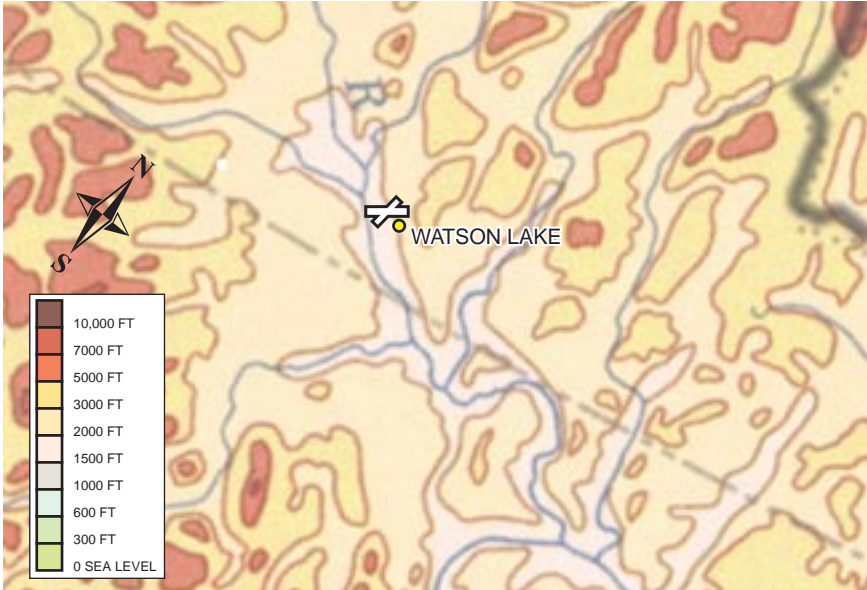
Flurries can arrive at Dawson as early as late August or as late as June, but the bulk of the snowfall occurs between September and January. Snowfall accounts for almost 40 percent of the areas average annual 183 millimetres of precipitation. Late summer snowfalls are often associated with the early arrival of arctic fronts, while the heaviest snowfalls producing the lowest ceilings and worst visibility are associated with the passage of Pacific frontal systems. At times, these disturbances will bring ceiling height and visibility to near zero. Poor flying weather is seldom persistent, however, and will often improve in the wake of fronts or within 24 hours of the passage of a low.

Incidences of blowing snow at Dawson are relatively small and, as such, aircraft operations are rarely affected. Over a 24-year period, from 1953 through 1976, blowing snow was reported a total of 313 times, making the rate of occurrence about 0.15 percent.

Severe cold temperatures can have adverse effects on aircraft operation and maintenance. With intrusions of arctic air in December, January and February, Dawson's temperatures can plunge to less than minus 40°C and remain bitterly cold for days or

even weeks at a time. While less common and generally less persistent, temperatures in this range will at times occur as late as March and as early as November.

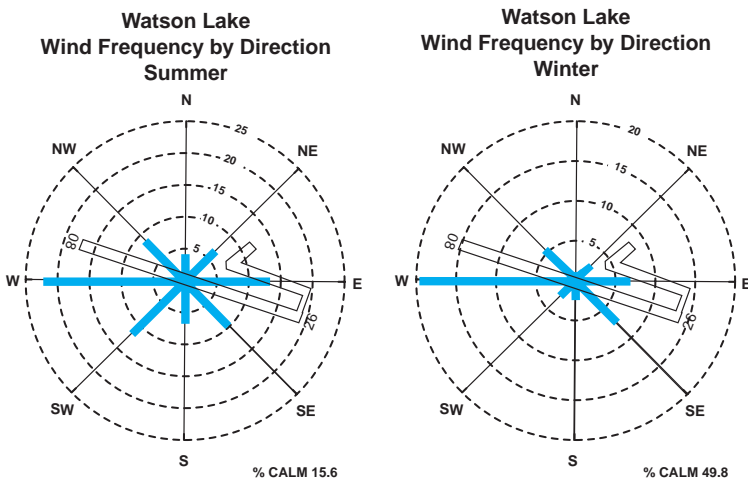
Watson Lake



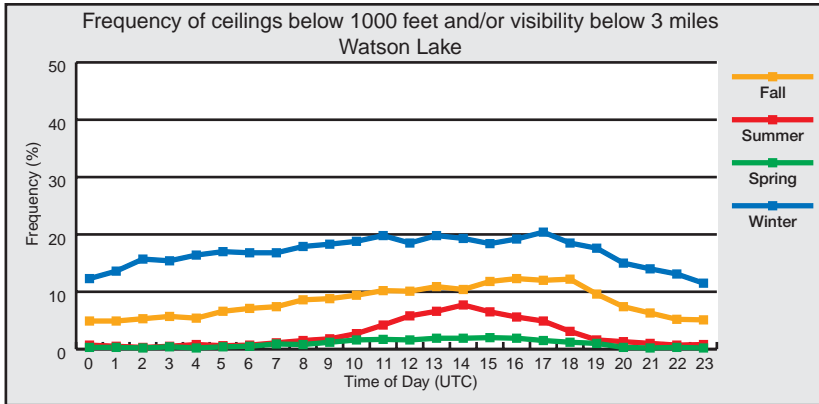
Watson Lake Airport is located within the broad Liard River Basin, at the northern end of the Rocky Mountain Trench in southeast Yukon. Built 5 n. miles northwest of the town centre on an area of flat land 30 feet above and protruding from the northern shore of Watson Lake, the airport is surrounded by water to the south, southeast and northwest. To the northeast, terrain consists of low, rolling, forested hills. A ridge runs northward from a point about 5 miles east of the airport, reaching elevations of between 3,000 and 4,000 feet ASL. The Liard River, 4 miles to the southwest of the airport, flows the length of the basin and is joined by the Frances River, 17 miles to the northwest and the Dease River at Liard Post, 17 miles to the southeast.



Photo 5-2 - Watson Lake Airport looking northeast



Prevailing winds, channelled across the broad Liard River Basin by surrounding mountains, tend to flow out of the west and northwest, but are only slightly more dominant over those that arise out of the east and southeast. Winds from the south and southwest, as well as from the north and northeast, occur about half as frequently. Because of the relatively open and even terrain and broad channelling effects of the Liard Basin, winds over Watson Lake tend to increase at a fairly uniform rate, with height and strong turbulence or directional shears rare. It should also be noted that calm wind prevail 27 percent of the time in the summer and over 49 percent of the time throughout the winter.



Watson Lake generally sees its best flying weather during the spring and early summer. Throughout this period, cloud cover is reported as scattered about 30 percent of the time and ceilings and restrictions to visibility seldom affect aircraft operations for significant periods of time. During the fall and early winter, however, the formation and persistence of fog and low stratus increases dramatically. Averaging over 300 occurrences per year, Watson Lake is second only to Dawson as one of the most fog prone airports in the Yukon.

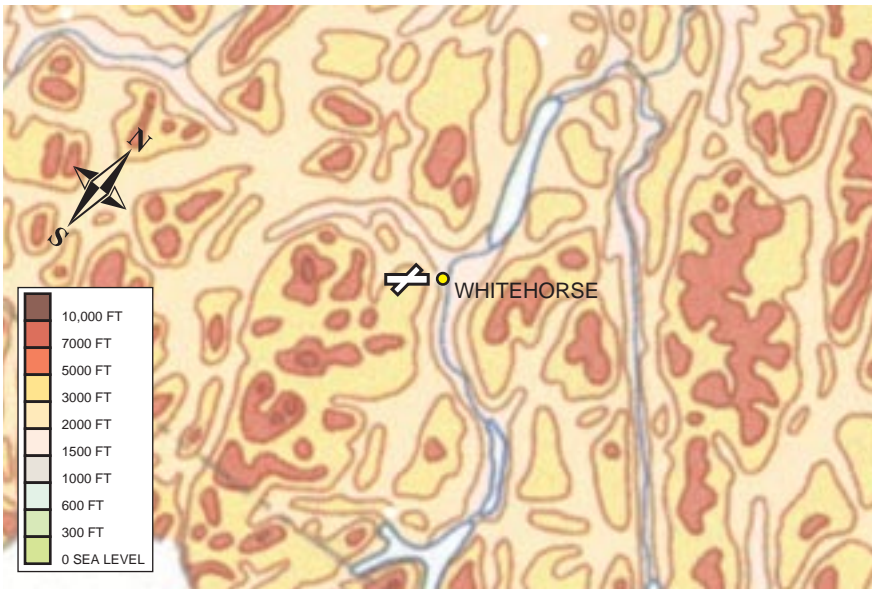
Throughout the late summer and early fall, incidences of fog begin to rise, often forming in the early morning hours and dissipating within several hours after sunrise. This diurnal pattern is depicted by the mid-morning (1800 UTC) summer peak in low ceiling and visibility that appears in the graph above. As the hours of daytime heating shorten throughout the fall, fog becomes more persistent and the diurnal peak in low ceiling and visibility flattens out. The relatively warm open water of Watson Lake and the Liard River provides a tremendous source of moisture for fog formation. Once these water bodies freeze over, much of the moisture needed to produce fog is withdrawn, and the occurrence of fog dense enough to restrict aircraft operations drops dramatically. Under very cold and calm conditions, ice fog will sometimes develop from moisture arising out of aircraft exhaust but settles out fairly quickly after engines are shut down or the aircraft departs. Throughout the winter, low cloud and snow, which starts and stops independently of time of day, displaces fog as the primary cause of low ceilings and restricted visibility.

While Watson Lake may see flurries as early as late August or as late as June, the bulk of the snowfall occurs between October and March. The Liard Basin is one of the wettest areas in the southern Yukon, and snowfall accounts for almost 44 percent of the average annual 425 millimetres of precipitation. Late summer snowfalls usually accompany the early arrival of arctic fronts. The heaviest snowfalls are associated with the passage of Pacific frontal systems and generally occur in November, December and January. They produce some of the lowest ceilings and worst visibility,

which at times can fall to near zero. Despite this, poor flying weather is seldom persistent. It will often improve dramatically across the basin area following the passage of cold fronts, and the poor flying weather, seldom lasts more than 24 to 36 hours with the passage of lows.

Blowing snow, despite Watson Lake's open exposure, occurs infrequently and seldom restricts aircraft operations for any extended period of time. In the thirty year period of record from 1953 through 1982, there were 209 reports of blowing snow, amounting to less than one percent of the airport's operational hours.

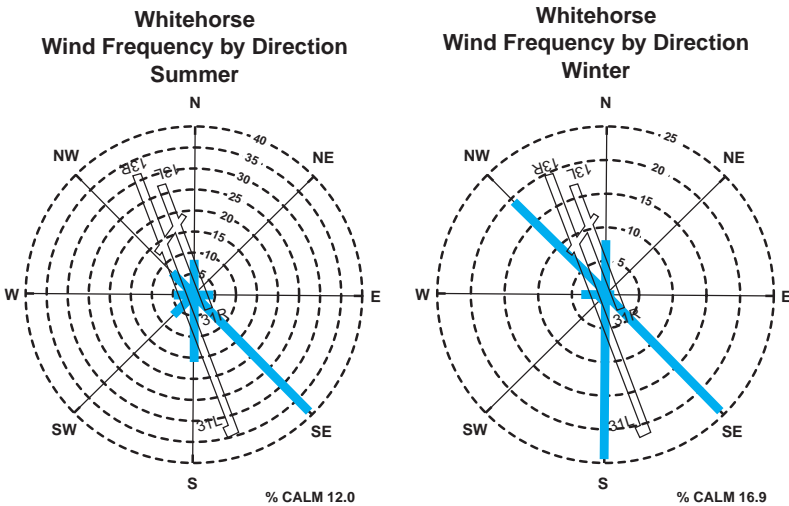
Whitehorse



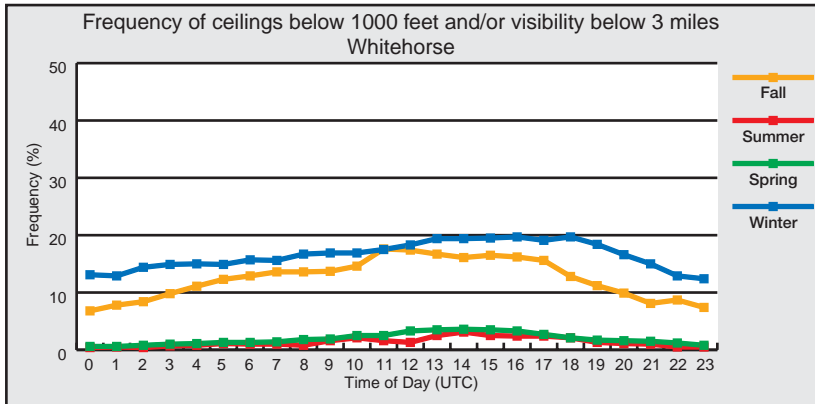
Whitehorse airport is located just to the west of the city on a level plateau approximately 225 feet above and parallel to the Yukon River. The Yukon River Valley, itself, is oriented along a north - south axis with large lakes and low, densely treed hills extending along its broad relatively flat floor. Lake Laberge lies 20 n. miles to the north and Marsh Lake 20 miles to the southeast. Mountain ranges rise on either side of the valley, reaching heights of over 6,000 feet ASL at 15 nautical miles to the southwest, 7 miles to the east, and 30 miles to the northwest of the airport.



Photo 5-3 - Whitehorse Airport looking south



Channelled by surrounding mountains, winds out of the south to southeast are dominant in direction and strength both summer and winter. North or northwest winds show a small increase in strength and frequency of occurrence during the winter, especially following an intense cold front, but appear only about half as often as those out of the south or southeast. Light winds will occasionally develop out of the west while easterly winds are rare. A combination of valley effects and regional pressure gradient combine to make Whitehorse one of the windier locations within southern Yukon. Winds, driven by moderate to strong southerly or northerly pressure gradients, increase at a fairly uniform rate with height, while turbulence remains at a minimum. However, strong overriding west to southwest winds aloft will generate more significant and widespread turbulence with directional shear appearing within a thousand feet of surrounding mountain top elevations.



Whitehorse is not overly prone to conditions of low ceilings or poor visibility. The spring and summer generally offer good flying weather; in fact, during April, the driest month, Whitehorse has less mean cloud cover than Banff or Calgary. From a pilot's point of view, the worst flying weather at Whitehorse can be found during the fall and winter, when aircraft operations are affected by low ceilings or poor visibility an average of 12 to 20 percent of the time. Fog, snow and low cloud are the primary contributing factors.

Fog is essentially a fall and early winter phenomena in the southern Yukon, forming in the early morning hours and usually dissipating by mid morning. The occurrence of fog dense enough to restrict aviation operations increases to a peak between December and January. Whitehorse is most prone to fog under a combination of light winds and cool temperature. Temperature may drop as a result of overriding cold air or radiation cooling associated with clear skies. The relatively warm open waters of the Yukon River, Lac Laberge and Marsh Lake contribute a significant amount of moisture for fog development. After freeze up, the occurrence of fog drops dramatically. During prolonged cold spells, ice fog can become a problem at Whitehorse. In years past periods of ice fog lasting a week have occurred playing havoc with scheduled flight. The critical for ice to form at the airport is -38°C .

Whitehorse may see flurries as early as late August or as late as early June, but the bulk of the snowfall usually occurs between October and February. Snowfall accounts for almost 45 percent of the area's average annual 261 millimetres of precipitation. Early snowfalls will often accompany the southward passage of arctic fronts, while some of the heaviest snowfalls and lowest ceilings follow Pacific frontal systems that wrap moisture into the Yukon from the south. At times, these disturbances will bring ceiling height and visibility to near zero, but poor conditions are seldom persistent and often improve in the wake of fronts, or within 24 hours of the passage of a low.

Blowing snow occurs infrequently, certainly less often than fog and, by itself, seldom

restricts aircraft operation for extended periods. In the thirty-year period of record from 1953 through 1982, blowing snow was observed on 275 occasions or about 0.1% of the time.

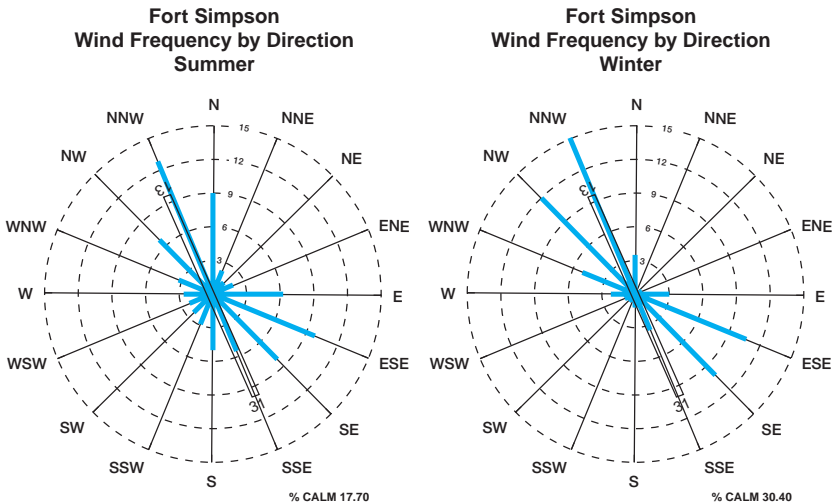
Airport Climatology of the Northwest Territories

Fort Simpson



Photo 5-4 - Fort Simpson Airport looking west credit: Pryde Schropp McComb Inc

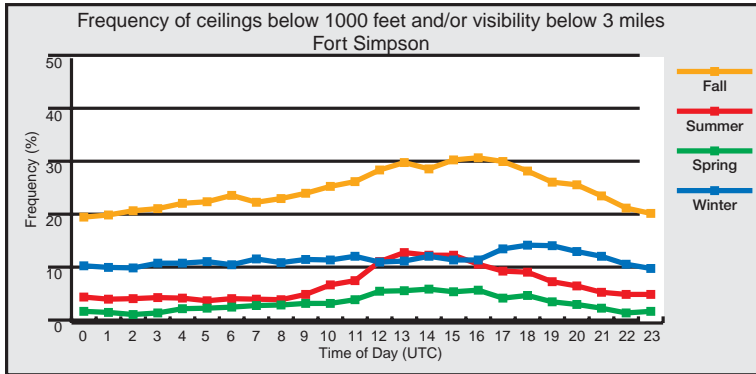
The Fort Simpson airport (elevation 555 feet ASL) is located approximately 8 miles southeast of the town, 5 miles south of the south bank of the Mackenzie River, and about 1/4 mile from the west bank of the Liard River. There is also an in-town landing strip (elevation 405 feet ASL) used by small aircraft. The town of Fort Simpson is located on an island immediately downstream of the forks of the Mackenzie and Liard Rivers. Formerly it was called Liidli Koe, which means, “place where rivers come together.” The Mackenzie River is aligned in a southeast-northwest direction north of the airport, while the Liard River is aligned in a northeast-southwest direction east of the airport. The terrain surrounding the airport is flat with a slight rise along the river valley. Trees surround most of the airport. Some 30 miles northeast of the airport is a land feature known as the Horn Plateau, with the terrain rising to approximately 2,500 feet ASL. One hundred miles to the south of the airport is a ridge rising to about 2,000 feet ASL, which extends in an east-west direction. The eastern slopes of the Mackenzie Mountains lie approximately 60 miles to the west of Fort Simpson. The Martin Hills rise to approximately 2,300 feet ASL and lie 25 miles southwest of the airport. The Ebbutt Hills lie about 40 miles northwest of the airport and rise to 2,265 feet ASL. The high terrain to the west and northwest of Fort Simpson is a genesis area for thunderstorms. The upslope effect enhances lift. Storms formed in this area tend to move eastward as the day progresses.



Percent wind 20 knots and greater													FORT SIMPSON			
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0
WINTER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.1

In the summer and winter, winds favour a northwesterly or southeasterly direction following the Mackenzie River Valley. Winds from the north-northwest and north tend to be the strongest. Occasionally, winds from the southeast will produce upslope

flow near the southern end of the Franklin Mountains bringing precipitation and stratus ceilings, which spread eastward toward the station. Most of the wind speeds are less than those found in open terrain because of the proximity of the aspen and spruce trees.



The best flying weather at the Fort Simpson airport occurs in the spring. However, low stratus ceilings and/or fog can develop overnight. Conditions improve during the morning as the sun rises and breaks up the cloud and dissipates the fog. Summer flying conditions are similar to those in the spring but with a higher frequency of early morning low ceilings and/or poor visibility in fog that linger through the morning. Showers or thunderstorms contribute periods of low ceilings. The worst flying weather occurs in fall. Low ceilings and/or fog that develop overnight routinely persist throughout the morning. As in the spring, the Liard River is a moisture source. Fog that develops over the river can move over the airport. In the winter, the flying weather is better than that during the fall, but poorer than that during the spring and summer. The winter flying weather shows little change throughout the day. Weather systems moving across the southern Mackenzie, or across northern BC to northern Alberta, can lead to significant snowfalls with associated low precipitation ceilings and poor visibility caused by falling snow.

In winter, a high pressure system over the area does not guarantee good flying weather. Visibility can be reduced by ice crystals and low diffuse cloud ceilings, particularly when the high pressure system is accompanied by temperatures in the upper minus 30's into the minus 40's. Throughout the year, a moist upslope flow from a northwesterly or southeasterly wind will spread stratus and, at times, precipitation to the area, giving poor flying weather.



Photo 5-5 - Fort Simpson town strip

Airport versus town strip - In fog situations and, for example, thundershower events, the weather at the town strip can differ significantly from that at the Fort Simpson airport. During the winter, in extreme cold temperature events, the town strip is more vulnerable to reduced visibility in ice fog than the Fort Simpson Airport. Both the airport and town strip are vulnerable to fog spreading over them from the nearby rivers. The airport is vulnerable to fog off the Liard River and the town strip is vulnerable to fog off the Mackenzie River.

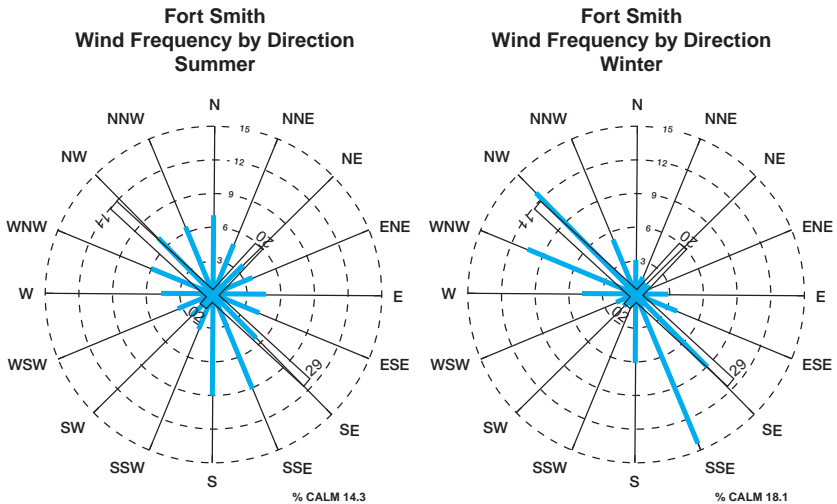
Fort Smith





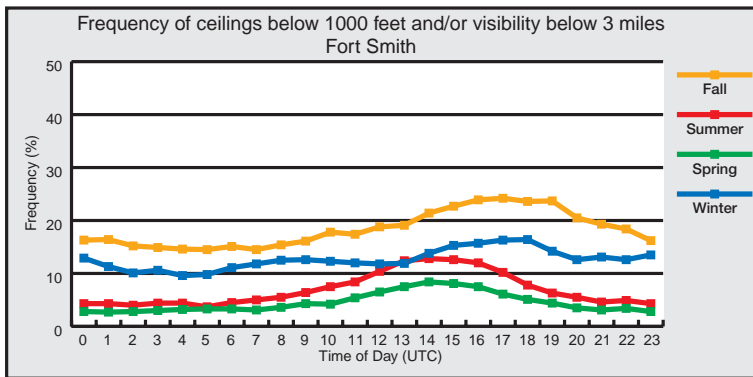
Photo 5-6 - Fort Smith Airport looking west credit: Pryde Schropp McComb Inc

The Fort Smith airport (elevation 673 feet ASL) lies southwest of the Slave River, 3 miles west-northwest of the town of Fort Smith and 2 miles north of the Alberta / NWT border. The town of Fort Smith is located along the southwestern bank of the Slave River. The area surrounding the airport is that of the Slave River Valley, which sweeps toward the west and then northwest toward Great Slave Lake, 105 miles to the north. At its closest point, the Slave River is about a mile from the airport. The four sets of rapids in the Slave River, between the towns of Fort Smith and Fitzgerald in Alberta, 17 miles to the southeast of the airport, drop the elevation of the river by about 115 feet. The river valley lies 135 feet below the elevation of the station. The surrounding area is relatively flat, with the highest elevation within a 12-mile radius being only 33 feet greater than that of the airport. Large stands of coniferous forest and marshland cover the region.



Percent wind 20 knots and greater																FORT SMITH			
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N			
SUMMER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
WINTER	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0	0			

Winds at Fort Smith favour northwesterly and southeasterly directions, in line with the orientation of the Slave River valley. Winds less than 10 knots will blow in any direction as the surrounding terrain is relatively flat. Winds greater than 20 knots occur more frequently in winter than in summer and tend to be from the west-north-west or northwest.



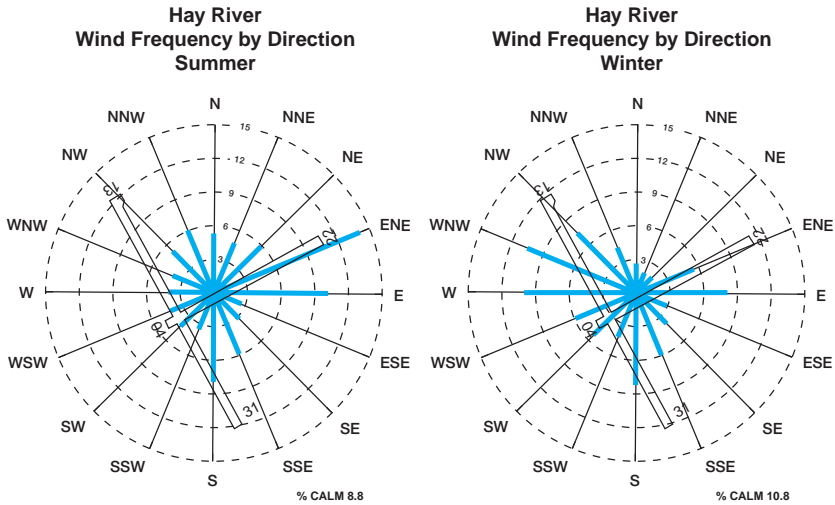
The most favorable flying weather at Fort Smith occurs in the spring. However, even in spring, low ceilings and /or reduced visibility can develop overnight. Such fog and low cloud is usually gone by mid day. Summer conditions show trends similar to spring, but with a higher frequency of poor flying conditions during the morning hours. Warm temperatures lasting into the day bring scattered showers and, at times, thunderstorms. The low cloud and reduced visibility of such events is usually short lived. Showers and thundershowers that occur overnight can provide the moisture that leads to early morning fog and/or low cloud. Fall brings the highest percentage of poor flying conditions. Lakes and rivers are open to provide moisture and the sun's rays are weak. Northwesterly winds routinely feed cloud south from Great Slave across the area. In the winter, the frequency of ceilings below 1000 feet and/or visibility less than 3 miles shows less variability through the day than during the other seasons. Snow and ice crystals are two common winter weather elements. Flying conditions during the winter are better than those during the fall but not as favourable as those during the spring and summer. During the spring and fall storms can bring heavy snow and sometimes freezing precipitation and strong winds.

Hay River



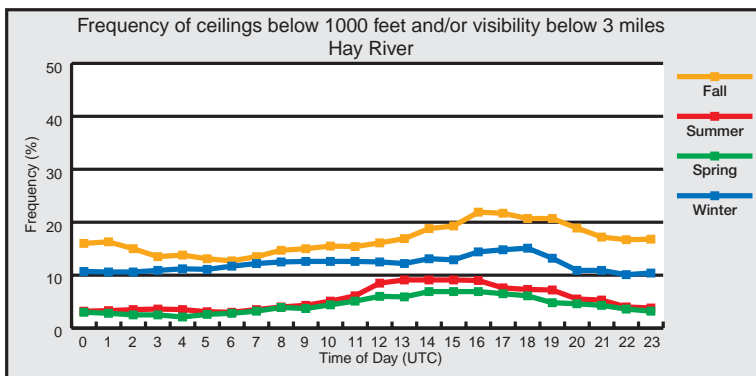
Photo 5-7 - Hay River Airport looking southeast credit: Pryde Schropp McComb Inc

The Hay River Airport (elevation 543 feet ASL) is located near the shore of Great Slave Lake on the southwest side of Vale Island, an island in the Hay River Delta which is prone to flooding. The airport is west of “old town” Hay River and north-northwest of “new town” Hay River. Old town Hay River is on the northeast side of Vale Island, while new town Hay River lies on the mainland on the west side of the Hay River. The 2001 population of Hay River is cited as 3,510. The terrain on Vale Island falls gently towards the north to Great Slave Lake. The island is generally composed of marsh with only a little soil on top of permafrost. Beyond the island, the surrounding countryside is generally flat with only a modest increase in elevation southwards from the site. The highest elevation within a 12-mile radius of the airport is about 660 feet, found nearly 12 miles to the south-southeast.



Percent wind 20 knots and greater														HAY RIVER			
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	
SUMMER	0	0	0.1	0	0	0	0	0	0	0	0	0.1	0.1	0.2	0.1	0	
WINTER	0	0	0	0	0	0	0.1	0	0	0	0	0.1	0.2	0.4	0.2	0	

During the spring and summer, when the land is warm compared to the ice covered and subsequently water covered Great Slave Lake, winds at Hay River favour the northeast direction as a cool lake breeze routinely kicks in. Both the channelling effect of the Mackenzie River Valley, spreading into the south-western shores of Great Slave Lake, and the weather patterns of the area promote northwesterly winds at Hay River year round. Indeed, once the lake has frozen over, west through northwest winds are dominant. The strongest winds at Hay River are from the northwest, particularly during the winter. Looking at the summer period in the table, the predominance to northwest wind continues, but the northeast lake breeze is also in evidence.



The frequency of ceilings below 1,000 feet and /or visibility less than 3 miles at Hay River are less common during the spring and summer than they are in the fall and winter.

When these conditions occur during the spring and summer, they happen more frequently in the early morning, with improvement by midday. Thunderstorms over the station are not as frequent as at Fort Simpson and Fort Smith. They are, however, relatively frequent over the mountains and hills south and southwest of Hay River. Most significant are the Caribou Mountains to the south and, to a lesser extent, the Cameron Hills, 60 miles to the southwest, where orographic lift and daytime heating come into play. During the spring and fall, storms can bring heavy snow and sometimes freezing precipitation and strong winds.

Fall brings a high frequency of ceilings below 1000 feet and/or visibility below 3 miles with the poorest flying conditions through the mid day period. Northwest winds can feed low cloud from the Mackenzie Valley into the Hay River area, while northeast winds can feed cloud and, in some cases, snow streamers from Great Slave Lake into the Hay River area.

Winter flying conditions are more favorable than the fall flying conditions, but not as favourable as the spring and summer conditions. During the winter, low pressure systems passing across northern BC and northern Alberta, or across the southern Mackenzie, bring cloud and periods of snow. Arctic high pressure systems dominate during the winter and ice crystals and thin diffuse cloud ceilings trapped below the inversion can give poor flying conditions.

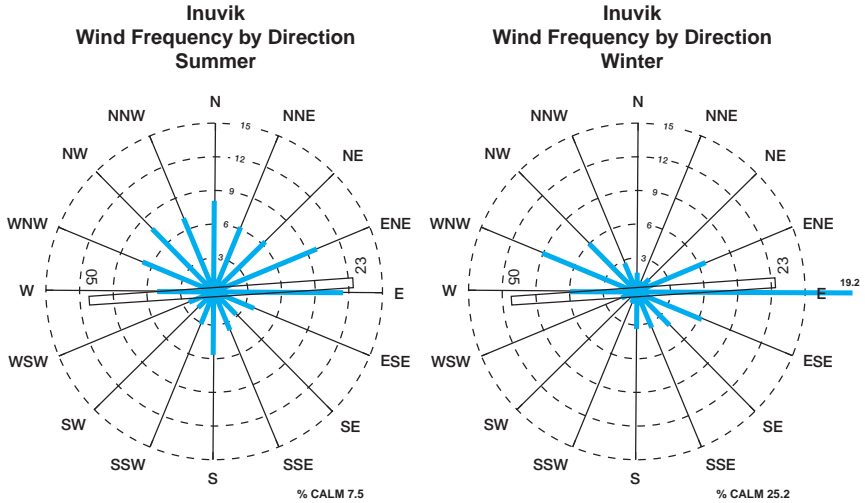
Inuvik





Photo 5-8 - Inuvik Airport looking north credit: Pryde Schropp McComb Inc

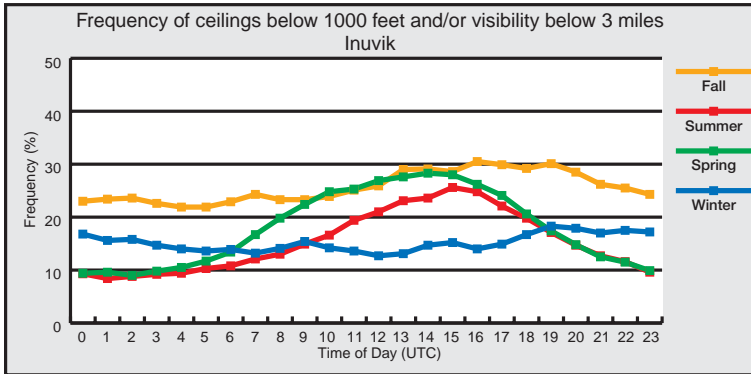
The Inuvik Airport (elevation 224 feet ASL) is located 5 miles east of the East Channel of the Mackenzie River Delta and about 8 miles southeast of the town of Inuvik. The town of Inuvik, which means “place of the people”, is located on the eastern edge of the Mackenzie River Delta, approximately 75 miles south of the Beaufort Sea. The Mackenzie River Delta, which is a vast landscape of lakes, swamps, river channels and landmasses, extends about 160 miles from its head at Point Separation, northward to the Beaufort Sea on the Arctic Ocean. At its widest point, the delta is 100 miles across. The airport is situated on a flat plateau on the north shore of Dolomite Lake. A series of rocky hills with elevations of 440 to 510 feet ASL rise above the airport, from the southeast to the south-southwest, at a distance of 3 1/2 miles. To the north through northeast, terrain heights reach 700 feet at about 3 1/2 miles from the airport. Beyond the delta region and about 60 miles west of Inuvik, the Richardson Mountains rise to 3,800 feet ASL and about 30 miles to the north-northwest the Caribou Hills rise to 600 feet ASL.



Percent wind 20 knots and greater														INUVIK		
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WINTER	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.2	0	0

In Inuvik, east and east-northeast winds dominate. West-northwest winds and northwest winds also prevail, particularly when considering strong winds.

When a surface ridge is east of the station, winds at Inuvik favour easterly. When low pressure systems develop or move east across Mackenzie Bay or the Delta, a strong northwesterly or westerly flow will occur in the low's wake over coastal sections and spill inland. The more intense the cold front and the deeper the cold air behind the cold front, the stronger the northwest winds. The strong northwest winds tend to be short lived. During the open water season, such northwest winds routinely bring low cloud and/or fog to Inuvik. During the winter, the strong northwest winds give blowing snow to the open channels of the river and open terrain north of Inuvik. Little of the blowing snow makes it to the airport.



Spring at Inuvik brings low ceilings and/or reduced visibility that develop at a much higher frequency during the overnight hours when compared to other stations in the Northwest Territories. The airport's proximity to abundant low-level moisture from the Mackenzie Delta and Beaufort Sea, along with a northwest flow, can push stratus ceilings over the station. An inversion can trap the stratus and it can linger through the morning into the afternoon. The passage of a surface ridge will bring a wind shift from easterly to west-southwest, which tends to lift this low cloud. Summer trends are similar to the spring, although poor flying conditions are not as frequent during the early overnight period.

Summer thundershowers are not common but do develop over the Richardson Mountains and routinely move east to arrive at Inuvik in the late afternoon or early evening.

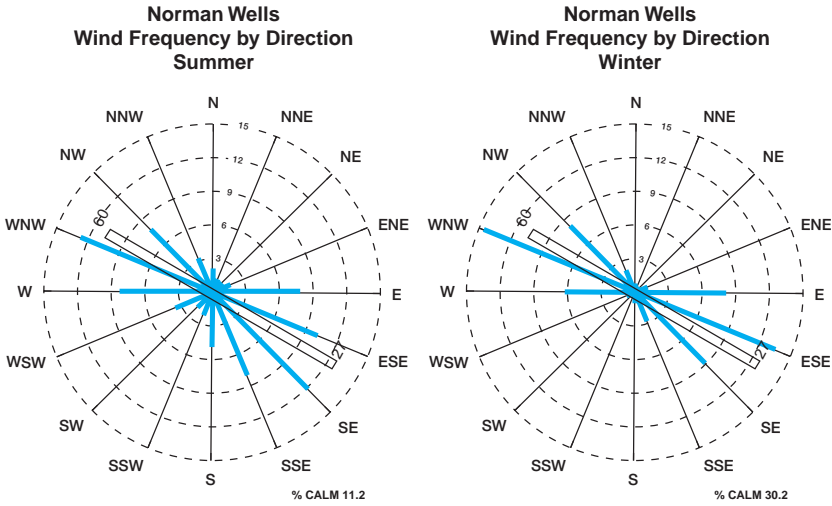
Fall has the highest frequency of ceilings below 1000 feet and/or visibility below 3 miles. Stratus and/or fog that develop or thicken overnight routinely persist through the morning and into the afternoon.

Norman Wells



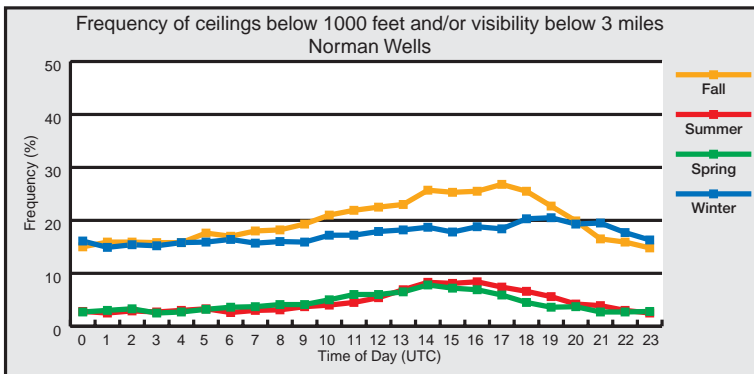
Photo 5-9 - Norman Wells Airport looking east credit: Pryde Schropp McComb Inc.

The Norman Wells Airport (elevation 241 feet ASL) is located immediately east of the town of Norman Wells. The town is located on the northern banks of the Mackenzie River. The Mackenzie River flows in a southeast to northwest direction to empty into the Beaufort Sea, 375 n. miles to the northwest. The river is dotted with numerous islands of alluvial composition. The airport lies in the Mackenzie River Valley, which is bordered on the north by the Norman Range of the Franklin Mountains and to the south by the Carcajou Range of the Mackenzie Mountains with peaks to 6,500 feet ASL about 35 miles to the southwest. The highest peak (no name) in the vicinity of Norman Wells Airport is 3,411 feet ASL and lies about 14 miles to the east-southeast. The second highest peak in the area is Hanmar Mountain, 3,220 feet ASL, and is found about 6 miles northeast of the airport.



Percent wind 20 knots and greater													NORMAN WELLS			
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0
WINTER	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.2	0	0

The winds at Norman Wells are influenced by the Mackenzie River Valley, and tend to blow either northwesterly or southeasterly, in the same orientation as the valley. The Franklin Mountains to the northeast and the Mackenzie Mountains to the southwest funnel the northwest winds. This funneling combined with, for example, a ridge of high pressure building vigorously southeast along the Mackenzie Valley helps explain the strong showing of west-northwest and northwest winds greater than 20 knots. In winter, with a building arctic high in the Yukon, gusty westerly outflow winds can develop. The higher terrain around Norman Wells promotes easterly and westerly winds during benign weather situations. Daytime heating leads to upslope winds while nighttime cooling leads to downslope or drainage winds.



Seasonally, ceilings below 1,000 feet and /or visibility less than 3 miles at Norman Wells are less common during the spring and summer than they are during the fall and winter. During the spring and summer, there is, however, a trend to poor flying conditions in the early morning hours, with conditions improving late morning. Additionally, spring and summer showers or thundershowers can give periods of poor flying weather.

The terrain west and southwest of Norman Wells is a prime area for the development of thunderstorms that can move over the airport. Daytime thunderstorms can continue well into the overnight period and may even last until early morning, although they tend to move eastward away from the airport.

During the fall and to a lesser degree during the winter, stratus and fog are common giving poor flying weather. In the fall, until the lakes and rivers freeze, the low cloud can be laden with supercooled water droplets giving aircraft icing. The low cloud can also be accompanied by freezing drizzle. In the winter, weather systems moving into the Northwest Territories from the Yukon can bring low ceilings and reduced visibility in snow. Pilots cite that, subject to temperature inversions in winter, there can be above freezing temperatures to $+5^{\circ}\text{C}$ at the top of the descent and -25°C at the surface with high moisture content giving rime icing. In light wind regimes, when there is an arctic ridge of high pressure over the area, moisture from sources such as the town can lead to a reduced visibility in ice crystals at the airport. Snow clearing activities at the airport can also put ice crystals into the air. The ice crystals can be slow to settle out of the air thereby reducing visibility at the airport.

Tuktoyaktuk





Photo 5-10 - Tuktoyaktuk Airport looking south credit: Municipal and Community Affairs, Government of the Northwest Territories

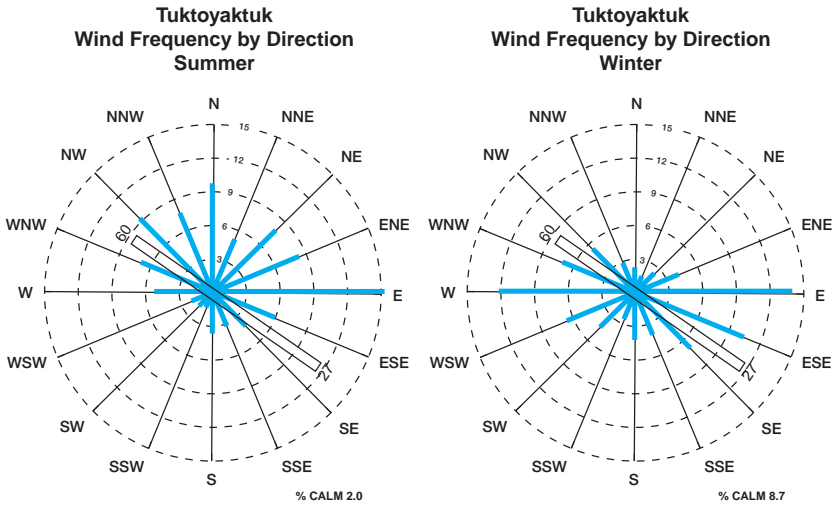
The Tuktoyaktuk Airport is located northwest of the town of Tuktoyaktuk on the Tuktoyaktuk Peninsula and adjacent to the east shore of Kugmallit Bay. Kugmallit Bay lies in the Beaufort Sea. Tuktoyaktuk means, “Resembling a Caribou”. The airport elevation is only 15 feet ASL and the surrounding terrain is marshland and open water. Indeed, the waters of Kugmallit Bay lie just beyond the west end of the runway.

The Tuktoyaktuk Peninsula has the world’s greatest concentration of pingos. A pingo is a frost mound consisting of a core of ice, produced primarily by injection of water, and covered with soil and vegetation. The largest pingo on the peninsula is about one mile southeast of the airport and is called Ibyuk pingo. It has a diameter of 1,000 feet and rises to 160 feet.



Photo 5-11 - Pingos near Tuktoyaktuk

credit: Natural Resources Canada

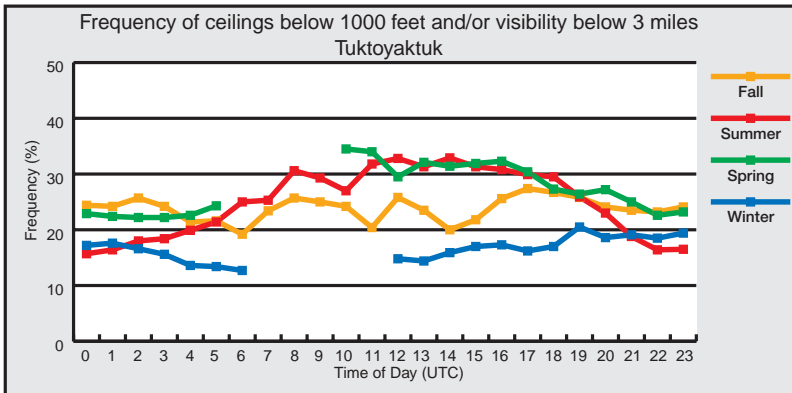


Percent wind 20 knots and greater													TUKTOYAKTUK			
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0.1	0.2	0.2	0.7	0	0.1	0	0.1	0	0.1	0.2	0.7	0.9	0.7	0.2	0.1
WINTER	0	0.1	0.1	0.5	0.4	0.3	0.1	0.1	0	0	0.3	1.6	1.5	1.0	0.1	0

Winds favour easterly directions especially in the warmer months. West through northwest winds are present year round but peak in the winter period. The summer easterly winds occur when weather systems are approaching and there is troughing or low pressure system development occurring along the Mackenzie Valley and across Mackenzie Bay / the southern Beaufort. Northwest winds occur each time a low pres-

sure system heads east from Mackenzie Bay/the Beaufort and/or a ridge of high pressure accompanied by a surge of cold air builds into the Delta/northern Mackenzie.

The terrain of the surrounding Delta and Tuktoyaktuk Peninsula is flat, and Mackenzie Bay and the Beaufort Sea are at hand. Additionally, the treeline is well south of Tuktoyaktuk. Thus, Tuktoyaktuk is exposed to the winds from storms moving across the region. The table showing winds greater than 20 knots, unlike those shown in the manual up to this point (all previous sites were within the treeline), shows values as high as 1.6 percent of the winds from a given direction being stronger than 20 knots. The strongest winds year round are those from the west through northwest. Easterly winds also occur both in summer and winter with up to 0.7 percent of easterly winds being great than 20 knots.



Spring and summer are the worst seasons weather-wise at Tuktoyaktuk. During these seasons, the most favorable flying weather occurs late evening and into the very early hours of the next day. The weather at Tuktoyaktuk, being on the coast of the Beaufort Sea, shows a strong correlation with wind direction. Easterly winds favour good flying weather and northwesterly winds bring in the cloud and fog that frequents the offshore.

During winter, onshore winds of sufficient strength (20 plus knots) can give reduced visibility in blowing snow. Also during winter, open leads that develop along the fast ice edge of the Delta and Tuktoyaktuk Peninsula, with easterly winds, feed moisture into the air creating low cloud. When winds shift to northwesterly, this low cloud is moved southeast across the Delta and Tuktoyaktuk Peninsula.

During the fall, prior to the Beaufort freezing over, northwesterly winds can bring snow streamers to Tuktoyaktuk reducing visibility at times in snow flurries. Also during late summer/early fall and sometimes lingering into late fall, there can be freezing drizzle and aircraft icing associated with the low cloud.

Summer thundershowers are rare with less than five events a year being typical.

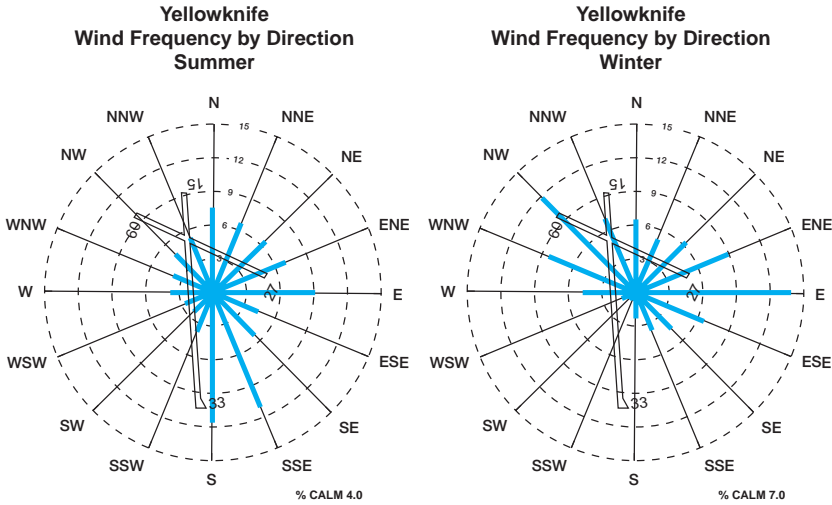
Yellowknife



Photo 5-12 - Yellowknife Airport

credit: Pryde Schropp McComb Inc

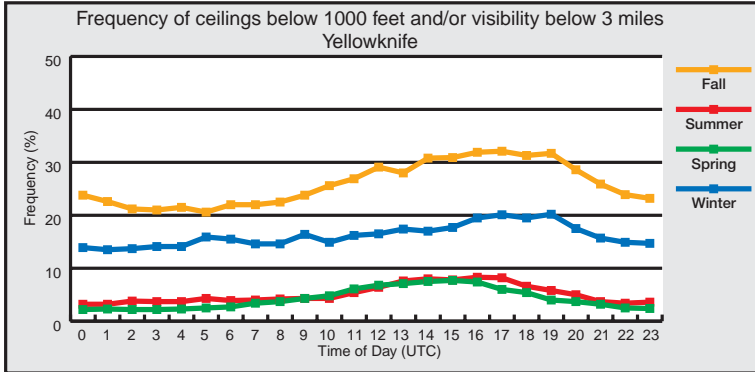
The Yellowknife Airport (elevation 675 feet ASL) is located 2 1/2 miles west-northwest of Yellowknife and just south of the Mackenzie Highway. The city of Yellowknife lies on the northeast shore of Yellowknife Bay on the North Arm of Great Slave Lake. The terrain surrounding the airport rises from about 515 feet ASL on Great Slave Lake to about 800 feet, approximately 12 1/2 miles to the north and northeast. The area is generally characterized by undulating rock oriented in a north-south direction that varies the elevation by 100 to 200 feet. There are numerous lakes and marsh areas surrounding the area within a 12-mile radius of the airport. The waters of Great Slave Lake are carried by the Mackenzie River to the Arctic Ocean, 750 n. mile northwest of the airport. The surrounding land surface is a mix of bare rock and stunted trees, mainly in depressions around lakes.



Percent wind 20 knots and greater													YELLOWKNIFE			
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0.2
WINTER	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.2	0.2	0

Winds at Yellowknife rarely blow from south-southwest through west-southwest at any time of the year. Winds from east quadrant directions and from the northwest are frequent in the spring, summer and fall. During the winter, northwest winds, and to a lesser degree, east winds dominate. Lake breezes develop during the warmer months bringing a southeasterly flow off Yellowknife Bay. Otherwise, winds out of the east are mainly due to weather systems passing from west to east, south of Great Slave Lake. The dominance of northwest winds in winter can be attributed to the dominant winter pattern of a ridge of high pressure lying along the Mackenzie Valley and westerly winds east of the ridge.

As shown in the table, the strongest winds at Yellowknife tend to be the northeast through north and west-northwest direction winds. Such winds routinely occur once an eastward moving low pressure system gets south and, subsequently, east of Yellowknife.



The best flying conditions of the year occur in the spring during the afternoon and evening hours. During the overnight period, as with other stations located near water, fog and stratus can develop by early morning but it usually dissipates by late morning.

During the summer, thunderstorms that move over Great Slave Lake will weaken as they encounter the cooler water, but storms that develop over the Horn Plateau to the west can continue eastward to pass over the airport.

Fall produces the highest frequency of poor flying weather. The lake is routinely cloud covered and any kind of onshore flow will spill this cloud over the airport. Prior to the lakes and rivers of the entire Great Slave area freezing over, the area is low cloud-prone. Fog, when it forms, is slow to burn off as the sun has lost much of its strength. The low cloud can be laden with supercooled water droplets and icing in cloud is common. Freezing drizzle is also common in the fall.

The flying weather in winter at Yellowknife is better than that during the fall, but not as good as that during spring and summer. In winter, Great Slave Lake and the myriad of lakes and rivers of the area are frozen over, cutting off the moisture supply. Weather systems that cross the southern Northwest Territories can, however, push snow into the Yellowknife area. During cold outbreaks (temperatures in the upper minus 30's and minus 40's), habitation fog can envelop the airport. Routinely, the northwesterly flows that originate over the Beaufort can stream low cloud over the area and, with a winter inversion in place and the sun at its weakest, the low cloud can linger.

Yellowknife airport versus Yellowknife Bay / Back Bay float plane /ski plane area

The Yellowknife Bay and Back Bay areas can have significantly different weather from that at the Yellowknife airport.

Additional Sites

Cambridge Bay, Nunavut

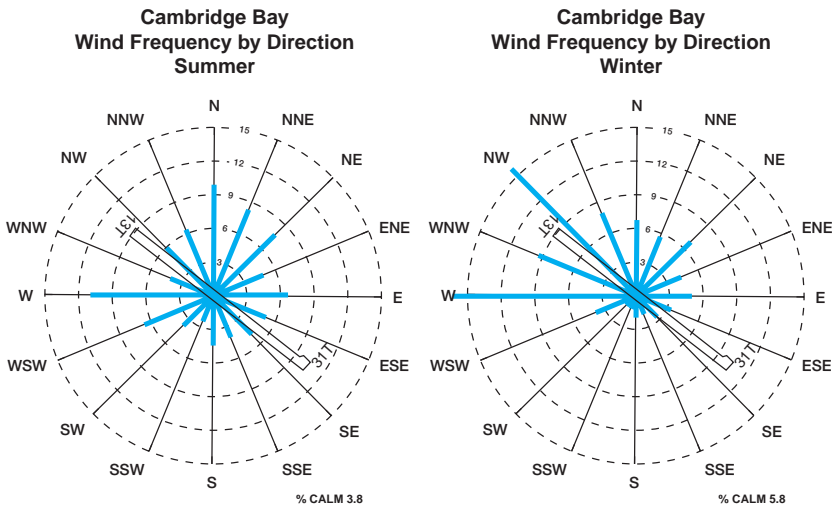


Photo 5-13 - Cambridge Bay area looking west credit: James P. Patterson



Photo 5-14 - Cambridge Bay Airport looking northwest credit: James P. Patterson

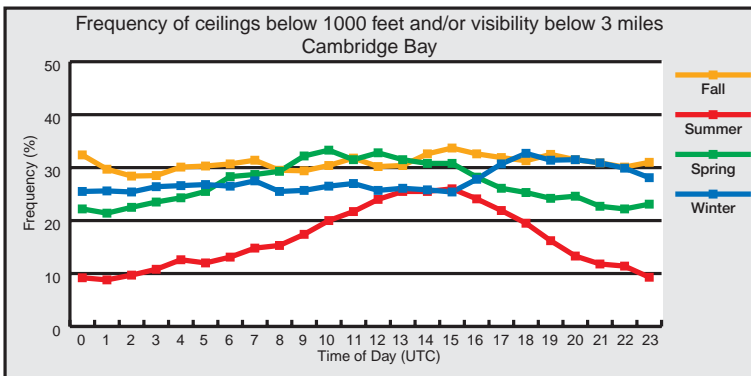
The Cambridge Bay Airport (elevation 90 feet ASL) is located 2 1/2 miles to the west of the town of Cambridge Bay. The town itself lies along the north shore of the west arm of Cambridge Bay, on the southeast coast of Victoria Island. To the south and west of the station lies Dease Strait, one of a series of gulfs and straits through which the waters of the Arctic Ocean pass. There are three large lakes in the area: Greiner Lake, 4 miles to the north-northeast; Kitiga Lake, 11 miles to the northwest; and Ferguson Lake, 18 miles to the north. The surrounding countryside is generally flat with the exception of a line of hills 11 miles to the northeast, where the highest peak, Mount Pelly, rises to a height of 689 feet. The land surface is composed of broken shale and glacial till with very little topsoil.



Percent wind 20 knots and greater										CAMBRIDGE BAY, NUNAVUT							
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	
SUMMER	1.4	1.0	0.7	0.4	0.3	0.5	0.4	0.1	0	0	0.2	0.9	0.7	1.4	1.4	1.8	
WINTER	0.9	1.0	0.3	0.3	0.3	0.4	0.2	0.1	0	0	0.2	1.8	1.5	3.4	2.1	1.6	

Winds at Cambridge Bay are stronger on average than those of the stations presented earlier in this chapter, with wind speeds greater than 20 knots occurring more frequently. There are two factors at work. Weather-system wise, Cambridge Bay routinely lies in the corridor of strong pressure gradient between a ridge of high pressure to the west (northwest to southeast across the Mackenzie) and a trough of low pressure to the east (north to south across Baffin Bay and Davis Strait). Secondly, the terrain across southeastern Victoria Island, including that in and around Cambridge Bay, is both flat and vegetation sparse. Most wind directions show a significant portion of winds being greater than 20 knots. Winds from northerly directions and in particular from the northwest not only dominate - more so in winter - but also like to blow strong. In winter, 3.4 percent of the northwest winds show as being greater than 20 knots. Southwest winds are rare year-round and east winds are rare in winter.

The strong northerly winds routinely generate blizzard conditions through the winter months.



Cambridge Bay has a higher percentage of poor flying conditions during the cooler seasons than most of the other stations in the GFACN35 domain. Looking at the fall, winter, and spring seasons, the occurrence of ceilings below 1,000 feet and/or visibility below 3 miles ranges from as low as 21 percent to as high as 33 percent. Spring and fall are stratus seasons while winter is a blowing snow season. Months for freezing drizzle are May and June and then again September and October.

Summer has the most favorable flying weather with the best conditions occurring during late afternoon and early evening. Per the graph of summer conditions, there is a strong diurnal trend that shows flying conditions deteriorating overnight then improving from mid morning through the afternoon.

Storms that develop over the southern Mackenzie Valley or the Great Slave area and move northeast can lead to snowfall at Cambridge Bay. When there is either a strong arctic high holding or building west of Cambridge Bay, the strong north or northeast winds can combine with the fresh snow to produce blowing snow.

Ekati, Northwest Territories

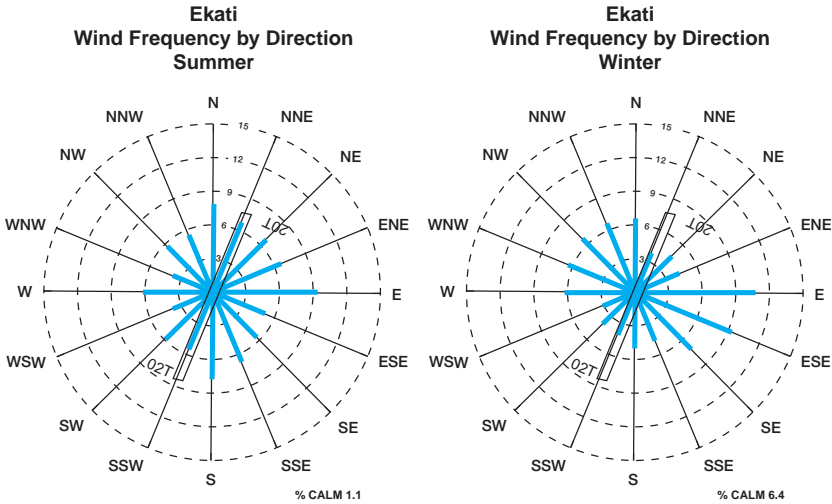


Photo 5-15 - First Air Hercules at Ekati airport

credit: Environment Canada,
Prairie and Northern Region
Technical Services

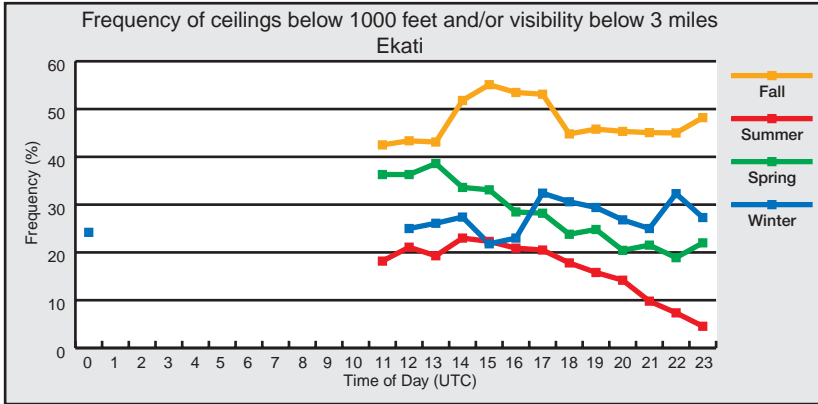
The Ekati airport (elevation 1,540 feet ASL) is located about 160 n. miles northeast of Yellowknife and beyond the treeline. The Ekati diamond mine camp and open

pit mine lie north of the runway. Ekati lies in a bowl and during fall and winter, low cloud and fog can linger. Additionally, camp and mine activity can generate ice fog in the winter and, hence, create weather that can affect the airport. Two small lakes are located adjacent to the west side of the runway, and these extend beyond the length of the runway at both ends. Surrounding terrain is treeless tundra, with many small lakes. Generally flat, the land rises to a sharp ridgeline that is some 328 feet higher than the runway, at a distance of 3,281 feet to 4,920 feet east of the runway. With strong easterly winds, this ridge can generate low level turbulence.



Percent wind 20 knots and greater (limited data)																EKATI, NWT	
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	
SUMMER	0.7	0.6	0.6	0.8	0.1	0.2	0.1	0.3	0.2	0.3	0.0	0.6	0.1	0.5	0.3	0.8	
WINTER	0.0	0.0	0.2	1.9	1.0	0.2	0.3	0.2	0.1	0.2	0.0	0.1	1.2	0.8	1.0	0.1	

Winds at Ekati favour north through east in summer. In winter, east and southeast winds dominate and are routinely the strongest. Northwesterly winds do, however, make a strong showing both in their frequency and their strength. Easterly winds, when they do occur, are routinely a product of a low pressure system developing in northern Alberta or the Great Slave Lake area and moving east.



Frequency of low ceilings and visibility at Ekati are high due to the elevation and location that gives upslope flow to the station.

Ekati, like Lupin lies on generally flat terrain that is upslope for the moisture from Great Slave Lake and Great Bear Lake to the west and southwest respectively, the arctic coast to the north, and the barrens to the east.

Flying conditions at Ekati are poorest during the fall, with conditions of ceilings less than 1,000 feet and/or visibility below 3 miles peaking, at times, to over 30 percent. Winter flying weather affected at times by, for example, blowing snow and habitation fog shows little diurnal change and hovers around the 10 percent mark for these conditions. The best flying weather of the year favours late afternoon through early evening, during the summer.

Late afternoon or evening thundershowers, though infrequent, can result in short periods of reduced visibility and lower ceilings.

Pilots cite the Ekati weather as being a measure of the weather for the entire area. If the weather at Ekati is good, then, the weather of the entire area is likely good. The converse is not true. Ekati is in a bowl and can have poor weather while the area around is enjoying good weather. Pilots also cite that strong south winds will generate mechanical turbulence over the open pit of the Ekati mine on final approach to runway 20T. The pit is now 500 feet deep.

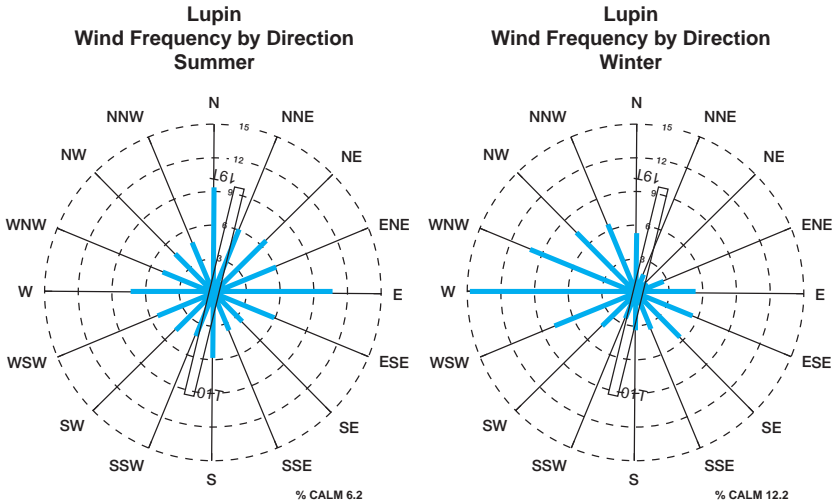
Lupin, Nunavut



Photo 5-16 - Lupin gold mine and airport looking southeast

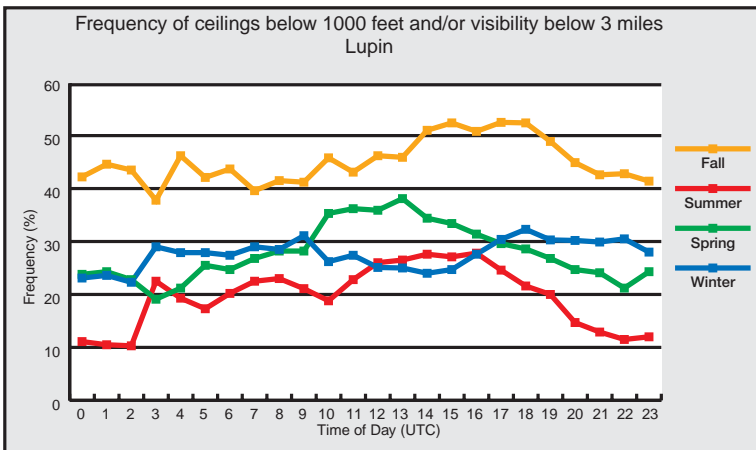
credit: Environment Canada, Prairie and Northern Region Technical Services

Lupin is a gold mine located on the southwest shore of Contwoyto Lake. The station elevation is 1,607 feet ASL and, as with Ekati, stratus ceilings are common throughout the year. The terrain surrounding the station is relatively flat with bare rock and no trees. There are many small lakes and to the northeast and northwest lie the Willingham Hills and the Peacock Hills that rise to over 1,600 feet and 2,100 feet ASL respectively.



Percent wind 20 knots and greater													LUPIN, NUNAVUT			
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0.2	0.3	0.1	0.2	0.1	0.1	0	0.2	0.1	0.2	0.1	0.2	0.2	0.5	0.3	0.4
WINTER	0.1	0	0	0.1	0.2	0.2	0.1	0.3	0.2	0.3	0.5	0.6	1.5	1.7	1.8	0.6

Prevailing summer winds for the Lupin airport are the northwesterly and easterly. The strongest winds in summer are the northwesterlies. In winter, with a ridge of high pressure often present along the Mackenzie Valley, west and northwest winds dominate and are often strong.



In a manner similar to that at Ekati, elevation and location give upslope flow to the Lupin area and low cloud is common. The frequency of ceilings below 1,000 feet and/or visibility below 3 miles through the day, during the fall, is almost exclusively greater than 40 percent and peaks at over 50 percent for a 5 hour period through the morning.

Flying conditions are better in the spring than in fall. However, poor flying conditions climb to close to 40 percent by 1300 UTC, after bottoming out mid afternoon, and again mid evening near 20 percent. Winter flying conditions show the least change through the day of any of the seasons with the condition of ceiling less than 1,000 feet and/or visibility less than 3 miles ranging from 22 percent at mid evening to 32 percent late morning. Open and flat terrain makes the area vulnerable to reduced visibility in blowing snow during the winter months.

Summer produces the best flying conditions at Lupin, but low level moisture and higher terrain can lead to radiation fog developing in the overnight hours and dissipating in the morning.



Photo 5-17 - Low cloud over the tundra, Lupin

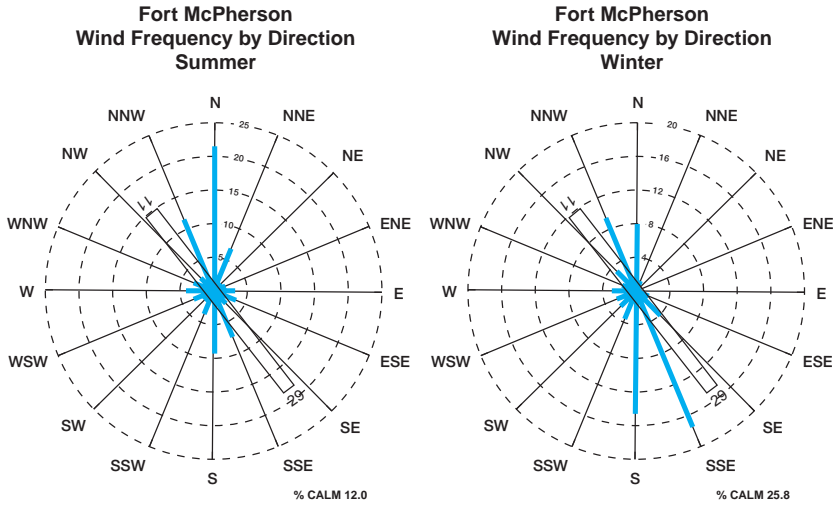
credit: Environment Canada,
Prairie and Northern Region
Technical Services

Fort McPherson, Northwest Territories



Photo 5-18 - Fort McPherson airport looking north
credit: Pryde Schropp McComb Inc

Fort McPherson airport (elevation 142 feet ASL) lies to the southeast of the town of Fort McPherson, with the town on the west side of the Dempster highway and the airport on the east side. The Peel River lies west of the town, and the junction of the Peel with the Mackenzie is about 29 miles north. The airport and town are located on rolling land between the Richardson Mountains and the Mackenzie River Delta. The land is lake, swamp and stunted tree covered.

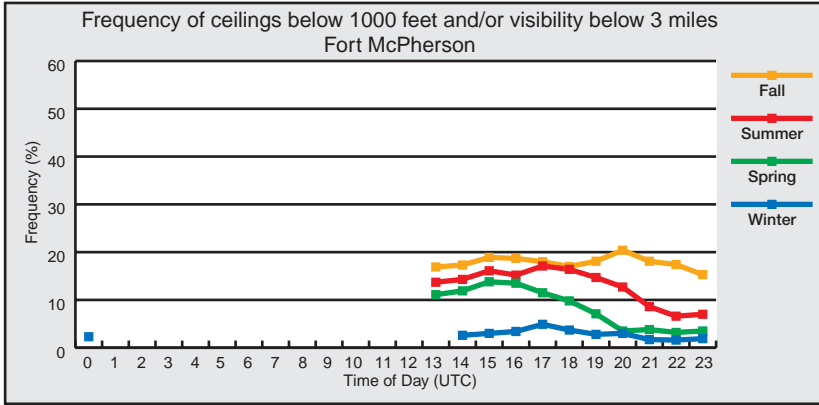


Percent wind 20 knots and greater											FORT MCPHERSON, NWT					
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WINTER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Winds at Fort McPherson are strongly influenced by its geographic location. To the west lie the Richardson Mountains, which tend to confine the winds to the northerly and southerly direction. Winds 20 knots and stronger at the airport are rare. Occasionally, downslope winds occur from the west off the Richardson mountains. Although at the airport such winds may only register at 15 to 20 knots, closer to the mountains they can be much stronger.

Summer winds favour the northerly directions north-northwest, north, and north-northeast, as well as the southerly directions south-southeast and south. It is the northerly summer winds that can at times bring a “burst of Beaufort” to Fort McPherson in the form of low cloud and/or fog accompanied, at times, with some precipitation. About 12 percent of summer winds are calm.

Winter winds have a reduced northerly component and, in particular, north-northeast winds. South-southeast and south winds hold their own. Calm winds at close to 26 percent of the time are more than twice as likely in winter than they are in summer.



Flying weather at Fort McPherson tends to be good. The location of Fort McPherson, close to the mountains and further inland than, for example, Aklavik and Inuvik, means that limited amounts of the low cloud and fog that pushes inland with northwesterly flows off Mackenzie Bay / the Beaufort Sea, during the open water season, reaches Fort McPherson. Summer into fall, prior to freeze-up, low ceilings are mainly associated with rain events or “bursts of Beaufort” where the winds are north-northeasterly rather than northwesterly. In winter, blowing snow is rare. Low ceilings and poor visibilities in winter and spring usually require falling snow.

Holman, Northwest Territories

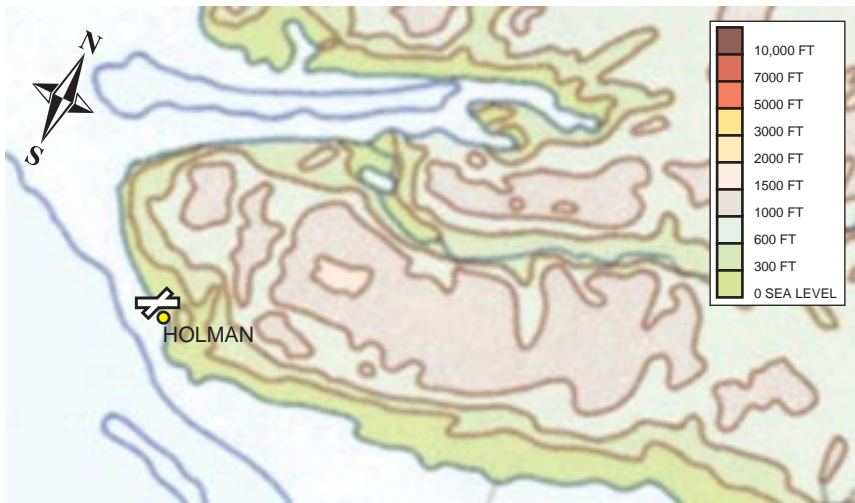




Photo 5-19 - Holman looking south

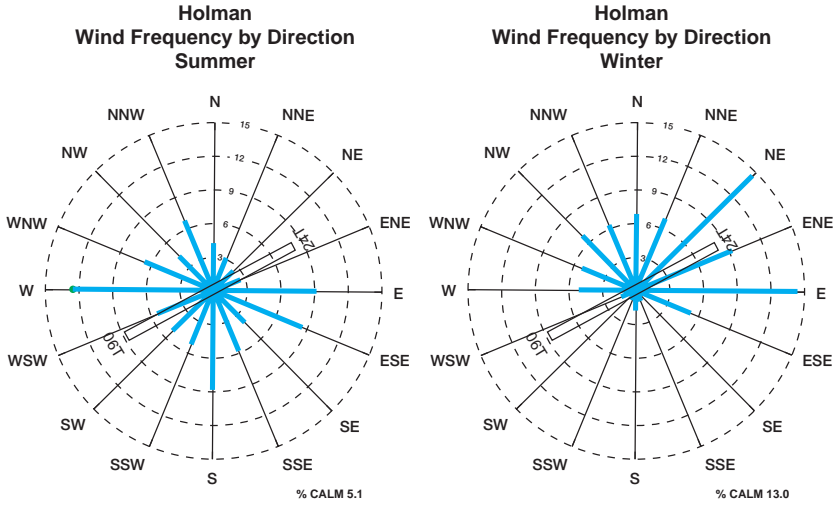
credit: Municipal and Community Affairs, Government of the Northwest Territories



Photo 5-20 - Looking south-southeast from airport to Holman

credit: Environment Canada, Prairie and Northern Region Technical Services

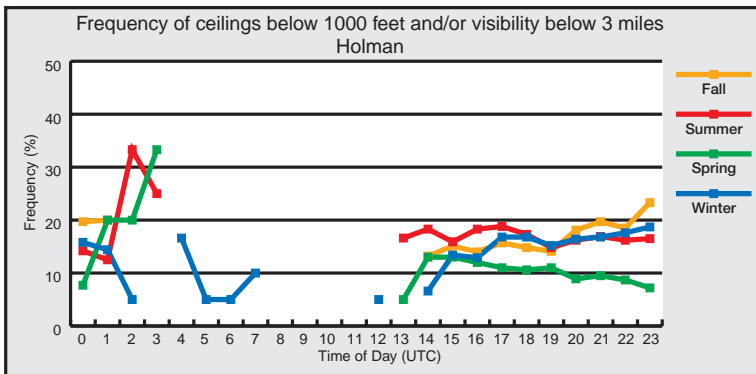
The Holman airport (elevation 117 feet ASL) is located 3 miles north-northwest of the town of Holman. Holman on the western side of Victoria Island, is located on inlets of Amundsen Gulf. Surrounding terrain rises to over 1,000 feet to the north and east of the station, with a peak elevation over 1,500 feet on Diamond Jenness Peninsula to the northeast.



Percent wind 20 knots and greater													HOLMAN,NWT			
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0.1	0.1	0	1.0	0.6	0.1	0.1	0	0	0	0	0.2	0.1	0.4	0.4	0.2
WINTER	0	0	0.1	3.6	1.2	0	0.1	0	0	0	0	0.2	0.3	0.7	0.6	0.2

The wind at Holman is a reflection of the channelling across Prince Albert Sound, which lies between the Diamond Jenness Peninsula, to the north, and the Wollaston Peninsula, to the south. Easterly winds dominate through the year both direction-wise and speed-wise.

Northwesterly winds show in the winter at the expense of a decreased easterly wind component and can at times be strong. Strong winter winds, irrespective of direction, can generate blowing snow and, thus, poor visibility.



During spring and summer, south and southeast winds can bring low cloud and/or fog to Holman. In winter, low cloud and/or poor visibility from the moisture of open leads can, on occasion, make its way to Holman. Strong winter wind events can, at times, generate ceilings and visibility obscured in blowing snow.

Kugluktuk, Nunavut

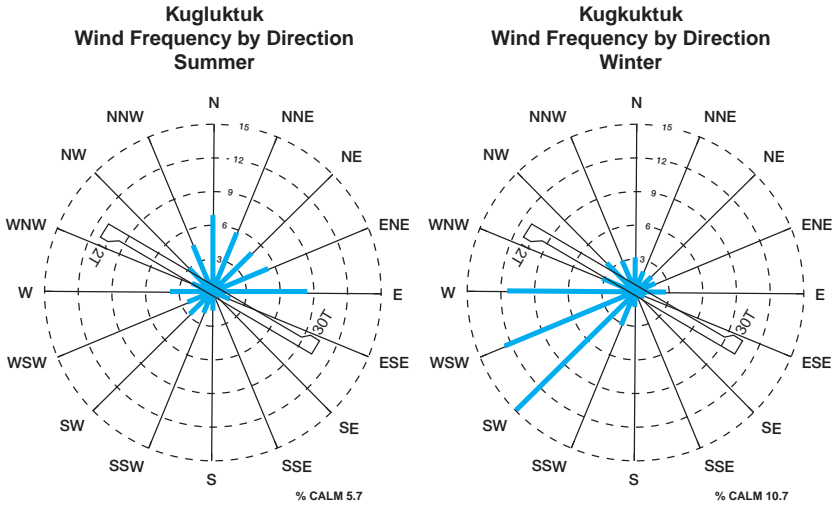


Photo 5-21 - Kugluktuk airport looking north

credit: Environment Canada,
Prairie and Northern Region
Technical Services

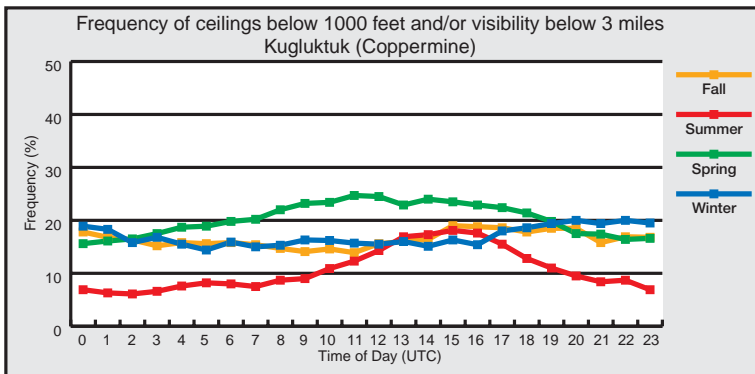
The Kugluktuk airport (elevation 74 feet) is located approximately 3 miles southwest of the town of Kugluktuk. The town, formerly known as Coppermine, is located on the banks of the Coppermine River and the shores of the Coronation Gulf. The

terrain towards the southeast is relatively flat away from the airport, but rises further from the site. The Coppermine Mountains are to the south. Coronation Gulf is towards the north and east, although the site is somewhat protected by its location in Richardson Bay, since there is higher terrain towards the northeast.



Percent wind 20 knots and greater											KUGLUKTUK, NUNAVUT					
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0	0	0.1	0.2	0	0	0	0	0.1	0	0	0.2	0.1	0.3	0.5	0.4
WINTER	0	0	0	0.3	0	0	0	0.1	0.4	0.8	1.2	1.3	0.4	1.2	1.0	0.2

Direction-wise north through east winds are dominant in the summer. West through southwest winds are dominant in the winter. The strongest winds tend to occur in the winter and to be from a southwest through west to north directions.



The percent of low ceilings and/or poor visibility at Kugluktuk show little diurnal variation during fall and winter, ranging from 15 to 20 percent over a 24 hour period. Winter blowing snow events occur primarily in a west to northwest flow.

In the spring, the poorest flying weather peaks at around 1100 UTC with slow improvement through the period 1400 UTC to about 20 UTC.

Summer brings the best flying conditions for Kugluktuk through the late afternoon and evening period, with less than 10 percent of the time having ceilings less than 1,000 feet and/or visibility less than 3 miles. Radiation fog and/or status ceilings routinely evolve overnight and persist through the morning.

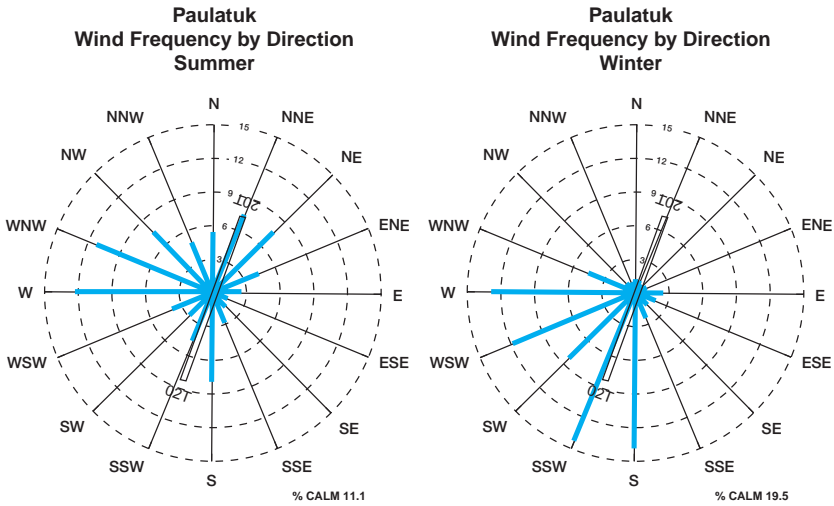
Paulatuk, Northwest Territories



Photo 5-22 - Paulatuk, NWT, looking north

credit: Municipal and Community Affairs, Government of the Northwest Territories

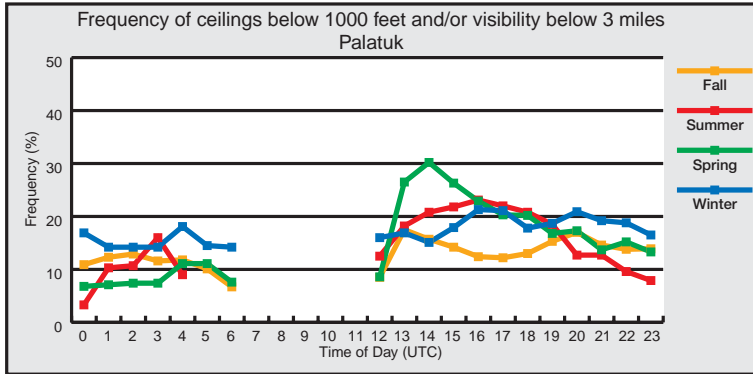
Paulatuk airport (elevation 18 feet ASL) lies northwest of the town. Paulatuk is located on the south shore of Darnley Bay, on an area of silt and sand with Amundson Gulf to the north. The Hornaday River is to the east of the town. There are many small lakes in the vicinity. The terrain gradually rises to 200 feet within 1 mile south of the site. Then, about 6 miles south of the site, there is an escarpment where the land rises from less than 300 feet to over 800 feet. East-southeast through southeast from the station, the escarpment is between 7 and 11 miles distant. Within 10 miles south of the airport, the land rises to over 1,200 feet ASL. The escarpment has significant impact on the local wind regime. Paulatuk lies north of the tree line.



Percent wind 20 knots and greater														PAULATUK, NWT			
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	
SUMMER	0	0	0	0	0	0.1	0.2	1.3	0.3	0.2	0.1	0.2	0.3	0.1	0	0	
WINTER	0	0	0.1	0	0	0.2	0.6	4.7	2.0	0.2	0.4	0.8	0.6	0	0	0	

Winds at Paulatuk show a strong tendency to blow strong from the south and south-southwest, moderate from the west, and light from the north to the east-southeast. The south and south-southwest winds can be very strong at times. Indeed, 1 percent of the 4.9 percent of the south winds that are 20 knots or stronger are in the 31 to 40 knots range and 0.2 percent are in the 41 to 50 knot range. At Paulatuk, a local scale wind system can develop over the Melville Hills beneath a winter inversion. Associated pressure jumps cause abrupt and sometimes violent changes in surface wind and severe turbulence in the lowest levels. The main core of the strong winds is close to Langton Bay and, at times, may not reach Paulatuk. During the months when the ground is snow covered, these very strong winds routinely generate blizzard conditions. Canada Flight Supplement provides the following “Caution” for

Paulatuk: “Subsidence, turbulence, and adverse cross-wind conditions may be encountered.” Weather maps during such wind events may show a rather innocent looking southeasterly through southwesterly gradient across the area.



Paulatuk experiences similar low ceilings and poor visibility conditions to that of other stations near the Beaufort Sea. Spring and summer show the highest percentage of poor flying weather, with the worst flying conditions through the morning most likely due to the formation of low cloud and/or fog overnight; albeit, the 1200 UTC and 1300 UTC observations show as having relatively good flying weather.

Conditions improve somewhat in the fall as the water freezes, and cold drier air moves over the region. Winter brings the most constant flying conditions with poor conditions occurring between 15 and 20 percent of the time. Blowing snow, snow, and ice crystals are the main restrictions to visibility in the late fall, winter and early spring.

Sachs Harbour, Northwest Territories

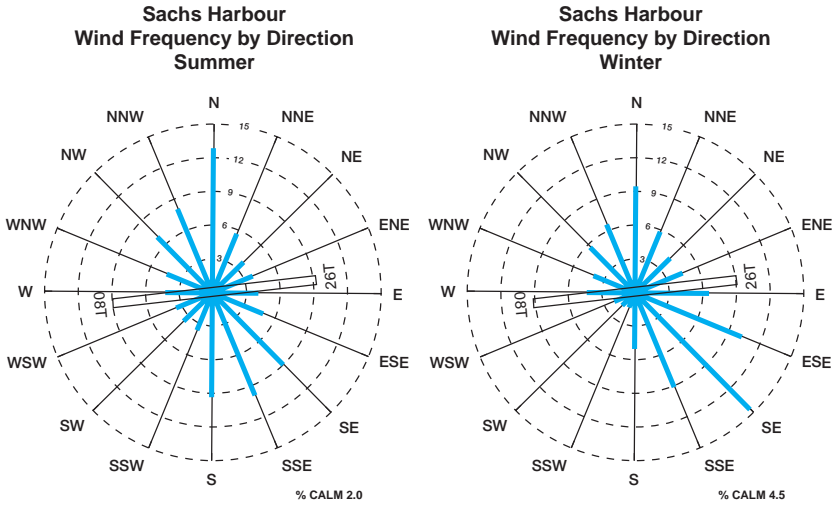




Photo 5-23 - Sachs Harbour town and airport looking north

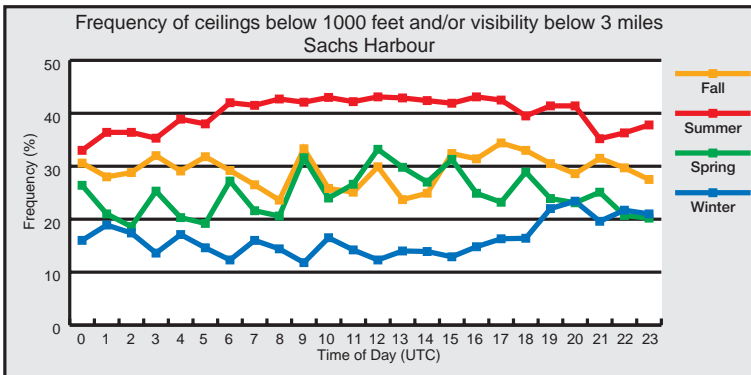
credit: Municipal and Community Affairs, Government of the Northwest Territories

The Sachs Harbour airport (elevation 281 feet ASL) is situated on a flat plateau less than a mile from the town. The town of Sachs Harbour is located on the north shore of Sachs Harbour, on the southwestern shores of Banks Island. It is the most northern community in the new Northwest Territories. The Canadian mainland lies approximately 135 n. miles to the south. Amundsen Gulf occupies the area from the southeast through to the west-southwest of the station. The Sachs River drains the area to the southeast and empties into Sachs Harbour about 4 miles east-southeast of the airport. The Kellett River, which drains the region to the north, empties into the Beaufort Sea, 12 miles northwest of the airport.



Percent wind 20 knots and greater													SACHS HARBOUR				
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	
SUMMER	0.4	0.4	0.2	0.1	0.2	0.8	0.7	0.1	0	0	0.1	0.4	0.5	0.6	0.7	1.0	
WINTER	0.1	0.2	0.2	0.3	0.6	0.8	0.7	0.2	0	0.1	0.1	0.1	0.6	0.2	0.5	0.5	

Southeast winds dominate at Sachs Harbour. North through northwest winds are also relatively common while southwest winds are rare. North-northeast through east-southeast winds are off land while remaining directions are onshore. Winds, when they are strong, tend to be from the southeast or northwest. The flat and limited vegetation across the area facilitates blowing snow during winter strong wind events.



At Sachs Harbour, the frequency of cloud ceilings below 1000 feet and/or visibility less than 3 miles is highest during the summer, the opposite of other stations in the GFACN35 domain. There is routinely low cloud and/or fog across the open water

and ice of the Beaufort during the summer, waiting for an onshore flow to push inland. The stratus and fog which moves over the station usually lasts through the day.

Winter provides the best flying conditions at Sachs Harbour. During winter, poor flying conditions range from 10 to 20 percent and when they occur are mainly due to snow, blowing snow and low cloud.

Other Sites in the Northwest Territories

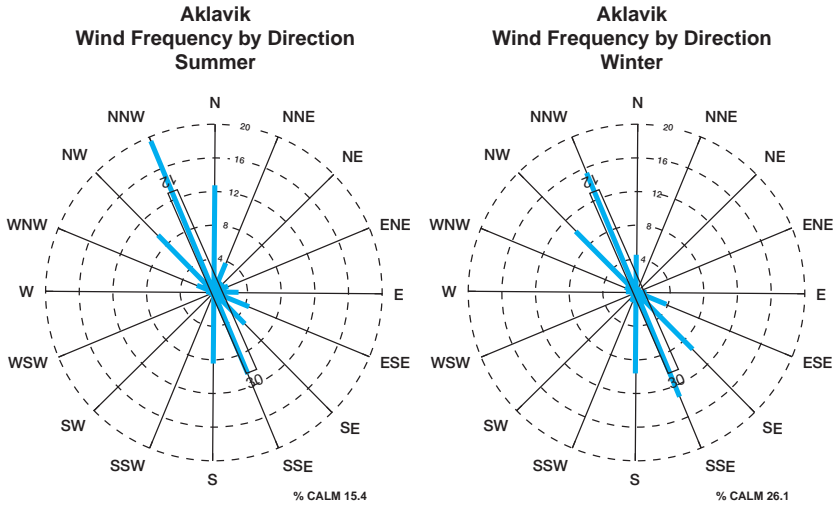
Aklavik



Photo 5-24 - Aklavik looking northwest

credit: Municipal and Community Affairs
Government of the Northwest Territories

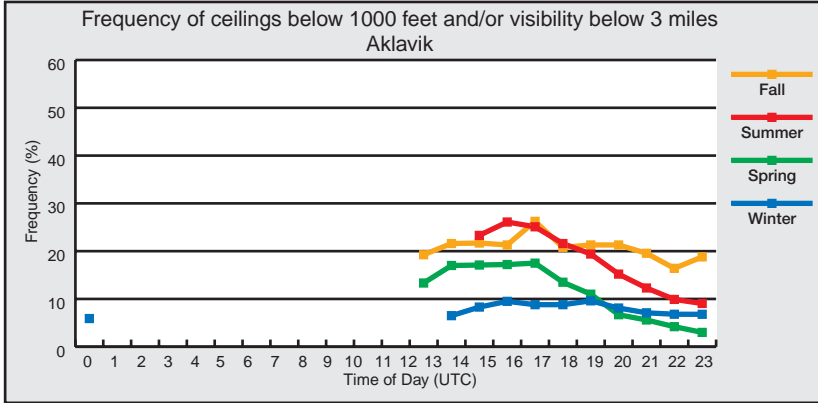
The Aklavik runway (elevation 21 feet) lies on the northeast side of the community. Aklavik lies on the Peel Channel of the Mackenzie River Delta.



Percent wind 20 knots and greater															AKLAVIK		
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	
SUMMER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	
WINTER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	

In winter, winds at Aklavik favour calm. When the winds blow, southeast, south-southeast and south winds, along with northwest and north-northwest winds, dominate. The strongest winter winds tend to be from the northwest and can generate blowing snow.

There is a similar trend in summer but calm winds give way to north-northwest winds. There are also a lot more north winds in summer than in winter. The strongest winds tend to blow from the northwest and north-northwest. These winds bring a “burst of Beaufort” with low ceilings and areas of fog across the Delta, including Aklavik.



Summer and fall show as having the poorest flying weather while winter has the best. In summer and fall, northwesterly winds routinely bring low cloud and, at times fog, to the area. Even without the northwest winds, being in a marine environment, fog and/or low cloud can develop overnight and linger. Diurnally, there is a daily trend to improved flying conditions as the day progresses, except in winter. This trend is most pronounced in summer, with the most favorable conditions late afternoon through evening. In winter, the Beaufort is frozen over except for leads and, thus, bursts of Beaufort are generally cloud free. In fall, the low cloud over the area can be freezing drizzle laden. Also, late summer into fall prior to the Beaufort freezing over, bursts of Beaufort can bring snowflurry activity to Aklavik.

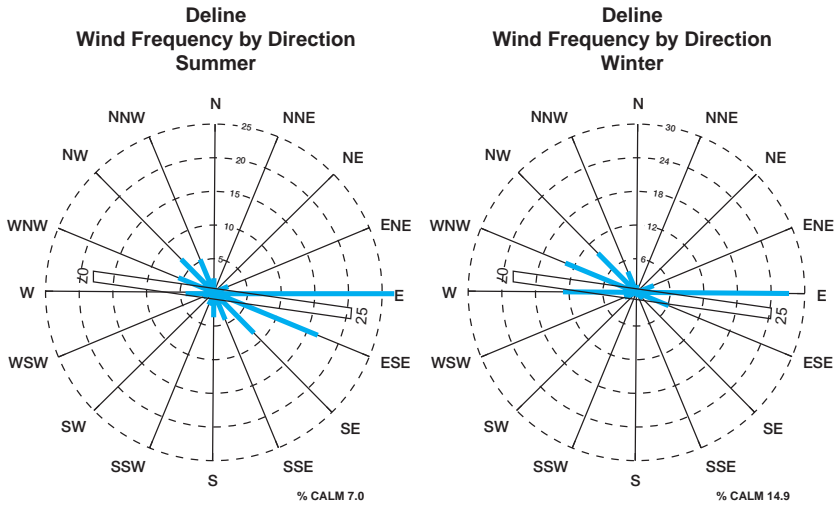
Deline





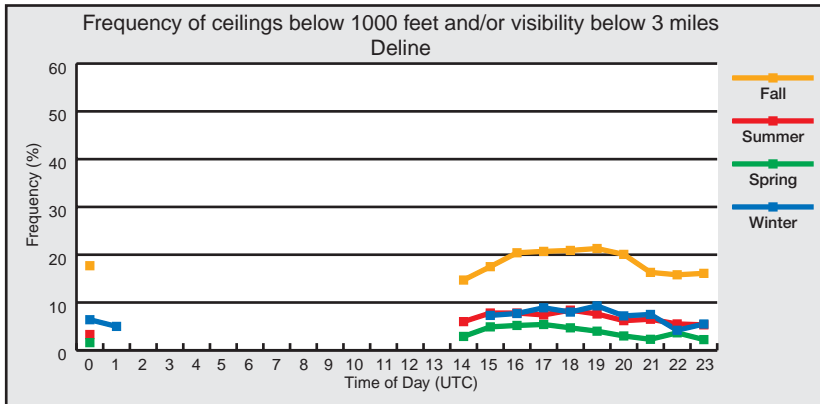
Photo 5-25 - Deline looking northwest credit: Municipal and Community Affairs, Government of the Northwest Territories

The Deline airport (elevation 698 feet) is a short distance north of the community. Deline lies on the north shore of Keith Arm, southwestern Great Bear Lake, about 6 miles from the head of the Great Bear River. The area is thinly forested and the land slopes toward the lake.



Percent wind 20 knots and greater																DELINE	
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	
SUMMER	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	
WINTER	0.0	0.0	0.1	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	

In winter, east winds dominant with respect to both frequency and strength. West, west-northwest and calm winds are other dominant winds. Summer winds tend to not be as strong as the winter winds and the frequency of calm winds is about half of that in winter. East and east-southeast are the dominant wind directions in summer.



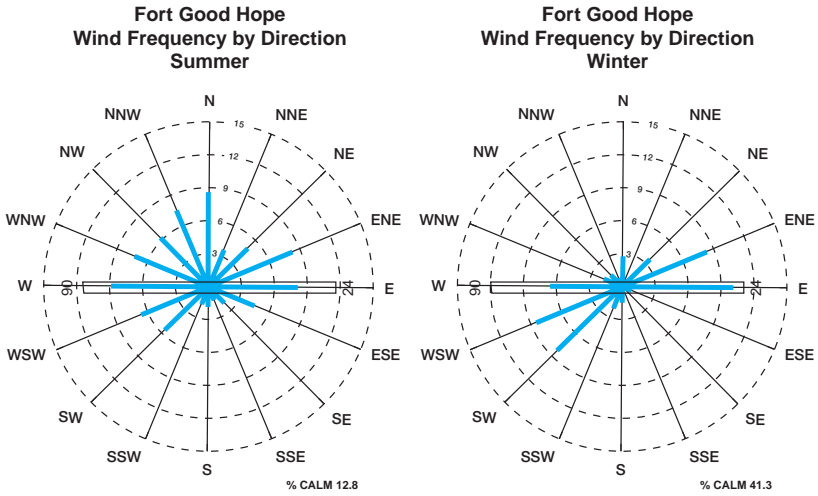
Flying conditions at Deline are poorest during the fall as low cloud from Great Bear Lake and/or the Mackenzie Valley routinely blankets the area. This fall cloud can be freezing drizzle laden. Flying conditions are best during the spring with its long hours of daylight, while the lakes - including Great Bear Lake - and the rivers of the area remain frozen over. Areas of open water persist through the winter at the head of Great Bear River, providing a source of ice fog. Looking at the graphs from the perspective of diurnal trends, late afternoon and early evening flying conditions show as being the most favorable.

Fort Good Hope



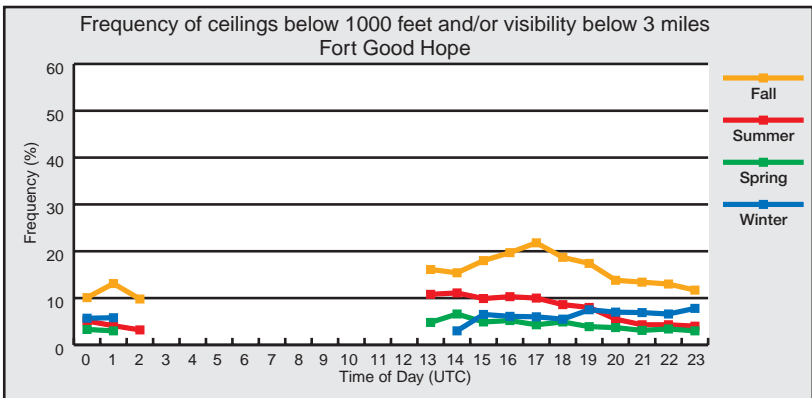
Photo 5-26 - Fort Good Hope looking southwest credit: Pryde Schropp McComb Inc

Fort Good Hope lies on the east bank of the Mackenzie River, about 15 n. miles south of the Arctic Circle and 3 miles south of the “Ramparts” limestone cliffs of the Mackenzie.



Percent wind 20 knots and greater													FORT GOOD HOPE			
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
WINTER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0

Weather observations from Fort Good Hope show winter winds favoring calm (41%) with east-northeast, east, southwest, west-southwest and west wind directions making a showing. At the expense of calm winds (down to 12%), and with south winds being the exception, summer winds at Fort Good Hope blow from any direction.



Fall has the poorest flying weather as low cloud routinely blankets the Mackenzie Valley. The fall cloud can be freezing drizzle laden. During the fall, flying weather shows improvement through the afternoon, such that the most favorable conditions generally occur late afternoon into evening. Spring has the best flying weather. Sunlight hours are long and the lakes and rivers of the area are frozen over.

Fort Liard

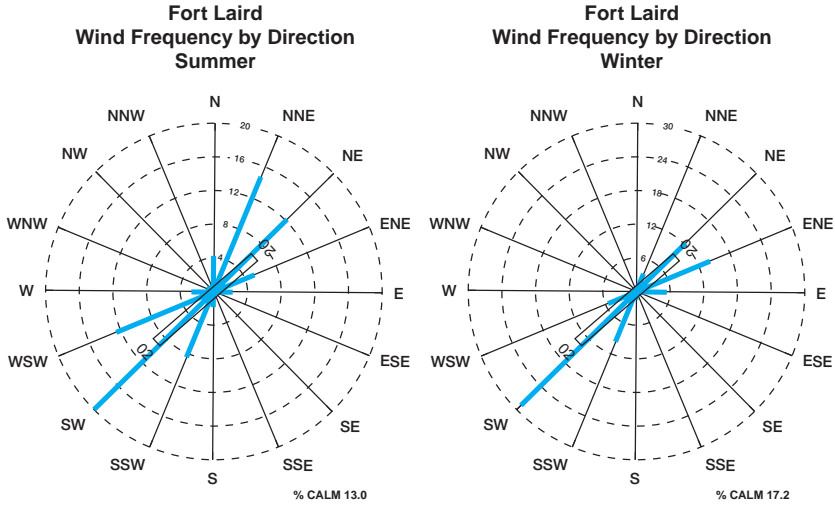


Photo 5-27 Fort Liard, looking southeast

credit: Municipal and Community Affairs, Government of the Northwest Territories

The Fort Liard airport (elevation 706 feet) lies just east of the community on the east banks of the Liard River, which runs northeast to southwest and north of the Petitot River. By air, the community is 14 n. miles north of the British Columbia border.

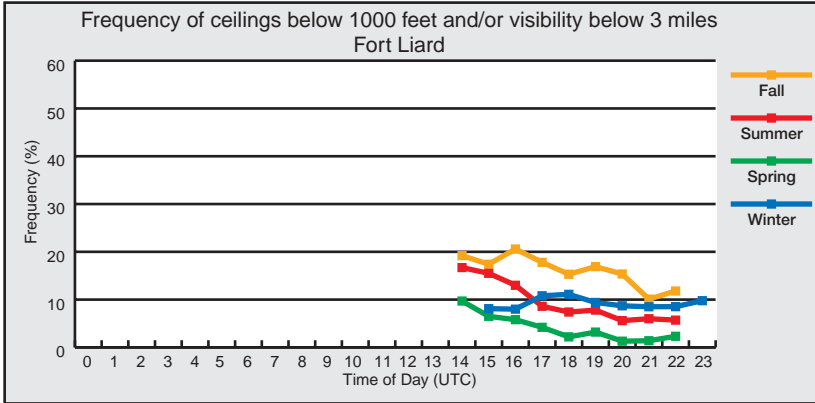
The terrain to the north and west of the airport rises to an elevation of over 4,000 feet ASL, with a maximum of over 5,200 feet in the Kotaneeire Range, 30 n. miles to the northeast. In the remaining directions, the terrain is much flatter with the area covered in trees.



Percent wind 20 knots and greater													FORT LIARD			
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WINTER	0.1	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0

Winds at Fort Liard line up with the Liard River Valley. A ridge of high pressure building southeast along the Mackenzie River Valley (pressure rises) will, in winter, give northeast or east-northeast winds. Disturbances approaching from the west or southwest (pressure falls) will give southwest winds in winter. In summer, north-northeast and northeast winds are routine with pressure rises, while southwest and west-southwest winds are routine with pressure falls.

Calm winds show at 17% in winter and 13% in summer. With southwesterly or westerly flow aloft, Fort Liard can experience lee or mountain waves which, in turn, can cause low level wind shear or turbulence.



Northeast winds can bring Mackenzie Valley low cloud to Fort Liard. Conditions at Fort Liard can be quick to change with upper disturbances approaching from the southwest or west. As these disturbances near, cloud can quickly thicken and ceiling and visibility lower, particularly in winter when the precipitation is snow.

Fall shows as having the poorest flying weather and spring the most favorable. Spring, summer and fall all show a diurnal trend with the most favorable flying weather occurring later afternoon into evening.

Fort Resolution

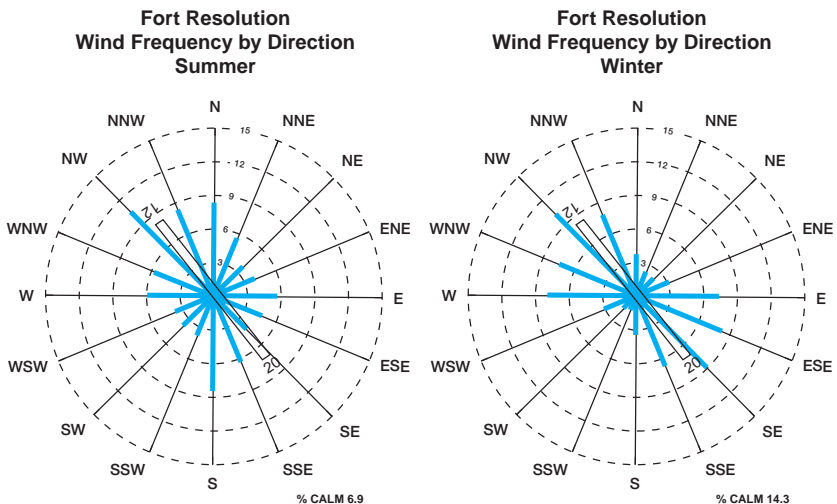




Photo 5-28 - Fort Resolution looking west.

credit: Municipal and Community Affairs, Government of the Northwest Territories

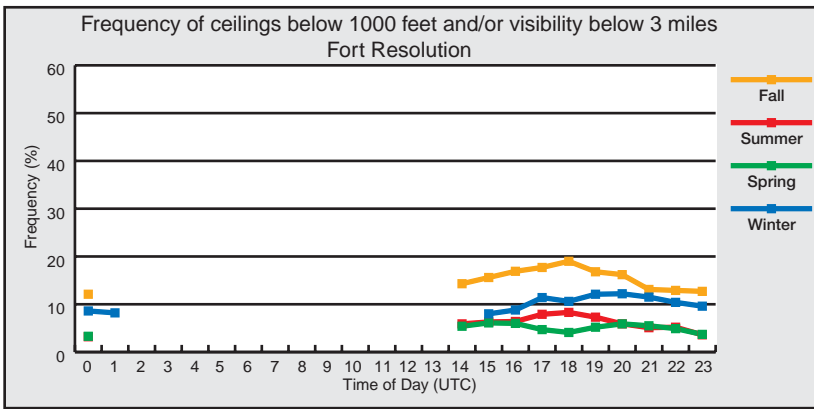
The Fort Resolution airport (elevation 526 feet) lies just northwest of the community. Fort Resolution lies on a peninsula southwest of the Slave River Delta, on the south shore of Great Slave Lake. The community is 95 n. miles southeast of Yellowknife.



Percent wind 20 knots and greater													FORT RESOLUTION				
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	
SUMMER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	
WINTER	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.1	

In winter, northwest and calm winds dominate. If the winter winds are strong, they are most likely to be from the northwest, north-northwest or north. East, east-south-east and southeast winds also figure with respect to both frequency and strength.

Summer winds show a similar pattern with respect to frequency and speed.



The most favourable flying conditions occur in spring as Great Slave Lake is frozen over and there is abundant sunlight. Summer flying weather shows almost as favorable flying conditions. Fall shows the poorest flying weather as northwesterly flows off Great Slave Lake push low cloud and, at times, snow streamers inland. The fall low cloud can be laden with freezing drizzle.

Lutselk'e

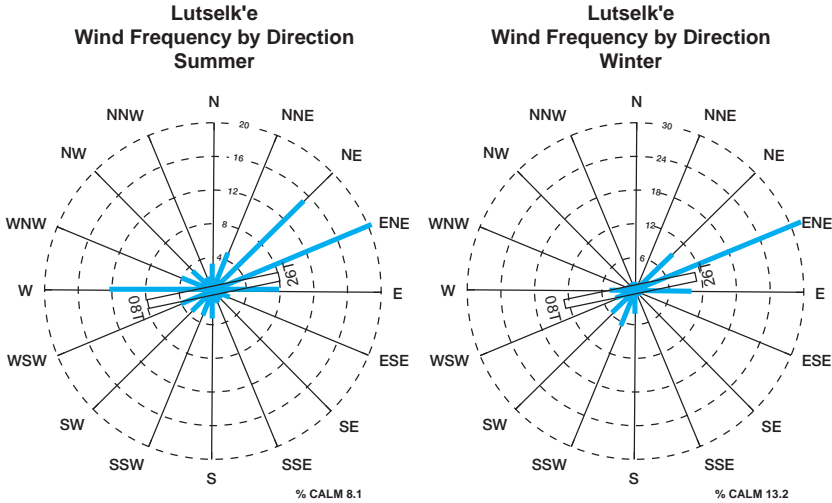


Photo 5-29 - Lutselk'e looking northeast credit: Municipal and Community Affairs, Government of the Northwest Territories

The airstrip (elevation 587 feet) lies east-northeast of the community of Lutselk'e.

Lutselk'e is about 108 n miles east of Yellowknife and lies at the end of a peninsula in Christie Bay, on the southern shore of the East Arm of Great Slave Lake.

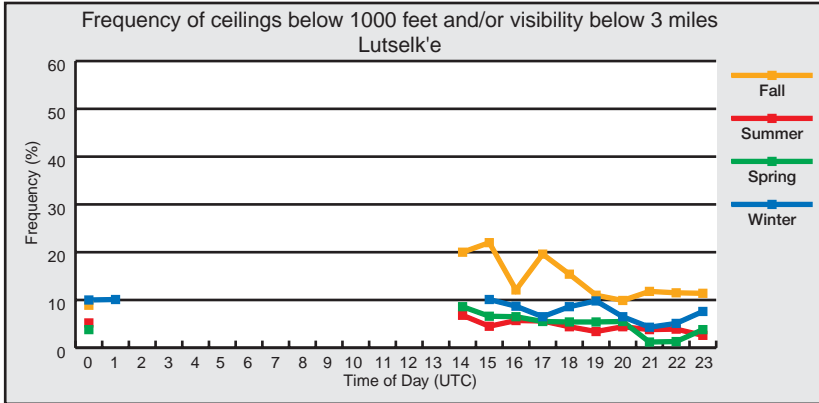
About 6 n. miles northeast of the airport terrain rises to 1175 feet.



Percent wind 20 knots and greater																
															LUTSELK'E	
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0.1	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
WINTER	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0

In winter, northeast, east-northeast, east and calm winds dominate at Lutselk'e. East-northeast winds are the most dominant at 32 percent. When winds are strong, they tend to be from the east-northeast or southwest.

In summer, there are more westerly winds than in winter but fewer calm winds and fewer northeasterly winds. The strongest summer winds are routinely from the northeast and, to a lesser degree, from the east-northeast.



Fall has the poorest flying weather while spring and summer have the most favorable. Low cloud from Great Slave Lake is routinely nearby during the fall and this cloud can be freezing drizzle laden.

Rae Lakes

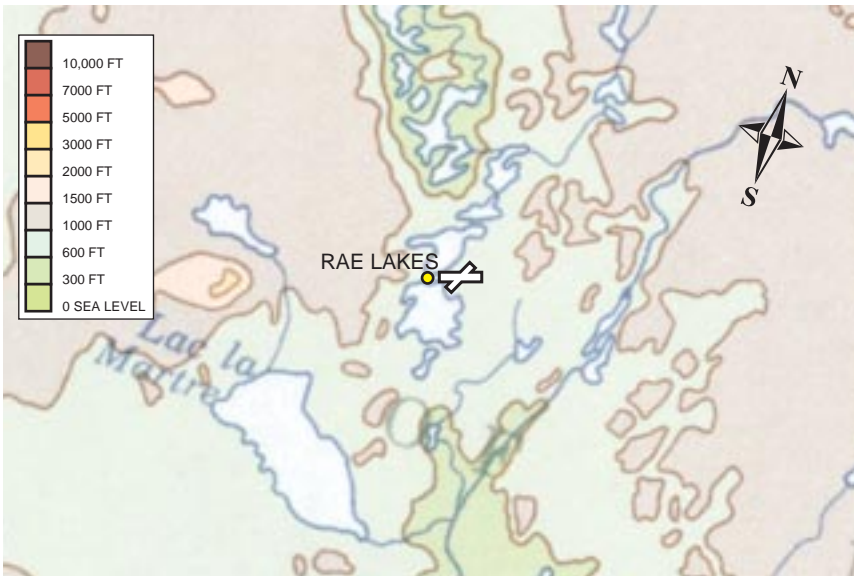
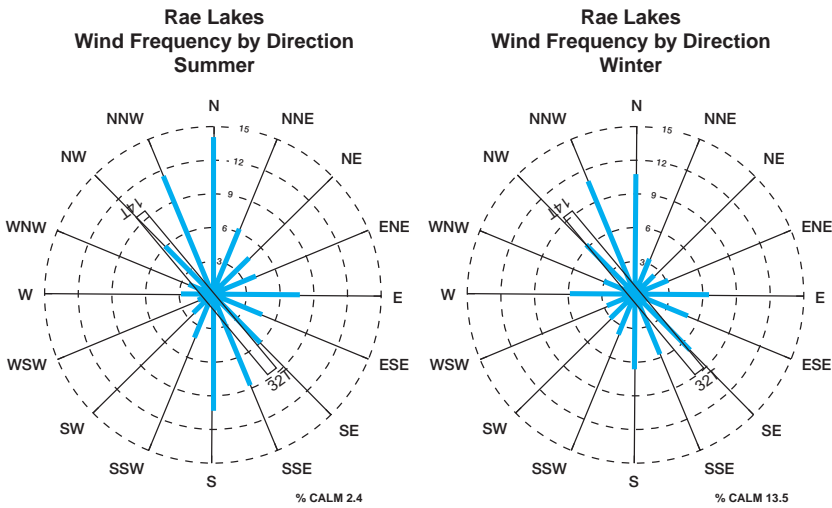




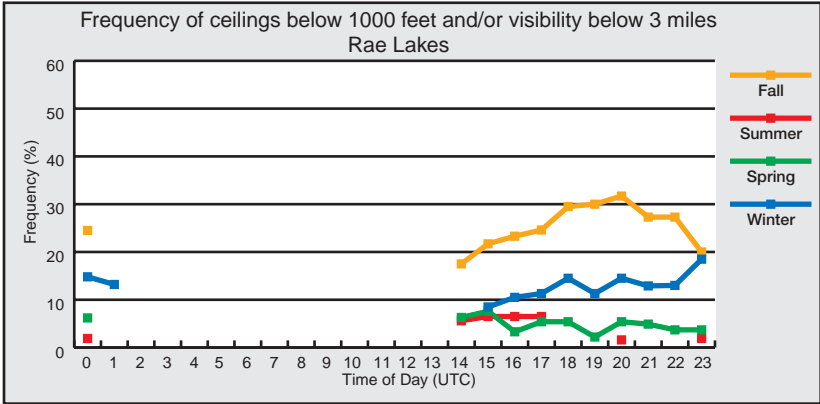
Photo 5-30 - Rae Lakes looking northwest. credit: Pryde Schropp McComb Inc

Rae Lakes airport (elevation 700 feet) lies on a peninsula which juts into Rae Lake. Rae Lakes lies in a realm of lakes between the 2 major lakes of the Northwest Territories - Great Slave Lake and Great Bear Lake.



Percent wind 20 knots and greater													RAE LAKES			
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.1
WINTER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1

In winter, north-northwest, north, and calm winds are dominant and winds, if strong, tend to be from the northwest through north direction. In summer, the same northwest through north winds show not only as being frequent but being the strongest. Calm winds are rare in summer while south winds are frequent.



The poorest flying weather occurs during the fall while the most favorable flying weather occurs during the summer and spring. Prior to freeze-up, northwest winds can feed low cloud from Great Bear Lake into the Rae Lakes area, while southeast winds have Great Slave Lake to tap for low cloud to push into the Rae Lakes area. Fall low cloud can be laden with freezing drizzle.

Tulita

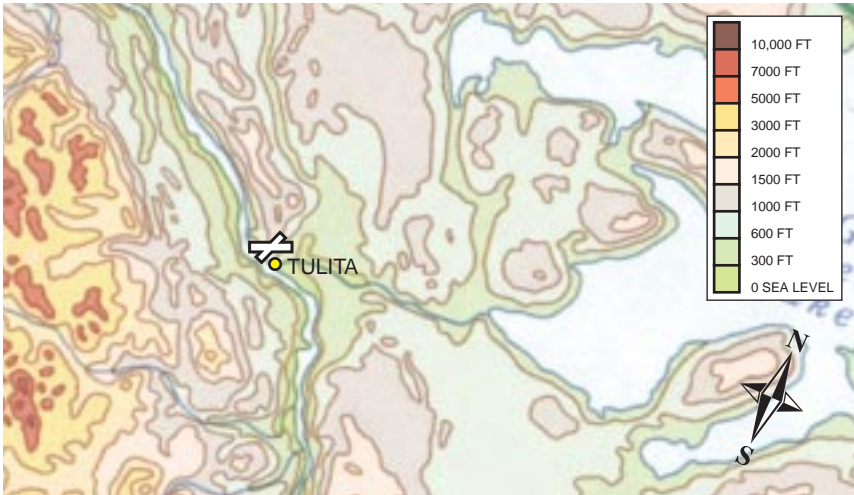
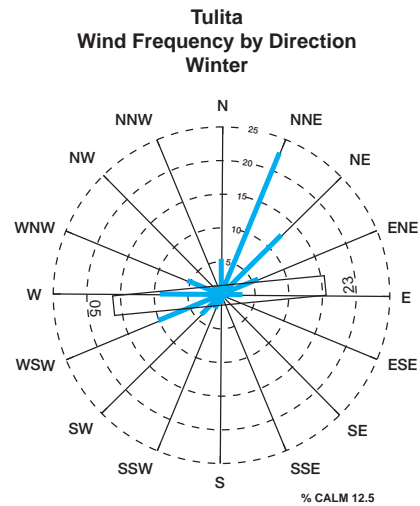
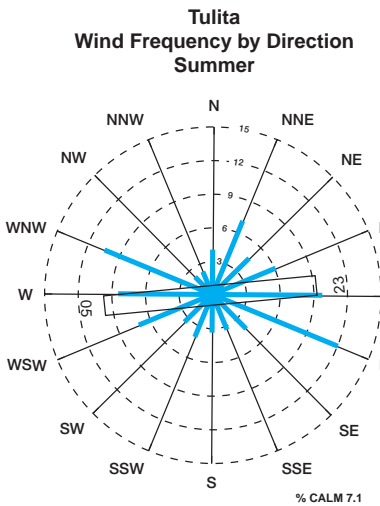




Photo 5-31 - Tulita looking north
(Great Bear River blue, Mackenzie River brownish)

credit: Municipal and Community Affairs, Government of the Northwest Territories.

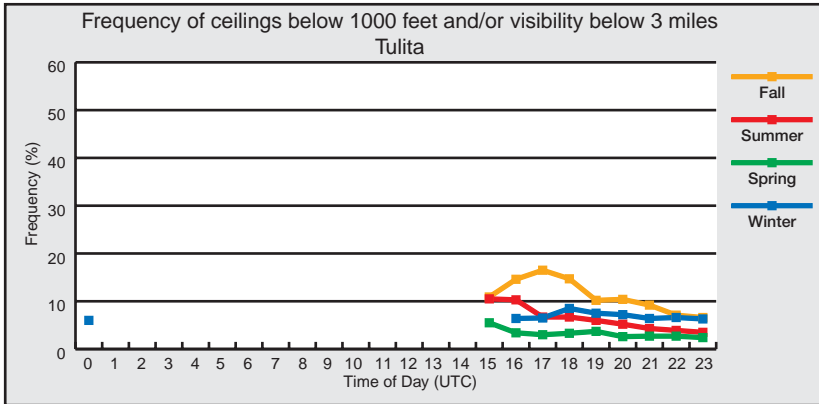
Tulita airport (elevation 332 feet) lies on the east bank of the Mackenzie River, south of its junction with the Great Bear River. Bear Rock (elevation 1436 feet), known for low level turbulence, lies about 5 n. miles west of the airport.



Percent wind 20 knots and greater														TULITA		
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.1	0.0	0.0
WINTER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0

In winter, the north-northeast wind is dominant while winds from the northeast, west-southwest, west and calm make a strong showing. The strongest winter winds tend to be those from the west, west-northwest and northwest. In summer, east, east-southeast, west and west-northwest winds are the most frequent. When winds are strong, they are most often from the west-northwest.

Bear Rock, about 5 n. miles west of the airport, is cited as an area of low level turbulence.



The poorest flying weather occurs during the fall, while the most favorable flying weather occurs during the spring. Fall low cloud can be laden with freezing drizzle.

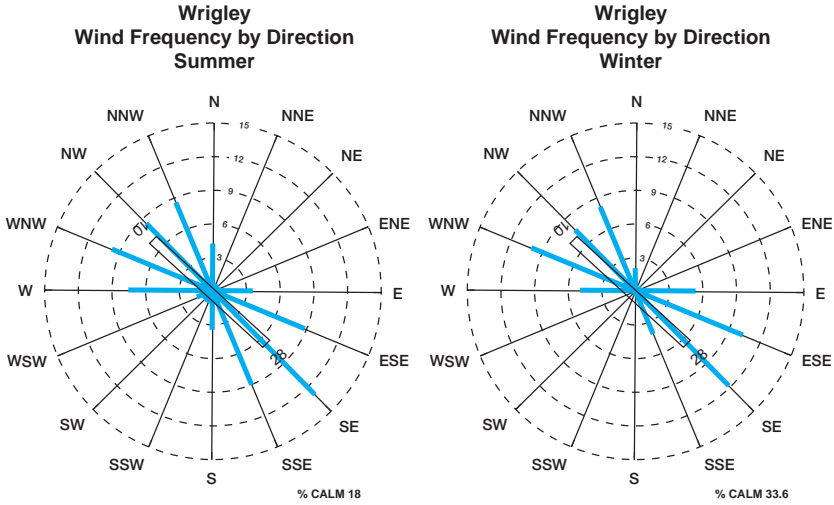
Wrigley



Photo 5-32 - Wrigley looking east

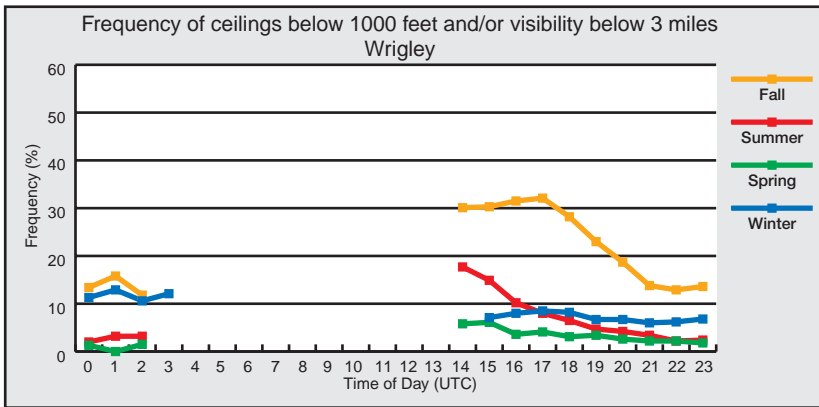
credit: Municipal and Community Affairs,
Government of the Northwest Territories

Wrigley airport (elevation 493 feet) is located 104 n. miles north of Fort Simpson and 252 n. miles northwest of Yellowknife. The community is on the east bank of the Mackenzie River, below its junction with the Wrigley River. The area is forested and mountainous terrain is nearby. The peak of Cap Mountain, for example, which is over 5,000 feet, lies about 7 n. miles northeast.



Percent wind 20 knots and greater															WRIGLEY	
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WINTER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0

In winter, winds at Wrigley favour calm (almost 34%) and when they do blow, east-southeast, southeast, and west-northwest directions prevail. The strongest winter winds tend to be from the north-northwest. In summer, calm winds are still dominant (18%) but to a lesser degree. Summer winds like to blow from southeasterly and northwesterly directions.



The flying weather at Wrigley is at its worst in fall and at its best during the spring. The fall weather shows a strong diurnal improving trend starting at about mid day and continuing through the afternoon, such that during the fall, the most favourable flying weather occurs late afternoon into evening.

Glossary of Weather Terms

- anabatic wind** - a local wind which blows up a slope heated by sunshine.
- advection** - the horizontal transportation of air or atmospheric properties.
- air density** - the mass density of air expressed as weight per unit volume.
- air mass** - an extensive body of air with uniform conditions of moisture and temperature in the horizontal.
- albedo** - the ratio of the amount of solar radiation reflected by a body to the amount incident on it, commonly expressed as a percentage.
- anticyclone** - an area of high atmospheric pressure which has a closed circulation that is anticyclonic (clockwise) in the Northern Hemisphere.
- blizzard** - a winter storm with winds exceeding 40 km/h, with visibility reduced by falling or blowing snow to less than one kilometre, with high windchill values and lasting for at least three hours. All regional definitions contain the same wind speed and visibility criteria but differ in the required duration and temperature criterion.
- cat's paw** - a cat paw-like, ripple signature on water given by strong downdrafts or outflow winds. A good indication of turbulence and wind shear.
- ceiling** - either (a) the height above the surface of the base of the lowest layer of clouds or obscuring phenomena (i.e. smoke) that hides more than half of the sky; (b) the vertical visibility into an obstruction to vision (i.e. fog).
- chinook** - a warm dry wind blowing down the slopes of the Rocky Mountains and over the adjacent plains.
- clear air turbulence (CAT)** - turbulence in the free atmosphere not related to convective activity. It can occur in cloud and is caused by wind shear.
- clear icing** - the formation of a layer or mass of ice which is relatively transparent because of its homogeneous structure and smaller number and size of air spaces; synonymous with glaze.
- climate** - the statistical collection of long-term (usually decades) weather conditions at a point; may be expressed in a variety of ways.
- cold front** - the leading edge of an advancing cold air mass.
- convection** - atmospheric motions that are predominately vertical, resulting in the vertical transport and mixing of atmospheric properties.
- convergence** - a condition that exists when the distribution of winds in a given area is such that there is a net horizontal inflow of air into the area; the effect is to create lift.
- cumuliform** - a term descriptive of all convective clouds exhibiting vertical development.

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

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

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

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

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

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

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

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

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

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

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

Table 1 - The Fujita Scale

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

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

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

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

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

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

Table 2 - Saffir-Simpson Hurricane Scale

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

icing - any deposit of ice forming on an object.

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

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

isothermal layer - equal or constant temperature with height.

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

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

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

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

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

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

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

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

meteorology - the science of the atmosphere.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

supercooled water - liquid water at temperatures below freezing.

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

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

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

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

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

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

turbulence - any irregular or disturbed flow in the atmosphere.

updraft - a localized upward current of air.

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

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

warm front - the trailing edge of retreating cold air.

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

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












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

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

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

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

Table 3: Symbols Used in this Manual

	<p>Fog Symbol (3 horizontal lines) This standard symbol for fog indicates areas where fog is frequently observed.</p>
	<p>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.</p>
	<p>Icing symbol (2 vertical lines through a half circle) This standard symbol for icing indicate areas where significant icing is relatively common.</p>
	<p>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.</p>
	<p>Turbulence symbol This standard symbol for turbulence is also used to indicate areas known for significant windshear, as well as potentially hazardous downdrafts.</p>
	<p>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.</p>
	<p>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.</p>
	<p>Snow symbol (asterisk) This standard symbol for snow shows areas prone to very heavy snowfall.</p>
	<p>Thunderstorm symbol (half circle with anvil top) This standard symbol for cumulonimbus (CB) cloud is used to denote areas prone to thunderstorm activity.</p>
	<p>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.</p>
	<p>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.</p>

Appendix





