Impact of Weather on Aviation

Suad Mohammad Ali Abdullah Abul

Abstract: This paper presents the effects of climate change and weather conditions on the air transport sector. And also examined turbulent weather conditions and their relationship to aircraft operations as well as the influence of dry and wet seasons on weather parameters of rainfall, thunderstorm and fog at the Port Harcourt International Airport. The aim was to identify which weather parameter affects aircraft operations which entails flight delay, cancellation and diversion.

Keywords: Introduction Atmosphere-Climate-Weather-Winds- Visibility- Ceiling-Steam Fog-Ice Fog- Thunderstorms-Snow-Icing and conclusion

I. INTRODUCTION

This chapter explains basic weather theory and offers pilots backgro Weather is an important factor that influences aircraft performance and flying safety. It is the state of the atmosphere at a given time and place with respect to variables, such as temperature (heat or cold), moisture (wetness or dryness), wind velocity (calm or storm), visibility (clearness or cloudiness), and barometric pressure (high or low). The term "weather" can also apply to adverse or destructive atmospheric conditions, such as high winds.
And knowledge of weather principles. It is designed to help them gain a good understanding of how weather affects daily flying activities. Understanding the theories behind weather helps a pilot make sound weather decisions based on the reports and forecasts obtained from a Flight Service Station (FSS) weather specialist and other aviation weather services. **[1]** Be it a local flight or a long cross-country flight, decisions based on weather can dramatically affect the safety of the flight.

A. Layers of the Atmosphere

Though people function primarily in the lowest level of the atmosphere, there are times, such as when we fly in aircraft or visit mountainous terrain, when we leave our normal altitude. The thinner atmosphere at these higher altitudes may affect us if we are not accustomed to it. Visitors to Inca ruins in the Andes or high-altitude Himalayan climbers may experience altitude sickness, and even skiers in the Rockies near mile-high Denver may need time to adjust. The air at these levels is much thinner than most of us are used to; by this we mean there is more empty space between air molecules and thus less oxygen and other gases in each breath of air.

As one travels from the surface to outer space, the atmosphere undergoes various changes, and it is necessary to look at the vertical layers that exist with Earth's atmospheric envelope. There are several systems used to divide the atmosphere into vertical layers.

One system uses temperature and rates of temperature changes. Another uses the changes in the content of the gases in the atmosphere, and yet a third deals with the functions of these various layers. **[2]** these layers provide. In this system, the atmosphere is divided into two distinct layers, the lowest of which is the ozonosphere. This layer lies approximately between 15 and 50 kilometers (10–30 mi) above the surface. The ozonosphere is another name for the ozone layer mentioned previously. Again, ozone effectively filters the UV energy from the sun and gives off heat energy instead. As we have noted, although ozone is a toxic pollutant at Earth's surface, aloft, it serves a vital function for Earth's life systems. From about 60–400 kilometers (40–250 mi) above the surface lies the layer known as the ionosphere. This name denotes the ionization of molecules and atoms that occurs in this layer, mostly as a result of UV rays, X-rays, and gamma radiation. Ionization refers to the process hereby atoms are changed to ions through the removal or addition of electrons, giving them an electrical charge. The ionosphere in turn helps shield Earth from the harmful shortwave forms of radiation. This electrically charged layer also aids in transmitting communication and broadcast signals to distant regions of Earth. It is in the ionosphere that the auroras occur. The ionosphere gradually gives way to interplanetary space

B. Weather and Climate

Weather: Temperature, pressure, wind, humidity and precipitation, interact with each other. They influence the atmospheric conditions like the direction and velocity of wind, amount of insolation, cloud-cover and the amount of precipitation. These are known as the elements of both weather and climate. The influence of these elements differs from place to place and time to time. It may be restricted to a small area and for a short duration of time. We very often describe this influence in the name of weather as sunny, hot, warm, cold, fine, etc depending upon the dominant element of weather at a place and at a point of time. Therefore, weather is the atmospheric condition of a place for a short duration with respect to its one or more elements. Two places even a short distance apart may have different kind of weather at one and the same time.

Climate: The average weather conditions, prevalent from one season to another in the course of a year, over a large area is known as climate. The average of these weather conditions is calculated from the data collected for several year (about 35 years) for a larger area. Rajasthan, for example, experiences hot and arid climate, Kerala has tropical rainy climate, Greenland has cold desert climate and the climate of Central Asia is temperate continental. Climate of a region is considered more or less permanent. **[3]**

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II. THE FOLLOWING SECTIONS DISCUSS VARIOUS WEATHER FACTORS OR WEATHER FACTOR CATEGORIES AND THEIR RELATIONSHIPS WITH AVIATION ACCIDENTS:

A. Visibility- Ceiling

Visibility refers to the greatest horizontal distance at which prominent objects can be viewed with the naked eye. Visibility is affected by factors such as precipitation, fog, and haze. For aviation purposes, a ceiling is defined as the lowest layer of clouds reported as being broken or overcast, or the vertical visibility into an obscuration like fog or haze. Visibility/ceiling was the second largest cause or contributing factor in weather-related accidents 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.

B. Types of Visibility

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

- **Horizontal visibility**

- The furthest visibility obtained horizontally in a specific direction by referencing objects or lights at known distances.

- **Prevailing visibility**

- The ground level visibility which is common to one-half or more of the horizon circle.

- **Vertical visibility**

- The maximum visibility obtained by looking vertically upwards into a surface-based obstruction such as fog or snow.

- **Slant visibility**

- Visibility observed by looking forward and downwards from the cockpit of the aircraft.

- **Flight visibility**

- The average range of visibility at any given time forward from the cockpit of an aircraft in flight.

- Causes of Reduced Visibility

- **Lithometers**

Litho meters 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.

- **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.

- **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. **[4]**

- **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.

C. 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.

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.

Advection Fog

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

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.

Snow Squalls and Streamers

Snow squalls are relatively small areas of heavy snowfall. They develop when cold arctic air passes over a relatively warm water surface, such as Lake Winnipeg, before freeze-up. An injection of heat and moisture from the lake into the low levels of the atmosphere destabilizes the air mass. If sufficient destabilization occurs,

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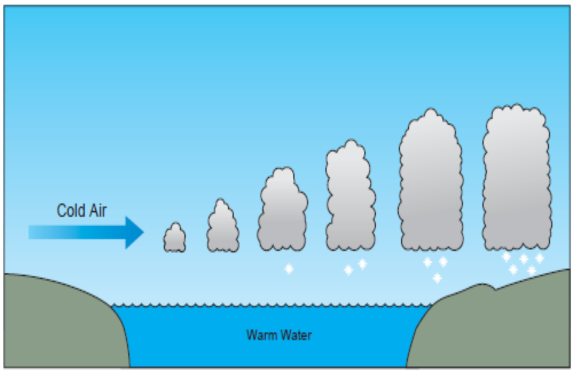
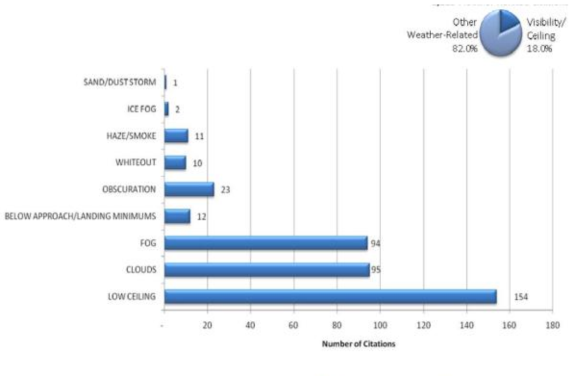


Snowsqualls building over open water

Visibility/Ceiling Citations 2003–2007

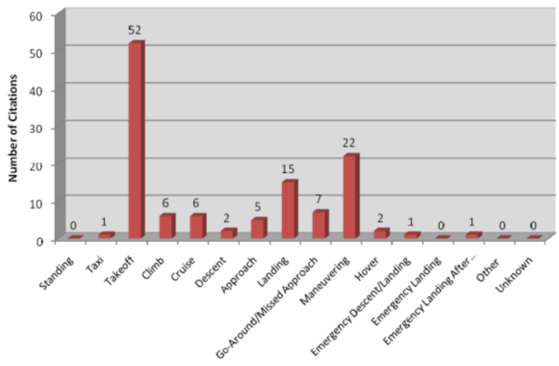


Not mutually exclusive. Total number of visibility/ceiling citations = 402.
Source: NTSB Aviation Accident and Incident Database

D. High Density Altitude

Density altitude is the vertical distance above sea level in the standard atmosphere at which given density is to be found. It is calculated by correcting altitude for nonstandard pressure and temperature. Density altitude is a significant factor in aircraft performance

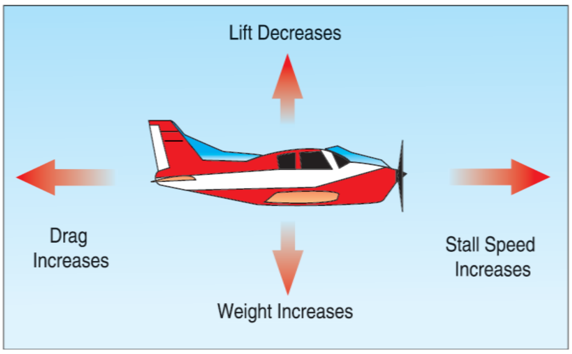
High Density Altitude Citations by Phase of Flight 2003–2007



Not mutually exclusive. Total number of density altitude citations = 120.
Source: NTSB Aviation Accident and Incident Database

E. Icing Conditions

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 super cooled 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 super cooled 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:



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. **[5]**

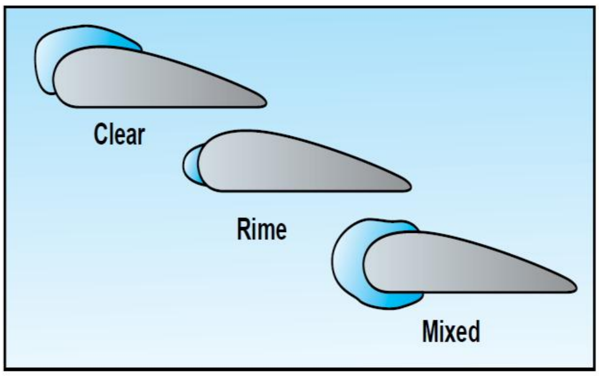
F. Types of Aircraft Ice

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..

Accumulation Patterns of Different Icing Types



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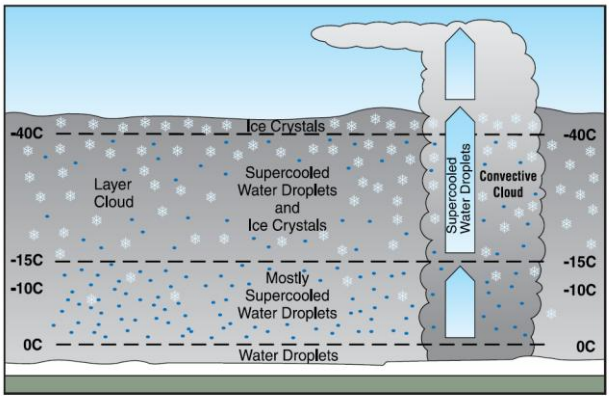
G. Meteorological Factors Affecting Icing

- **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 higher liquid water content than those that form in cold air.
Despite this, some generally accepted rules have been developed:



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.

H. 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.

I. Supercooled Large Drop Icing

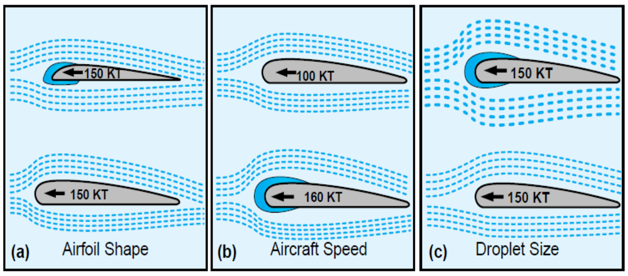
Supercooled large drop (SLD) icing has, until fairly recently, only been associated with freezing rain. Several accidents and significant icing events have revealed the existence of a deadly form of SLD icing in non-typical situations and locations. It was
found that large cloud drops, the size of freezing 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 through out 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,

The Glory: A Warning Sign for Aircraft Icing

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.

J. 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. **[6]**



Variations in Collection Efficiency

III. OTHER FORMS OF ICING

- **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.

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Such conditions are relatively common in the winter and tend to last a little longer in valleys than over flat terrain.

- **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.

- **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, evaporation 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.

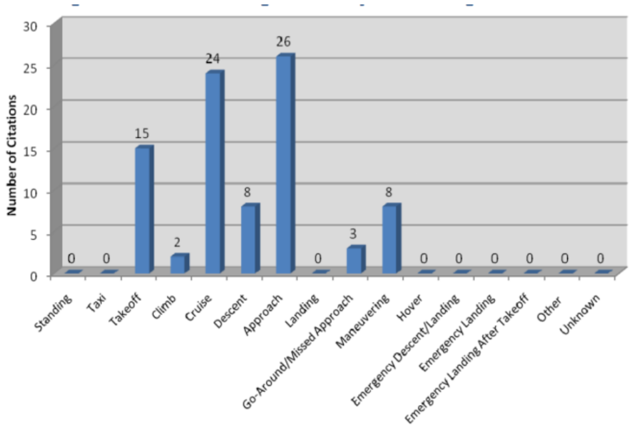
- **Freezing Spray**

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.

- **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.

***Carburetor Icing Citations by Phase of Flight 2003–2007**

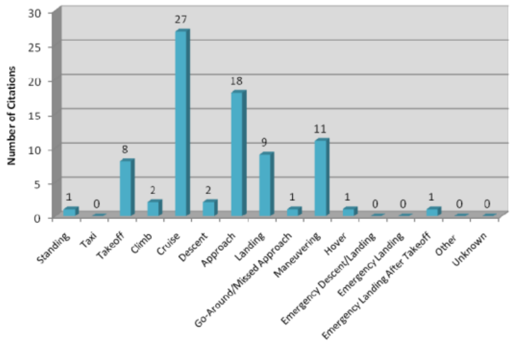


Not mutually exclusive. Total number of carburetor icing citations = 86.
Source: NTSB Aviation Accident and Incident Database

A. Precipitation

Precipitation is defined as any type of water particle that forms in the atmosphere and then falls to the ground. Forms of precipitation include drizzle, rain, snow, and hail. Precipitation can affect the safety of flight by reducing visibility,

***Precipitation Citations by Phase of Flight 2003–2007**



Not mutually exclusive. Total number of precipitation citations = 81.
Source: NTSB Aviation Accident and Incident Database

B. Thunderstorms

Thunderstorms occurring as the result of surface heating are known as air mass thunderstorms. Those occurring as the result of weather systems are known as steady-state thunderstorms. Hazards associated with thunderstorms include hail, tornadoes, windshear, microbursts, icing, and turbulence. Thunderstorm citations are broken down into the following categories No other weather encountered by a pilot can be as violent or threatening as a thunderstorm.

Thunderstorms produce many hazards to the aviation community, and, since they are so common on the prairies in summer time, it is important that pilots understand their nature and how to deal with them. To produce a thunderstorm, there are several ingredients which must be in place. These include:

C. 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:

- **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.

- **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.

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At the same time, the drops begin to evaporate as they draw in dry air from the edge of the cloud, and then fall through the drier air beneath the base of the cloud. This evaporation causes the air to cool and become denser, resulting in a downwash of accelerating cold air. Typical downdraft speeds can reach values of 2,500 feet per minute.

- **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. **[7]**

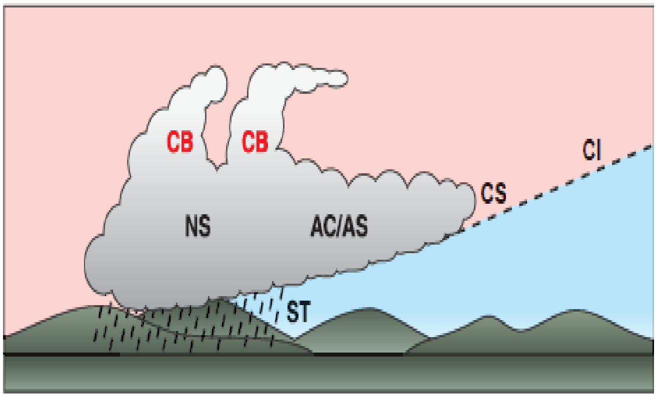
IV. TYPES OF THUNDERSTORMS

- **Air Mass Thunderstorms**

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

- **Frontal Thunderstorms**

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



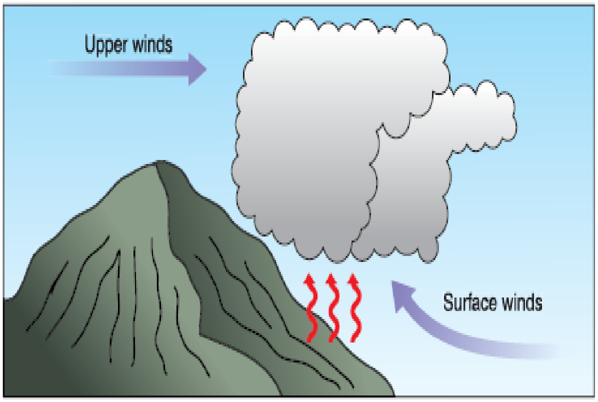
Warm Frontal Thunderstorms

- **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.

- **Orographic Thunderstorms**

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



Orographic thunderstorms form on the foothills of the Rocky Mountains

- **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.

- **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,

- **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".

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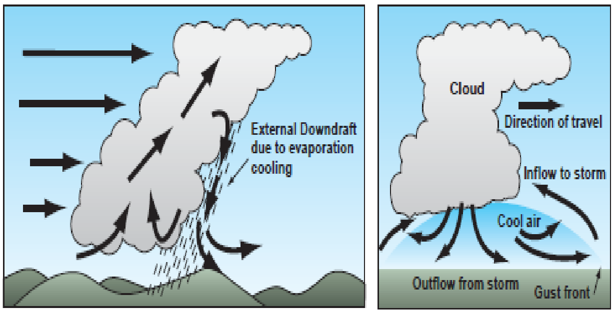


Steady state" tilted thunderstorm The gust front

- **Funnel Cloud, Tornado and Waterspout**

The most violent thunderstorms draw air into their base with great vigor. The incoming air tends to have some rotating motion and, if it should become concentrated in a small area, forms a rotating vortex in the cloud base in which wind speeds can exceed 200 knots. If the vortex becomes strong enough, it will begin to extend a funnel-shaped cloud downwards from the base. If the cloud does not reach the ground, it is called a funnel cloud. If it reaches the ground, it is refered to as a tornado and if it touches water, it is a waterspout. Any severe thunderstorm should be avoided by a wide margin as all are extremely hazardous to aircraft. **[8]**

Severe Thunderstorm

- **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.

- **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.

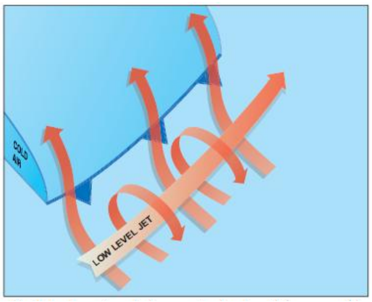
In the aviation world, the major concern is how abruptly the change occurs.

V. 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.

A. 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 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. Idealized low and frontal system showing the position of the low-level and upper-level jet



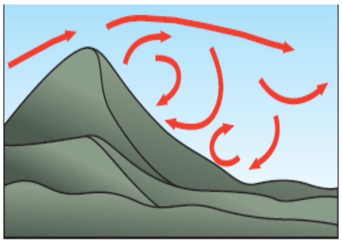
B. Low-Level Jets - Nocturnal

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.

C. Topographical Effects on Wind

- **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.



Lee effects

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- **Friction Effects:**

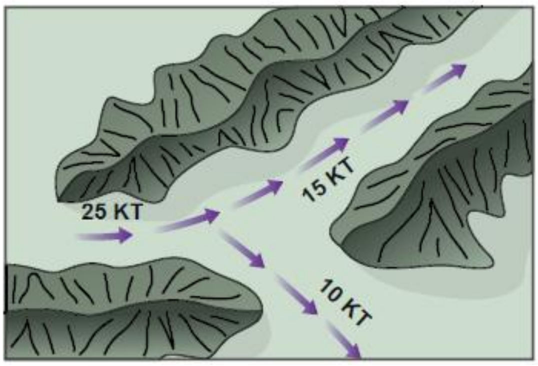
The winds that blow well above the surface of the earth are not strongly influenced by the presence of the earth itself. Closer to the earth, however, frictional effects decrease the speed of the air movement and back the wind (turns the wind direction counter-clockwise) towards the lower pressure.

- **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.

- **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.

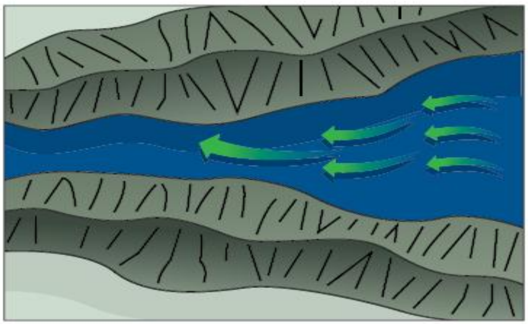


- **Corner Winds**

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.

- **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.



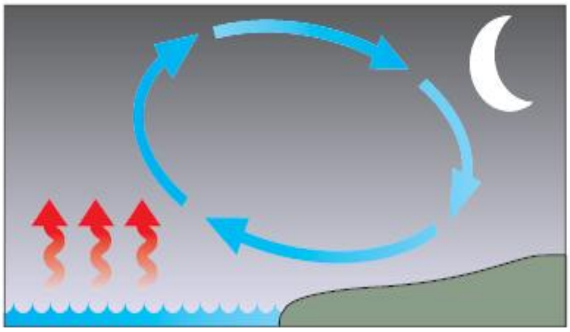
- **Channelled Winds**

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.

- **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.

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.

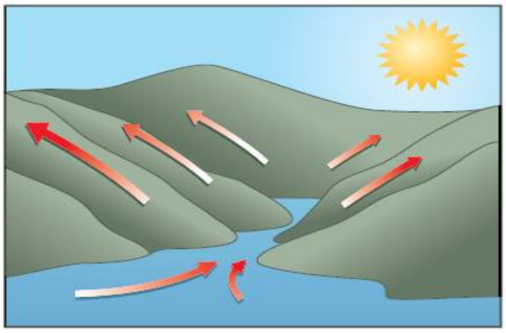


Land breeze

Both land and sea breezes can be influenced by channelling and funneling 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”.

D. Anabatic and Katabatic Winds

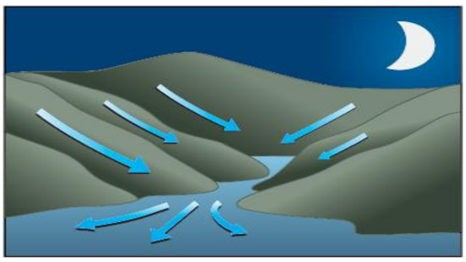
During the day, the sides of the valleys become warmer than the valley bottoms since they are better exposed to the sun. As a result, the winds blow up the slope. These daytime, upslope winds are called anabatic winds .**[9]**



Anabatic Winds

At night, the air cools over the mountain slopes and sinks to the valley floor. If the valley floor is sloping, the winds will move along the valley towards lower ground.

The cool night winds are called drainage winds, or katabatic winds, and are often quite gusty and usually stronger than anabatic winds. Some valley airports have windsocks situated at various locations along their runways to show the changeable conditions due to the katabatic flow. Katabatic winds are observed frequently in locales such as Banff or Jasper.



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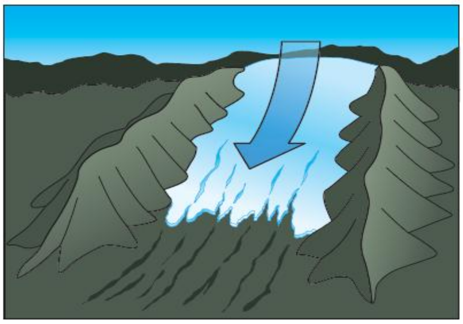
E. Glacier Winds

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.



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. **[10]**

F. 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 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. **[10]**

G. 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.

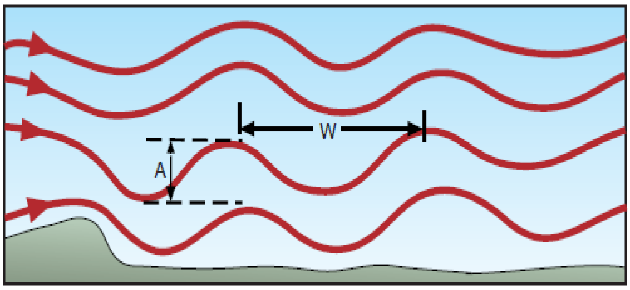
• individual wave amplitude can exceed 3,000 feet.

• 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.

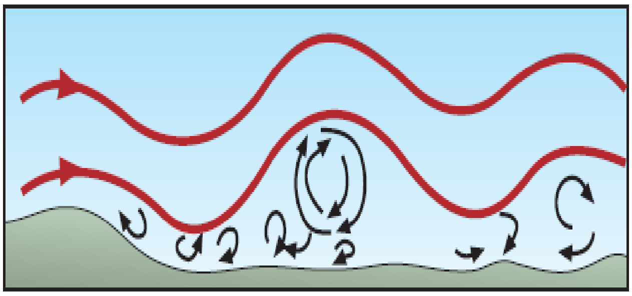
• induced vertical currents within the wave can reach values of 4,500 feet per minute.

• 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.



Amplitude (A) and wavelength (W) in lee waves
Stronger wind in wave crest in lee waves



A rotor may form beneath wave crests

H. 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.

- **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.

- **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.

- **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. **[11]**

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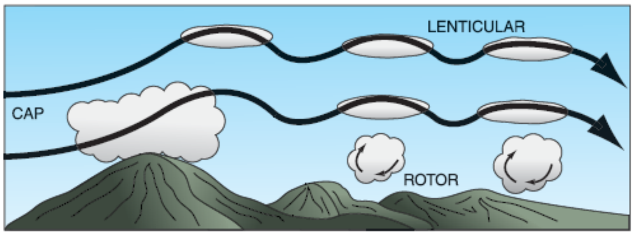
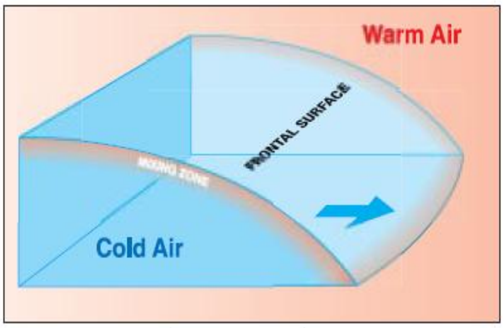


Characteristic clouds formed by lee waves

I. 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.



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.

- **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.

- **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. **[12]**

- **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.

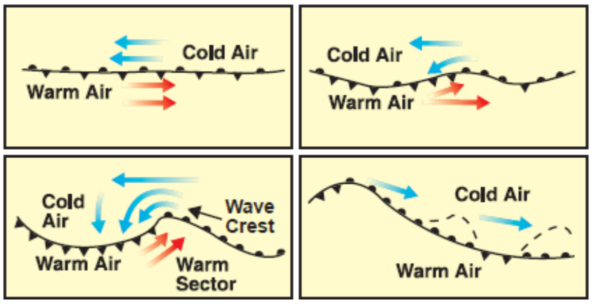
A steep frontal surface, such as is seen in cold fronts, tends to produce a narrow band of convective weather. Although blustery, the period of bad weather is short-lived and the improvement behind the front is dramatic.

- **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:

- **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. **[13]**

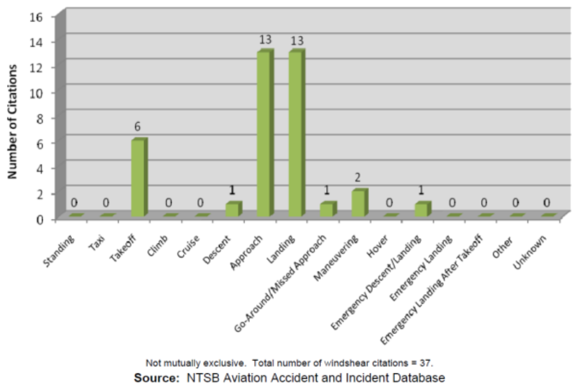


Stable wave

- **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.

Windshear Citations by Phase of Flight 2003–2007



Turbulence Citations 2003–2007

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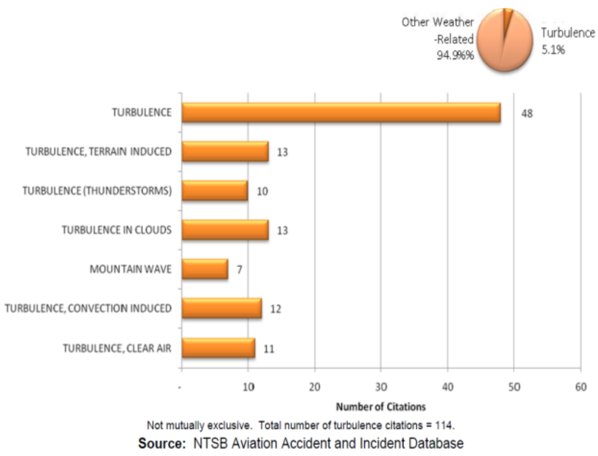
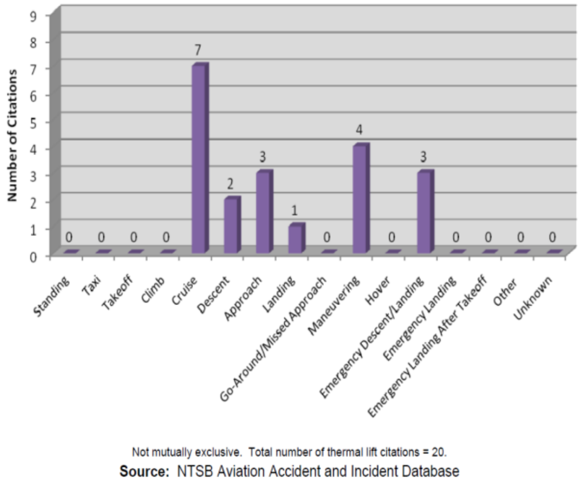


J. Thermal Lift

Thermal lift is defined as a buoyant plume or bubble of rising air.

Thermal Lift Citations by Phase of Flight 2003–2007



K. Cold Weather Operations

Operating an aircraft in extremely cold weather conditions can bring on a unique set of potential problems. **[14]**

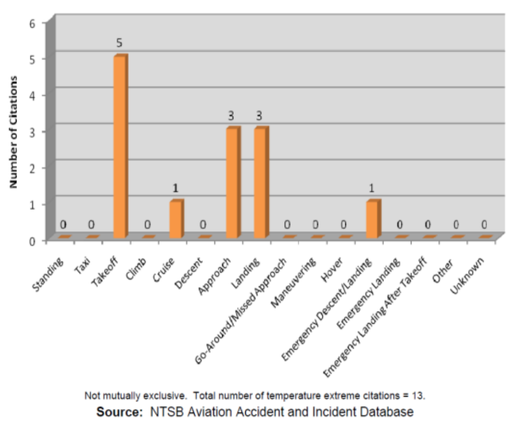
L. Temperature Inversion and Cold Air Outbreaks

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. **[15]**

VI. TEMPERATURE EXTREMES

Extremely high or low temperatures can have an impact on aviation safety in a variety of ways, some of which are described here. Extreme high temperatures increase density altitude and can negatively impact aircraft performance. High temperatures can also cause a situation known as vapor lock.

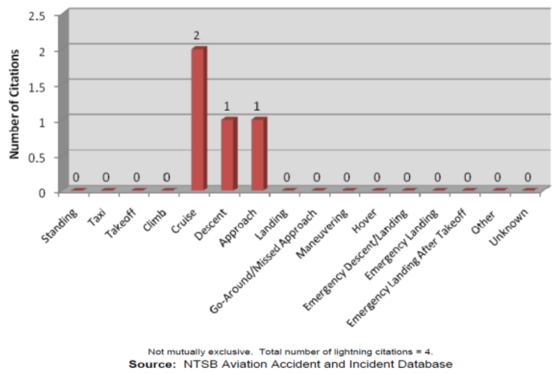
Temperature Extreme Citations by Phase of Flight 2003–2007



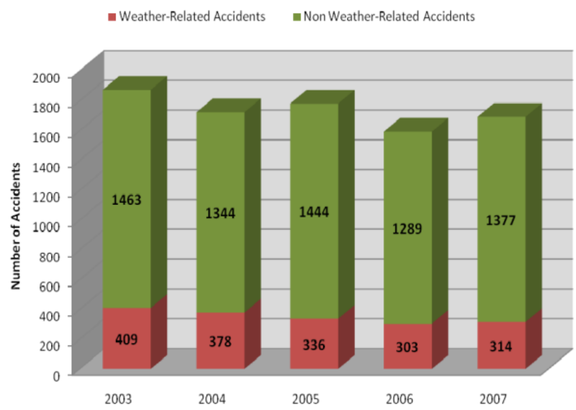
A. Lightning

Although aircraft structures are built to withstand lightning strikes, there are some hazards that are associated with lightning. Navigation and communication equipment, such as radios and magnetic compasses, can be damaged by lightning. Lightning also can temporarily blind a pilot**[16]**

Lightning Citations by Phase of Flight 2003–2007



Weather-related Versus Non-weather-related Accidents 2003–2007



Source: NTSB Aviation Accident and Incident Database

Weather-related Accident Injury Levels 2003–2007

VII. CONCLUSION

The Weather has the greater impact on aviation safety. Factors related to weather enhance the probability of occurrence of other factors to come into play such as mechanical failure problem, pilot error etc. arises due to poor weather conditions and increment in the probability of severe accident and incident.

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Factors related to atmospheric conditions have greater negative impact to influence the performance of flight. Factors related aircraft facilities and aviation. Temperature and air density are related to altitude and the performance to meteorological and geographical are also angerous for aircraft flight performance, to reduce their effect awareness of pilot should be enhanced. Climate change related shifts in weather patterns might also affect infrastructure disruptions. For road transport most studies focus on traffic safety and congestion. With respect to traffic safety by far the most important variable is precipitation, most studies finding that precipitation increases accident frequency, but decreases accident severity. The mediating effect in here is likely that precipitation reduces traffic speed, thereby reducing the severity of an accident when it occurs. Furthermore, most studies show a reduction in traffic speed due to precipitation and especially snow. Finally, changes in temperature and precipitation have consequences for riverine water levels. Low water levels will force inland waterway vessels to use only part of their

Maximum capacity, which may considerably increase transportation costs in the future. It is clear that changes in weather conditions due to climate change will affect the competitive positions of the different transport modes,

REFERENCES

1. A D Graaff (2000), Aviation Safety an Introduction, Air & space Europe, 3, 3/4,
2. Adefolalu D.O. (1984) Bio-climatological Aspects of hamattan Dust Haze in Nigeira. Arch Net Geog. Biol. Services. Vol 33, 304-44
3. A Klein-Paste, A B Huseby , J D Anderson , P Giesman ,H J Bugge , T B Langedahl (2012), Braking performance of commercial airplanes during operation on winter contaminated runways, Cold Regions Scienceand Technology
4. Adefolalu, D.O. (2006) Weather events, climate variability and change in relation to NEEDS and MDGs “Problems and prospects of the Nigerian Economy
5. C Magono (1980), Thunderstorms, Amsterdam, Elsevier Scientific Publication Co
6. Civil Aviation Authority of New Zealand (2006), Mountain flying,
7. Federal Aviation Administration (2008),Pilot's Handbook of Aeronautical Knowledge: FAA-H-8083-25A,Flight Standards Service, U.S. Department of Transportation.
8. G Smith (2011), Natural Disaster Vulnerability: A Real Risk for Airports, Aviation Special Report,
9. I Waitz, J Townsend, J Cutcher-Gershenfeld, E Greitzer, J Kerrebrock (2004), Aviation and the environment: A National Vision Statement, Framework for Goals and Recommended Actions,
10. K E Shanhua, Z Xueqing (2007), A Discussion on First Aid and Medical Support Capabilities of Highland Airports [J], Aviation
11. K L McFadden, B S Hosmane (2001), Operations safety: an assessment of a commercial aviation safety program. Journal of Operations Management,
12. L JBattan (1961), The Nature of Violent Storms, Science study series, Doubleday & co., Inc.
13. L Spirkovska, S K Lodha (2002), AWE: aviation weather data visualization environment, Computers & Graphics
14. P Guégan, R Othman, L Lebreton, F Pasco, P Villedieu, J Meyssonnier, J Wintenberger, (2011), Experimental investigation of the kinematics of postimpact ice fragments, International Journal of Impact Engineering,
15. P R Mahapatra, D S Zrnic (1991), Sensors and Systems to Enhance Aviation Safety against Weather Hazards,Proceedings of the IEEE,
16. T J Casadevall (1993), Volcanic Hazards and Aviation Safety: Lessons of the Past Decade, Flight safety foundation, Flight safety digest,

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