14 Tertiary circulation: local winds

Introduction

The tertiary atmospheric circulation is at the smallest level of the atmospheric circulation. Within the primary atmospheric circulation systems are the secondary circulation systems and within the secondary circulation systems are yet another smaller scale circulations of air which operate over relatively short distances, usually less than 160 km and over short periods of time.

The Tertiary or local atmospheric circulation systems may be thermally direct, such as, the convection cells, which arises from differential heating of the Earth's surface having energy transfer quite similar to the single cell model of the primary atmospheric circulation system. They may also operate as modifications of established larger scale airflows, which are called **local winds**. The topography of the ground surface greatly modifies the characteristics of the air flowing across it. In this case, kinetic energy is derived directly from the regional wind.

The tertiary atmospheric circulation system comprise squall lines, thunderstorms and associated phenomenon like tornadoes and water spouts and local winds (dust devils, dust storms, microbursts, land and sea breezes, mountain and valley winds, föhn winds, depression winds, convection winds)and urban heat island circulation.

Land and Sea Breezes

Coastal areas often experience land breezes and sea breezes. They are caused due to diurnal differential heating of land and sea. During the daytime, the land warms up more than the water. Thus, there is low pressure over land and high pressure over water body. Over the land, as the warmed air rises, creating a low pressure, air from the surrounding ocean which are comparatively cool and moist blows into the land to replace the air that is rising. This flow of air is called a **Sea Breeze**. During the night, the land cools more rapidly than the water. This not only produces a local High Pressure but conserves heat and remains warmer for a longer period. The resultant energy and high pressure induces a flow of air from land to sea. This flow is called a **land breeze**.

Sea and land breezes are common in the tropics during most of the year and at middle latitudes during the summer. Sea breezes usually produce a line of clouds just inland along a tropical coastline or above tropical islands.

The influence of sea breeze is over a small area and does not exceed 25 km from the Coast. Its speed is between 8-30 km/ph and is generally stronger in tropical than temperate regions. The coastal resorts are most benefitted by these winds.

The life of the fishermen in the tropical coastal area hinges on these winds. During the night time they are blown seaward by the land breeze while during the day time the sea breeze blows them back towards the coast.

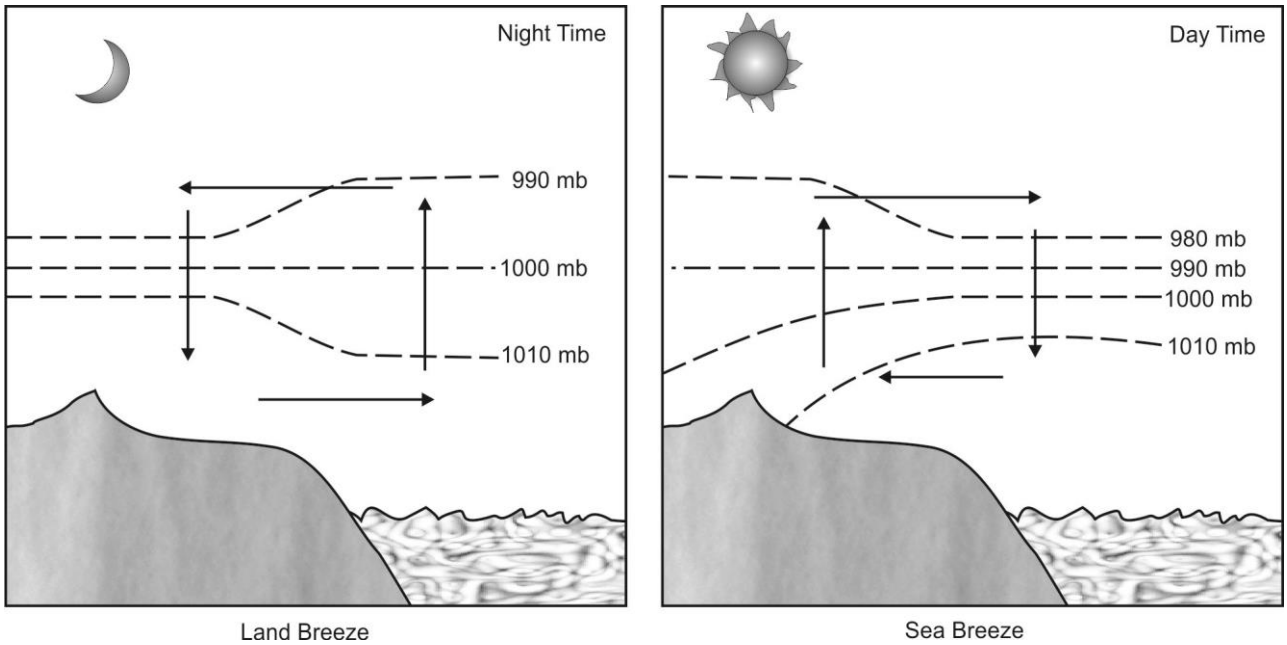


Figure 14.1 : Land and Sea Breezes.

Mountain and Valley Winds

On clear nights, long wave radiation loss from the mountain ridge will lead to considerable cooling of that surface and its overlying air. Cooling of the valley sides and floor will be much less marked because of the radiation exchanges between the two valley walls and the floor. As a result, the cooler denser air of the top will start sinking to the floor following the mountain slope (hence **slope winds**), moving down as low generally smooth flow. This is the **katabatic wind**. Steep slope accelerate katabatic flow. Along the edge of massive Greenland and Antarctica ice sheets, katabatic winds frequently exceed 100 km^{-1}/h. Although the speed of the flow depends on the angle of slope and the roughness of the surface, it is found to be approximately proportional to the square root of the temperature difference between the top and the bottom of the valley. Katabatic winds are frequently experienced in certain areas and are given local names. In the Adriatic Sea, a katabatic wind forms between north and east, which usually blows in winter and is known as *Bora.* The *Mistral,* which blows down the Rhône valley and over the Gulf of Lyons is another Katabatic wind. Where such winds reach the sea, being cold and dry, they increase the density of water through cooling and evaporation and thus, promote convective mixing of the water in addition to mechanically induced turbulence.

During sunny days in summer, the higher parts of mountains, the slopes facing the Sun, in particular, become appreciably warmer than the adjacent valleys. This is because the air above the mountain slope, besides being heated by insolation, is also warmed by conduction more effectively than the valley floor. Thus, the air just above the valley top becomes warmer than the air at the same level over the valley itself. This causes convectional activity, leading to light and irregular drift of air up and along the mountain slope. This is known as **anabatic wind**.

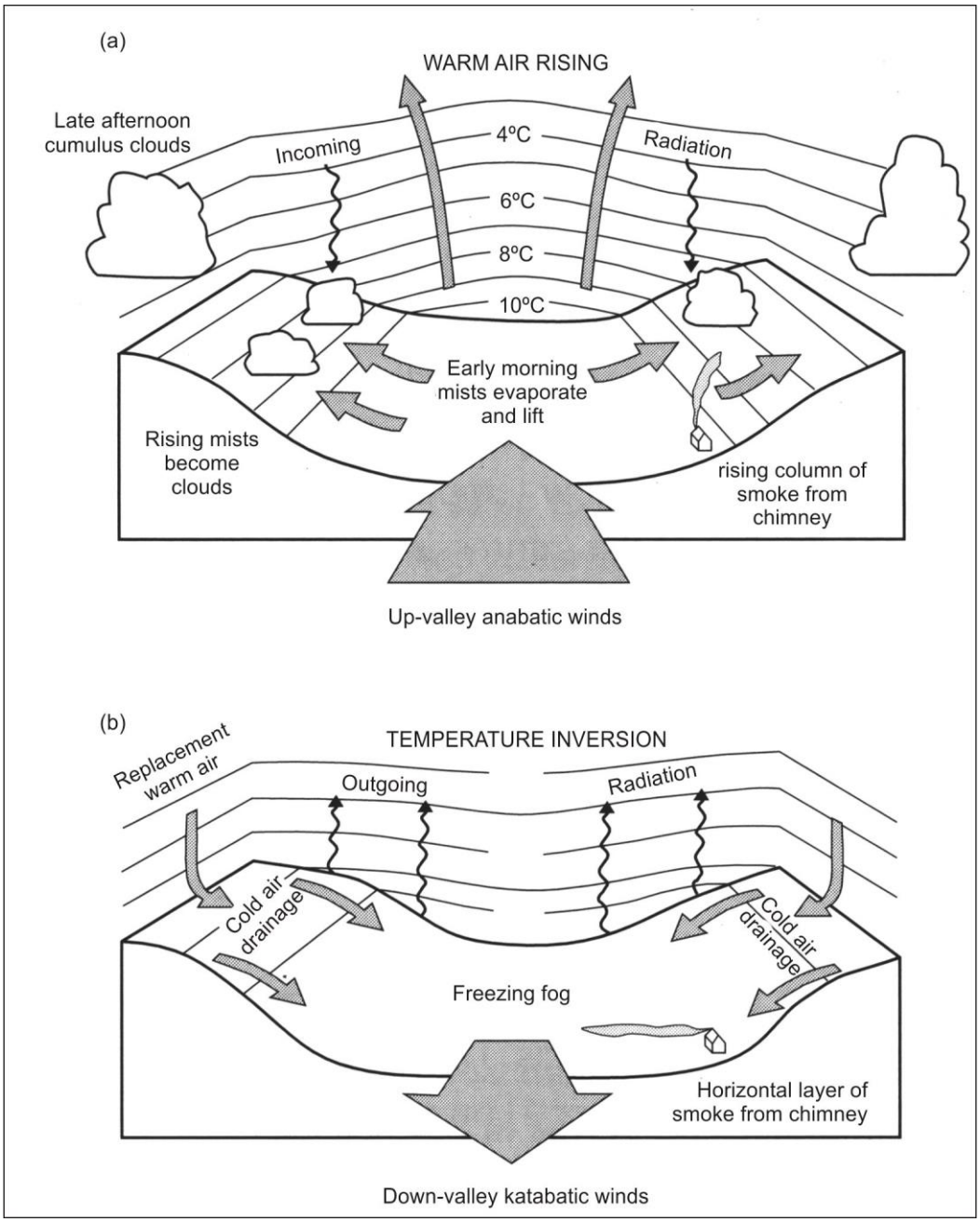


Figure 14.2 : The Development of (a) Anabatic Winds (b) Katabatic Mountain Winds.

A variation of these winds is the **glacier wind**, which arises as the air adjacent to the icy surface is cooled and moves downslope because of gravity. These may blow continuously as the refrigeration source is always present but they tend to reach their greatest depth and intensity in the mid- afternoon, when the thermal contrast is greatest.

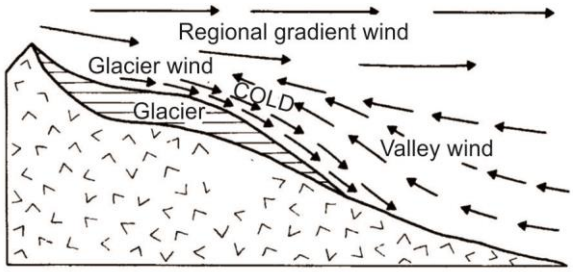


Figure 14.3 : Glacier Winds.

Föhn Winds

It is a general name given to winds caused by barrier effect and they have their own name in different parts of the world.

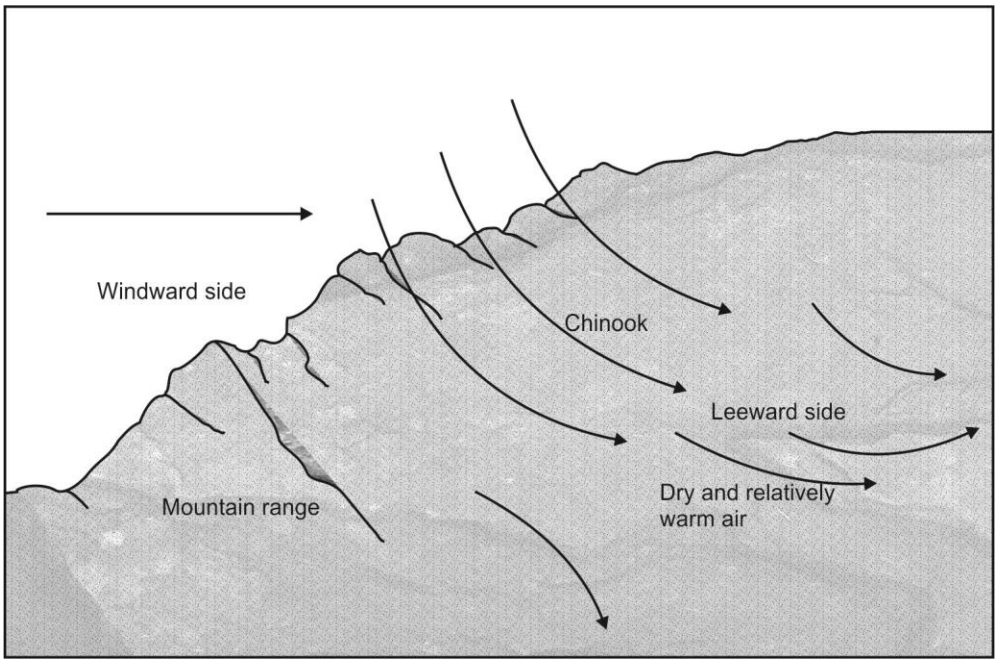


Figure 14.4 : Chinook or Foehn Winds.

Air, which is forced to flow over a hill or a mountain range, produces distinctive changes in the characteristics of the flow locally. One such modification is the ***föhn*** wind, which blows as a warm and dry wind down ice slopes (leeward side).

This wind develops when relatively mild air descends the leeward slopes of mountain ranges and is adiabatically compressed with increased pressure. For every 1000 m of descent the air temperature rises about 10^0C, thus the air is greatly warmed as it descends. Similar type of winds are known as ***Chinook*** in the Andes and Rockies. Chinook literally means snow-later-in local Red Indian language in America. Chinook melts snow and causes avalanches. But, it brings lots of benefits as well, such as it makes the winter milder, it hastens the growth of crops and fruits through the snow covered pastures.

Similar winds in other parts of the world are ***Yamo*** in Japan, ***Tramontane*** in Central Europe, ***Samun*** in Iran, ***Norwester*** in New Zealand, ***Berg*** in South Africa, etc.

Lee Waves and Rotors

A further consequence of the barrier effect on winds is the creation of **lee waves**. When the wind passes over a mountain, its normal flow is disrupted and a train of waves is created that extends downwind for considerable distances. Such lee waves are associated with high wind speed up to 160 km per hour. Lee waves may also have **rotors**, roll-like circulation that develops into the immediate lee of the mountains.

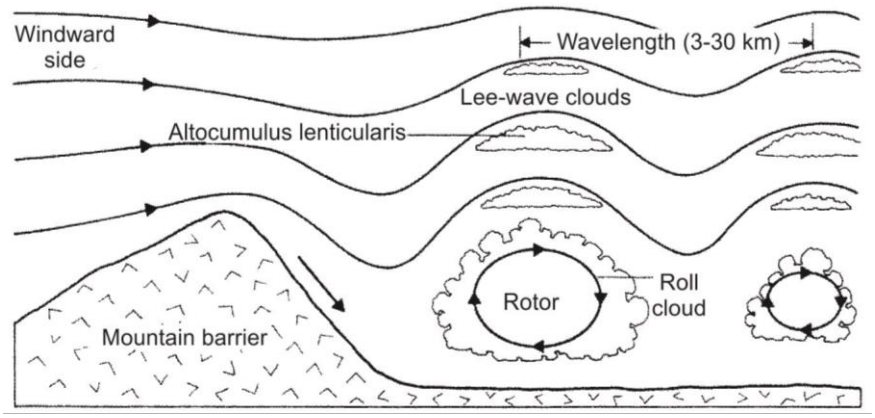


Figure 14.5 : Formation of Rotor and Lee-wave Clouds.

Depression Winds

The position and relief of certain regions gives distinctive character to winds associated with depressions. A moving wind involves air masses originating both on its poleward and equatorward side and therefore, both warm and cold winds result. A depression moving towards Mediterranean results in warm dry winds from the Sahara in the warm sector. The ***Sirocco*** in Italy, the ***Leveche*** in Spain, the ***Khamsim*** in Egypt, the ***Gibli*** in Tunisia and the ***Brickfielders*** of Victoria in Australia are examples of this. The Polar masses cause strong cold winds. They are ***Southerly burster*** in New South Wales, the ***Pampero*** of Argentina, the ***Friagem*** or ***Surazo*** in Brazil, the **Norther** in Texas, and the **Norte** and ***Papagayo*** in Mexico. In the Mediterranean-Mistral over southern France and the Bora over the Adriatic.

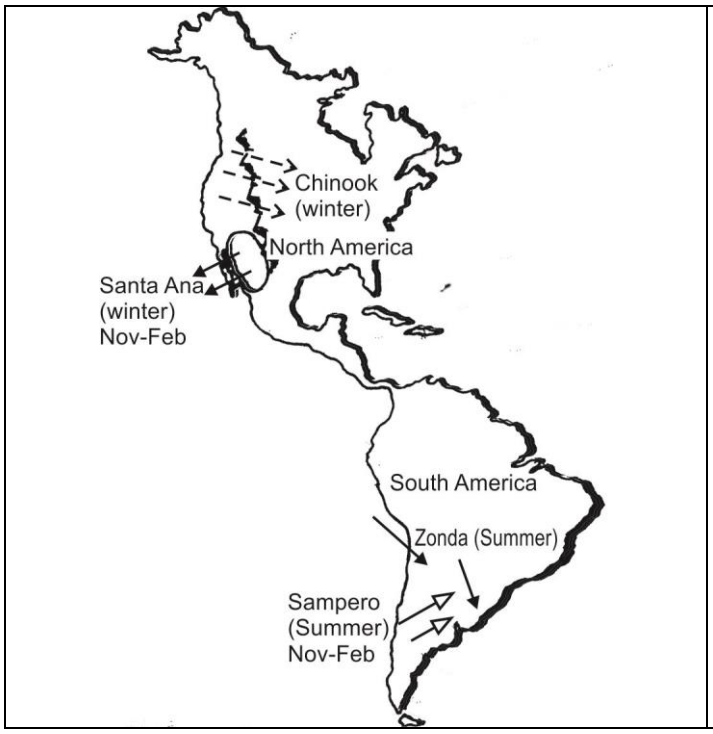
Table 14.1 : Local Winds of the World

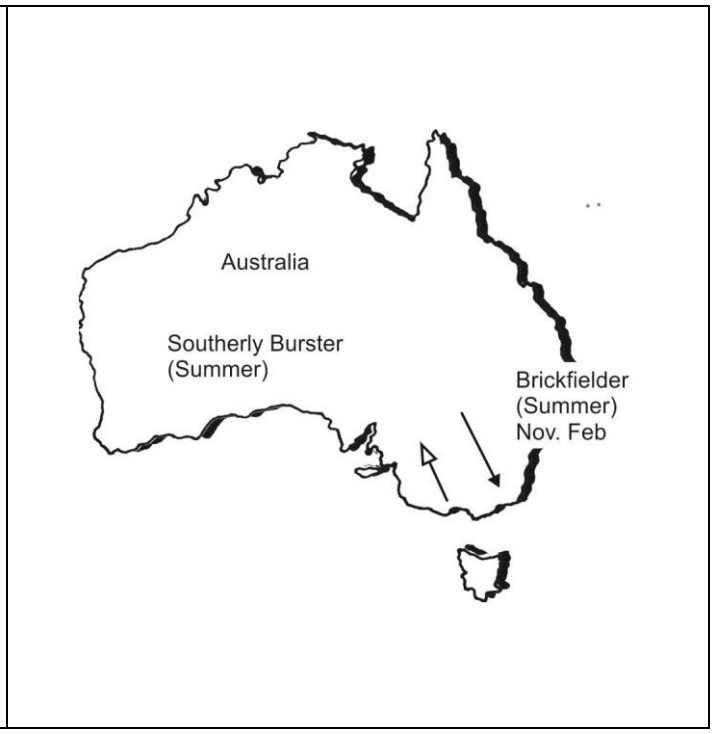
Name	Location	Characteristics	Season
Bendabales	Gibralter Strait and Eastern Spain		
Berg wind	South Africa, particularly along the country's cool western coast,	A warm and dry wind lasting for between two and three days at a time.	It is found most regularly during winter, when the atmospheric pressure is low over the adjacent Atlantic Ocean and the country's inland plateau is the focus of a strong anticyclone.
Blizzard	Experienced in the U.S.A in winter, but now used widely, especially in Antarctica.	A very strong, bitterly cold, wind accompanied by masses of dry powdery snow or ice-crystats, with poor visibility (white-out), under polar or high-altitude conditions.	
Bora	Blows down off highlands of (erstwhile Yugoslavia) and affecting the Adriatic Coast.	Cold, gusty north—easterly wind.	
Brickfielder	Blows across southeastern Australia,	The wind is accompanied by clouds of dust, and a prolonged spell of hot weather during which daily temperature frequently rises above 38°C (100°F).	Usually during the summer
Chinook	Eastern slopes of Rockies	A warm wind that may, at times, result in sudden and drastic rise in temperature.	Most violent in winter
Cockeyed bob	American South West Desert and Western Australian Desert		
Dust Devil	Arid and semi-arid areas	A dust devil is an upward spiralling, dust filled vortex of air that may vary in height from only a few metres to over 300 metres.	
Etaesian	Eastern Mediterranean	Cool, dry north easterly wind that recurs annually	Summer and early autumn
Fohn	Alpine lands	Similar to Chinook. Characterised by warmth and dryness	Most frequent in early spring
Friagem	Tropical grasslands of Brazil lying to the south of the Amazon basin	A cold wave	Winter

Gibli (Ghibli, Chibli)	Tunisia	A hot dust bearing desert wind in North Africa similar to Fohn	
Gregale	The name applied to a strong wind which blows from the northeast in the central regions of the southern Mediterranean.	The weather associated with a Gregale is little rain and a small drop in the average temperature	
Haboob (arbic)	Southern margins of Sahara (Sudan)	Hot, damp wind often containing sand.	Early summer
Harmattan	A dry dusty northeastern wind blowing out of the Sahara across the Sahel	Inland the wind is dust-laden and unpleasant. Because of its dryness and relative coolness it is reputed to bring a health contrast (hence its name 'Doctor') to prevailing humidity,	It is hot from about March to June and cool from November to February.
Inverna	Lake Como in Swiss region	Lake breeze	
Jooran	From Jura Mountains to Lake Geneva	Cold and Dry	
Karaburan.	In the interior of the Central Asian land mass, blows across central China's Sinkiang Province	A hot and strong north easterly wind produced by the rapid heating.	From early spring until the end of summer, chiefly in the daytime.
Khamsin	North Africa and Arbia	Hot, dry south easterly wind. Other wind include Ghibli (Libya), Sirocco (Mediterranean), Levenche (Spain)	Latter winter, early spring
Leste	Commonly felt by the inhabitants of the island of Madeira lying off the northwest coast of Africa,	Hot, dry, and dust-carrying wind which occurs in advance of a passing depression. It is a southerly to easterly wind.	
Levanter	Western Mediterranean	Strong, easterly wind, often felt in strait of Gibraltar and Spain.	Autumn, early winter to late spring
Leveche	Spain	Either a fohn or a hot southerly wind in advance of a low pressure area moving from the Sahara desert.	
Meltemi	Greek and Turkish coast	Sand laden wind brings dust storms	
Mistral	Rhone valley south Valence	Strong cold wind channelled down Rhone valley.	Most frequent in winter
Nevados, Nevadas	Cold down-valley wind blowing from Andean snow-fields to high valleys of Ecuador.	A type of katabatic wind, strengthened by chilling of air in contact with a snow surface, resulting in a gravity flow downhill.	
Norte (Mexican extension of the Norther)	Mid USA (N. America)	A strong cold north easterly wind.	Winter
Norther	Texas, Gulf of Mexico to West Caribbean	Cold, strong northerly wind	Winter
Norther	Texas, Gulf Coast, Mexico, Central America, California and Portugal	A cold dry North winter wind bringing low temperatures to Texas and Gulf coast of U.S.A.	
Norwester	India and New Zealand	The names given to particular types of wind. The first is a wind that brings	

		thunderstorms, heavy rain, and hail to the plains of northern India during the April-June hot season, while the second is a hot and dry wind that flows down from the mountains of New Zealand's South Island.	
Ora	Italy	A regular valley wind at Lake Garda in Italy	
Pampero	Across the Pampas grasslands of Argentina and Uruguay	An unexpected spell of cold polar air and unsettled weather following in the path of a depression as it tracks across the Pampas grasslands of Argentina and Uruguay.	Winter
Papagayo	Mexican coast	A cold northerly wind which blows across the Mexican interior and is similar to the North American norther and the norte found in the Mexican coast.	
Ponente	Around Corsica, France and Italy around Rome	A pleasant sea breeze.	Summer
Purga	Siberia and Tundra region	Very much like Buran, this cold north westerly wind is found in Siberia, especially in Tundra Regions, and is usually associated with snow.	Winter
Samoon	Blows across Iran from its place of origin in Kurdistan	Similar to the Fohn wind in western Europe, a hot and dry wind.	
Samun	Iran	A fohn like wind	
Santa Ana	Santa Ana, California	A hot dry fohn likes desert wind blowing in a pass or a river valley.	
Seistan	Blows across the province Seistan in eastern Iran	An extremely strong northerly wind capable of speeds in excess of 128 kmph	Summer.
Shamal	Blowing across the basin of Tigris and Euphrates in Iraq,	The wind is associated with dust storms.	Summer
Simoom	Sahara and Arabian desert	Hot and dry wind that carriers large amount of sand.	Spring and summer
Sirocco	Blowing north across the Mediterranean Sea.	A hot, dry wind	
Sirocco	Italy	A warm south or south east wind in advance of a depression moving eastwards across the southern Mediterranean sea or North Africa.	
Southerly buster	Southern and southeastern Australia	A sudden burst of cold air advancing from the south and moving over southern and southeastern Australia.	Most frequent in spring and summer.
Sumatra	Malacca strait	A squall, usually most common during the night in the local monsoon season.	

Surazo	Brazil	A cold wind experienced in Surazo, Brazil, the result of an anticyclone in winter.	Winter
Takuwind	Alaska	A strong, gusty, east northeast wind, occurring in the vicinity of Juneau, Alaska (Named after Taku river).	Between October and March.
Temporale	Central America	A rainy wind from the south west to the west resulting from the deflection of the south east trades of the eastern south Pacific on to the Pacific coast of the Central America.	
Tramontane	Central Europe	A fohn like wind	
Virazon	Spain and Portugal, Andes Mountains	A very strong westerly sea-breeze	
Williwaw	Southern tip of Argentina	A sailor's term for a sudden squall, especially in the roaring forties.	
Yamo	Japan	A fohn like wind	
Zonda	Argentina	A warm, dry wind on lee of the Andes. Can attain 33 ms^{-1}. Comparable to Chinook and Fohn. In dry weather carries much dust	Winter





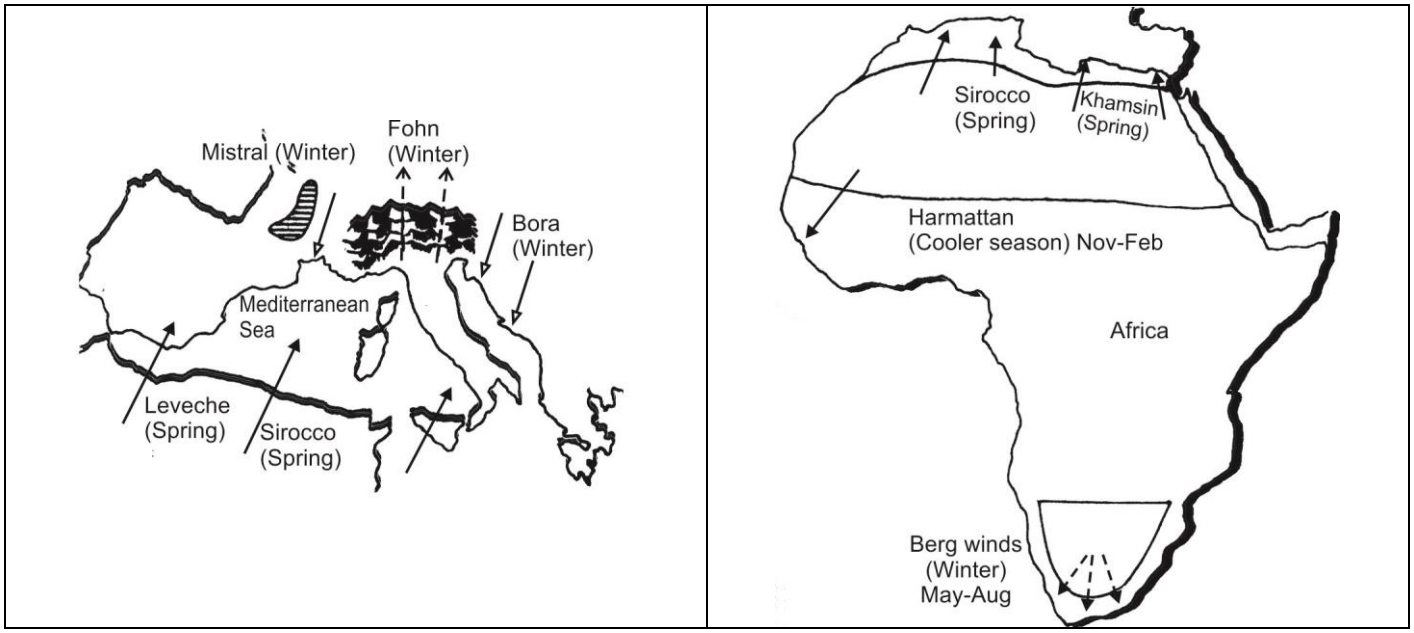


Figure 14.6 : Local Winds in various Continents.

Convection Winds

Certain desert winds are the product of intense heating of the ground producing a steep lapse rate, which in turn, induces vigorous convection and gusty surface winds. The strength and gustiness of the wind varies with the intensity of solar radiation, so that wind speed and gustiness peak in early afternoon and during warmest months.

Some variation in desert surface characteristics cause some spots to become hotter than others. If regional winds are weak, local surface winds converge toward hot spots, replacing the hot air rising over hot spots. As the winds converge, they rotate about its vertical axis on much the same way, as water converges towards a drain in a sink. In the process of this rotating convergence, dust is lifted from the ground and the circulation is visible as whirling mass of dust laden air, known as **dust devil**. **Microbursts** and **dust storms** are other forms of convection wind.

Dust Storms

A cloud of raised dust is generally considered to be a dust storm, if visibility is reduced to about one kilometer. It is considered severe, if visibility decreases to half a kilometre or less.

Dust storms are caused largely by strong winds. Strong winds are always capable of lifting topsoil and scattering it over large areas, but occasionally, certain conditions combine to produce huge walls of moving dust that carry thousands of tons of soil and debris to another location. Such events tend to occur after an extended drought has left the ground dry and dusty.

Dust storms can lift particles as high as 3000 m and travel several thousand miles. Dust storms generated by vigorous fronts over southeastern Australia have carried soil right across the Tasmania Sea to New Zealand producing a dust coloured red snow on the New Zealand Alps. In North America, a similar phenomenon occurs in the plains. The dust carried from the plains produce dust coloured snow and rain along the Atlantic coast.

Large dust storms leave an enormous amount of fine dust that infiltrates every corner of the house. But the most serious

DUST STORMS

Strong wind blowing across a desert surface also creates dust storms and sand storms, which can significantly reduce visibility, affect communications and pose a major threat to agriculture. Such type of dust storms commonly take place in Sahara, Arabian desert, Iranian desert and almost all deserts of the world.

The frequency of dust storms in the Sahel region appears to be increasing by a combination of drought and human mismanagement of the sensitive dryland environment. Changes in wind direction can distribute desert dust across wide areas. With strong southerly winds, for example, dust can easily be blown from the Sahara across much of mainland Europe.

problem that it poses is the removal of the valuable topsoil from farmland.

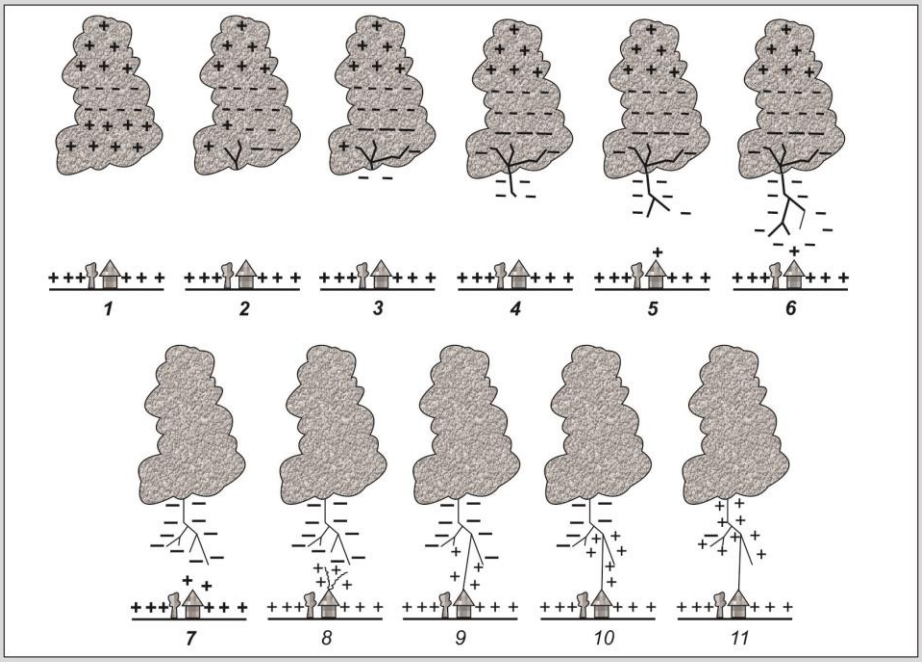
Thunderstorms

A thunderstorm is a violent storm that develops from cumulonimbus clouds on a hot and humid afternoon. Thunderstorms get their energy from the condensation in the clouds.

In fair weather, the ground is negatively charged to balance the positively charged ionosphere. During a thunderstorm, however, the negative charges that form in the cloud repel the negative charges in the ground. The negative charges are pushed deep into the ground, which becomes positively charged as a result.

LIGHTNING

If the difference in charge between the cloud and the ground is great enough, lightning occurs. Lightning is a stroke of electrons travelling at speeds of about 1000 km/s. The charge forms a tunnel between the cloud and the ground. Lightning can also occur within a cloud or between clouds. The temperature inside the tunnel through which the lightning travels rises to 30 000°C, pressure causes a shock wave that travels through the atmosphere. It is this shock wave that is heard as thunder.



Lightning emits not only visible light but also X rays, ultraviolet light, and radio waves. These radio waves can cause radios to crackle during a thunderstorm.

Lightning is observed as soon as it shoots out of the cloud because light travels extremely fast: about 30 million m/s. Sound, however, travels much more slowly: only about 340 m/s.

Lightning strikes the highest object in area. This is the reason one should not stand under a tall tree during a thunderstorm. Lightning is likely to strike high structures, such as church steeples, factory chimneys, or ship masts. Because of this, it is unsafe to be in the open, to be on top of tall structures, or even to be near tall structures or trees during thunderstorms.

The metal rods on top of structures called lightning rods. They are connected to the ground by means of a thick wire, a rod, or a pipe. If lightning strikes the structure, it will hit the rod first because that is the highest point. The rod will channel the electrical charge into the ground, where it will discharge harmlessly.

Tornadoes

A tornado is a small, extremely violent storm. Tornadoes are a kind of **cyclone** because the air is rapidly circulating around a small area of very low pressure. Tornadoes appears like a dark funnel cloud.

Tornadoes occur where two very different air masses collide. One air mass must be warm and humid, the other cool and dry. The advancing cool air pushes the warm air up and away. Warm air rising rapidly along the front condenses into a line of thunderclouds called a **squall line**. The energy given off by condensation causes violent motions along the squall line, and many small, but very intense, low-pressure areas develop. Some of these areas may form tornadoes.

A tornado starts as a centre, or vortex, of low pressure. The tornado's vortex develop from the bottom of the thundercloud toward the ground. These clouds are called as **Mamma Clouds**. This downward extension is caused not by the air moving toward the ground, but by the air below the cloud being drawn into the vortex.

Air pressure at the center of the vortex is estimated to be 10 to 15 per cent lower than the pressure outside the storm. This sudden pressure drop causes the air drawn into the vortex to become saturated with water vapour. When saturation occurs, water vapour in the cloud begins to condense, making the funnel visible.

The path of a tornado along the ground averages 5 km in length. However, tornado paths often are not continuous. The funnel may touch down and destroy one house on a street and not even disturb the house next door. A tornado lasts, on the average, only five to ten minutes.

Tornadoes are very destructive because of their wind speeds. Horizontal wind speed within a tornado can be as high as 500 km/h. Upward wind speed may be as high as 300 km/h. There are few precise measurements of wind speed within a tornado because the measuring instruments are usually destroyed by the wind. Wind speeds are estimated from the damage caused by the tornado. Updraft speed is based on the fact that objects such as roofs, farm machinery, cattle, and even people have been lifted and carried for hundreds of metres.

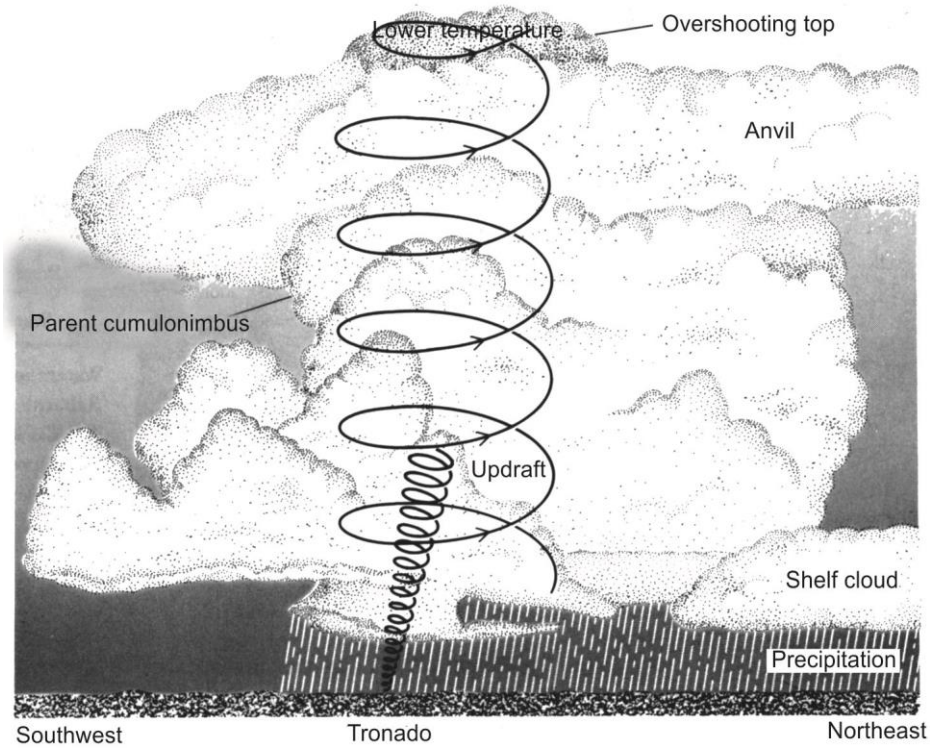


Figure 14.7 : Typical Structure of a Tornado.

Tornadoes occur in specific parts of the Earth, and they are most frequent in an area of the United States called **tornado alley**. As many as 300 tornadoes form there each year.

A **Waterspout** is a vortex that occurs over open water. Waterspouts are much less powerful than tornadoes because the temperature difference between air masses at sea is usually less than it is over land. Wind speed within waterspouts rarely exceeds 80 km/h. Waterspouts are common in the coastal waters or tropical and semi-tropical areas.

Table 14. 2 : Tornadoes

Features	Characteristic Magnitude	Typical Range
Diameter	100 metres or less	2 km to 3 km
Path Length (distance travelled across terrain)	3 km	A few meters to hundreds of km.
Duration	4 minutes	A few seconds to several hours
Wind Speed	90 ms^{-1}	80 ms^{-1} to 225 ms^{-1}
Speed of motion	10 to 20 ms^{-1}	0 to 20 ms^{-1}
Direction of travel	Southwest to Northeast	Variable
Pressure fall	25 mb	20 to 200 mb

IMPORTANT TERMS

Anabatic Wind
Anvil
Arcus Cloud
Dart Leader
Downdraught
Dust Dome
Dust Plume
Glacier Wind
Graupel Pellets
Gust Front
Katabatic wind
Lake Breeze
Land Breeze
Mamma
Mountain Wind
Return Stroke
Roll Cloud
Sea Breeze
Shelf Cloud
Skyview Factor
Slope Wind
Squall Lines
Stepped Leader
Supercell Thunderstorm
Thunder
Urban Heat Island
Valley Wind

(See in Glossary)