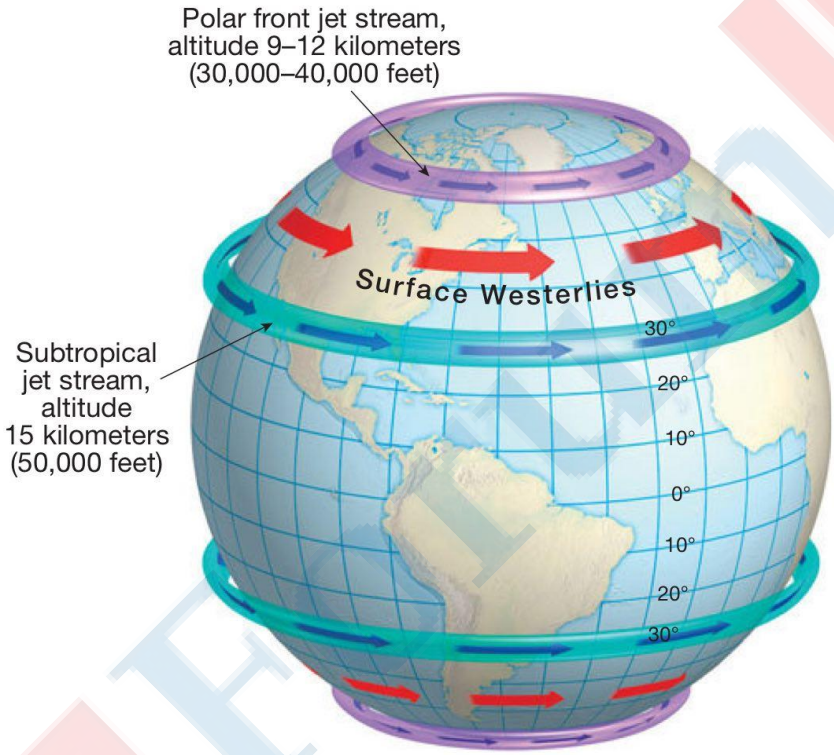
Although the surface westerlies are somewhat variable, **the geostrophic winds aloft**, however, blow very prominently from the west.

The belt of the westerlies, a **meandering river of air moving generally from west to east around the world** in the midlatitudes

This jet stream is a feature of the upper troposphere located over the area of greatest horizontal temperature gradient—that is, cold just poleward and warm just equatorward.

Commercial air travel can be significantly influenced by the high-speed flow of upper tropospheric winds.



The jet streams are characterized by the following properties.

The circulation of jet streams is from **west to east** in a narrow belt of a few hundred kilometers width at the **height of 7.5 -14 km** in the upper troposphere.

Seasonal change – stronger in winters, max speed 480 KMPH

Generally, their circulation is observed between poles and 20 degree latitudes in both the hemispheres. These are also called **circum-polar whirl because these move around the poles in both the hemispheres.**

Their circulation path (trajectory) is wavy and Meandering

Types Of Jet Streams

On the basis of location- 5 types :

Polar front jet streams are formed above the convergence zone (40-60 lats.) of the surface polar cold air mass and tropical warm air mass.

The thermal gradient is steeper as two contrasting air masses converge. This is irregular jet

Subtropical westerly jet streams - West to east in more regular manner Key role – Winter rainfall and Snowfall in India

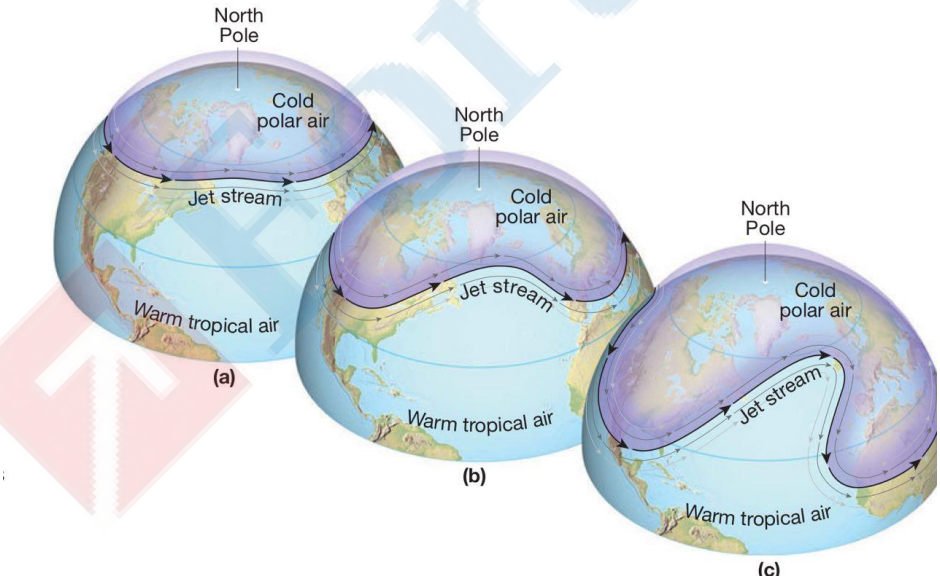
Tropical easterly jet streams develop in the upper troposphere above surface easterly trade winds *over India and Africa during summer season due to intense heating of Tibetan plateau* - *Vital role in Indian Monsoon*

Polar night jet streams, also known as stratospheric subpolar jet streams, develop in winter season due to steep temperature gradient in the stratosphere around the poles at the height of 30 km.

Local jet streams are formed locally due to local thermal and dynamic conditions and have limited

Rossby Waves

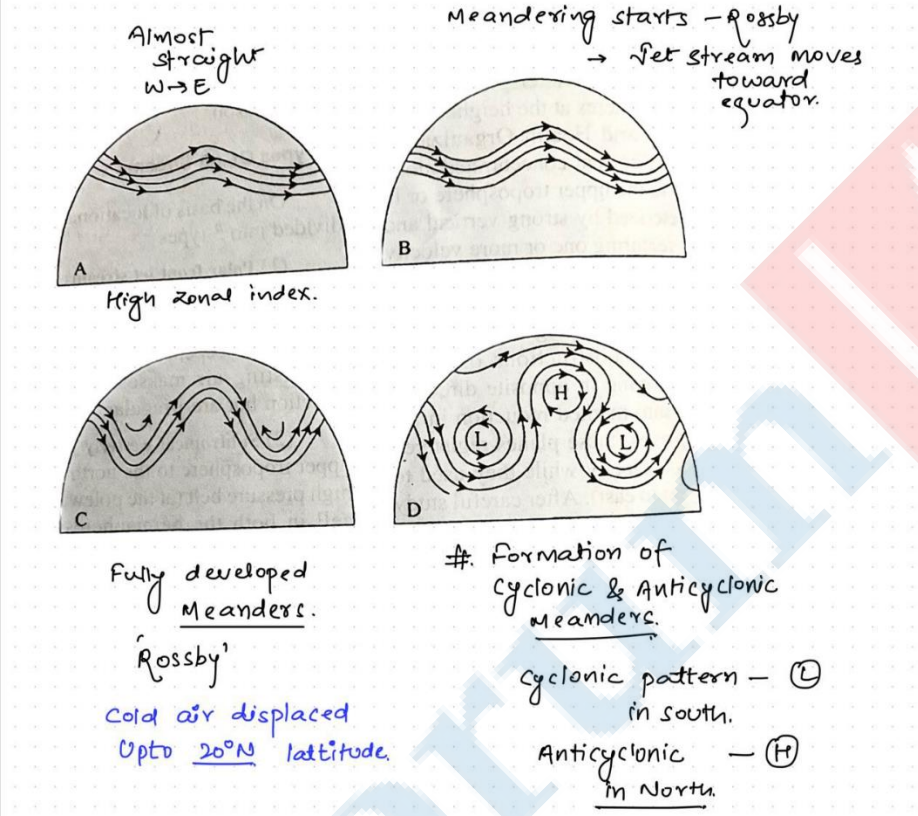
Surface high pressure is intensified over the surface of arctic region due to subsidence of cooled heavy air during winter season in the northern hemisphere. On the other hand, upper air low pressure develops in the upper troposphere above the high pressure of ground surface of the arctic region.



Due to this phenomenon a cyclonic system (west to east) of air circulation in the form of a whirl develops around upper tropospheric low pressure. The general direction of this circulation is from west to east.

There are changes in the position of extent of jet stream from poles towards equator. The wavy (meandering) jet stream is called Rossby waves.

The period of transformation of straight path of jet stream to wavy or meandering path is called index cycle which is completed in four successive stages-

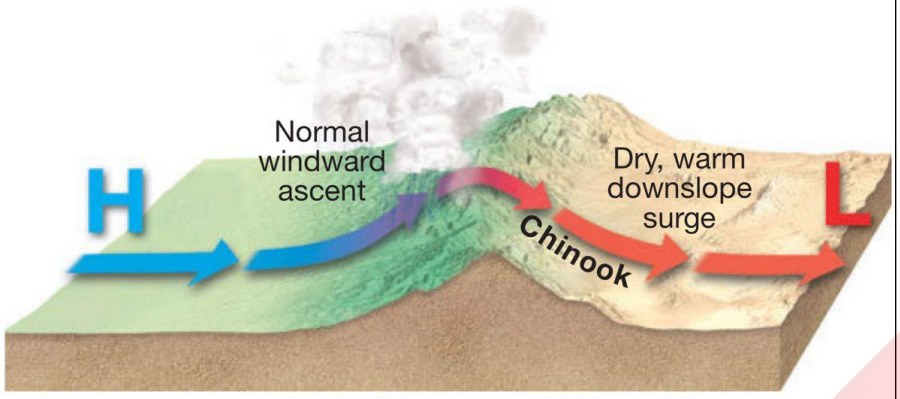


Local winds

Chinook And Foehn

Warm and dry local winds blowing on the leeward sides of the mountains are called chinook in the USA and foehn in Switzerland.

These local vertical winds are of cyclonic origin and largely influence the weather conditions of the affected areas locally. The winds associated with the cyclones after descending through the eastern slopes of the Rockies become warm and dry and thus give birth to chinook. (Snow Eater)



▲ **Figure 5-36** A chinook is a rapid downslope movement of relatively warm air. It is caused by a pressure gradient on the two faces of a mountain.

The winds ascend through the western slopes of the Rockies mountains and thus are cooled at the dry adiabatic rate of 5.50F per 1000 feet (10°C per 1000 metres).

Foehn – Northern Slope of Alps

Harmattan

The warm and dry winds blowing from northeast and east to west in the eastern parts of Sahara Desert are called harmattan.

These winds become extremely dry because of their journey over Sahara Desert. While blowing over Sahara these winds pick up red sands.

The weather becomes suddenly dry and pleasant at the arrival of harmattan as the relative humidity of the air is remarkably reduced due to high temperature and hyperaridity of harmattan. This is why harmattan is known as 'doctor' in the Guinea coastal area of western Africa.

In fact, harmattan is very dusty and stormy wind blowing with so gusty speed that trees are uprooted.

These winds are usually associated with dust storms resulting into marked reduction in the visibility.

Similar warm, dry, very strong and dust-laden winds are called

"**Brickfielder**' in Victoria province of Australia

Blackroller' in the Great Plains of the USA

'**Shamal**' in Mesopotamia and Persian Gulf

'N**orwester**' in New Zealand.

Sirocco

Sirocco is a **warm, dry and dusty** (full of sands) local wind which blows in northerly direction from Sahara Desert and after crossing over the Mediterranean Sea reaches Italy, Spain etc. .

There are different local names for sirocco in Africa e.g. **khamsin in Egypt (UAR), gibli in Lybia, chilli in Tunisia etc**.

The warm and dry dusty winds in the **Arabian Desert are called 'simoom'**.

Sirocco, while passing over the Mediterranean Sea picks up moisture and yields rainfall in the southern part of Italy where the rain associated with sirocco is called **blood rain**' because of fallout of red sands with falling rains.

Mistral

Mistral is a cold local wind which blows in

Spain and France from north-west to south-east direction.

Effective during winter season because of development of high pressure over Europe and low pressure over Mediterranean Sea.

Bora

Bora is an extremely cold and dry north-easterly wind which blows along the shore of the **Adriatic Sea**.

Unlike mistral, bora is relatively moist wind because it picks up moisture while coming from over the Adriatic Sea

Blizzard

Blizzard is a **violent stormy cold and powdery polar** wind laden with dry snow and is prevalent in north and south polar regions, Siberia, Canada and the USA.

They are called **'norther'** in the southern USA and '**burran**' in Siberia.

OTHER LOCAL WINDS

Purga-a snow-laden cold wind in RussianTundra.

Bise-an extremely cold wind in France.

Levanter-a strong easterly cold wind in southern Spain.

Pampero-a northwesterly cold wind in the 'pampas' of S. America.

Norwester-a warm, dry and gusty wind in New Zealand.

Santa Ana - a warm and dry wind in the USA.

Yamo- a warm and dry wind in Japan.

Zonda - a warm wind in Argentina.

Tramontane - a warm wind in central Europe.

El Nino

During an El Niño event, a**bnormally warm water appears at the surface of the ocean off the west coast of South America,** replacing the cold, nutrient-rich water that usually prevails.
Every three to seven years, however, the warming of the ocean is much greater.

Every few years, the normal pressure patterns in the Pacific change High pressure develops over northern Australia and low pressure develops to the east near Tahiti. This "seesaw" of pressure is known as the **Southern Oscillation**

For many months before the onset of an El Niño, the trade winds pile up warm water in the western Pacific near Indonesia. A bulge of warm equatorial water perhaps 25 centimeters (10 inches) high then begins to move to the east across the Pacific toward South America. Such slowly moving bulges of warm water are known as ***Kelvin waves***

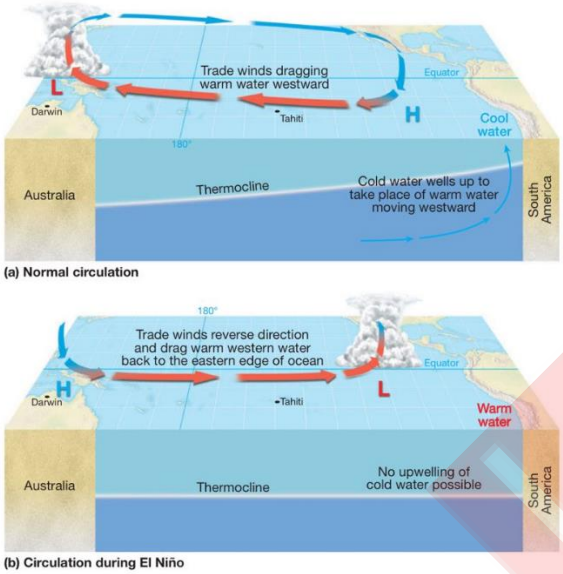
Arrival of El Niño Conditions:
When the Kelvin wave arrives at South America, sea level rises as the warm water pools.
The usual high pressure in the subtropics has weakened; upwelling no longer brings cold water to the surface, so ocean temperature increases still further—an El Niño is under way.

By this time, the trade winds have weakened or even reversed directions and started to flow from the west—blowing moist air into the deserts of coastal Peru.
The thermocline boundary between near-surface and cold deep ocean waters lowers. Pressure increases over Indonesia and the most active portion of the ITCZ in the Pacific shifts from the now-cooler western Pacific, toward the now-warmer central and eastern Pacific basin. **Drought strikes northern Australia and Indonesia; the South Asian monsoon may fail or develop weakly.**

La Nina

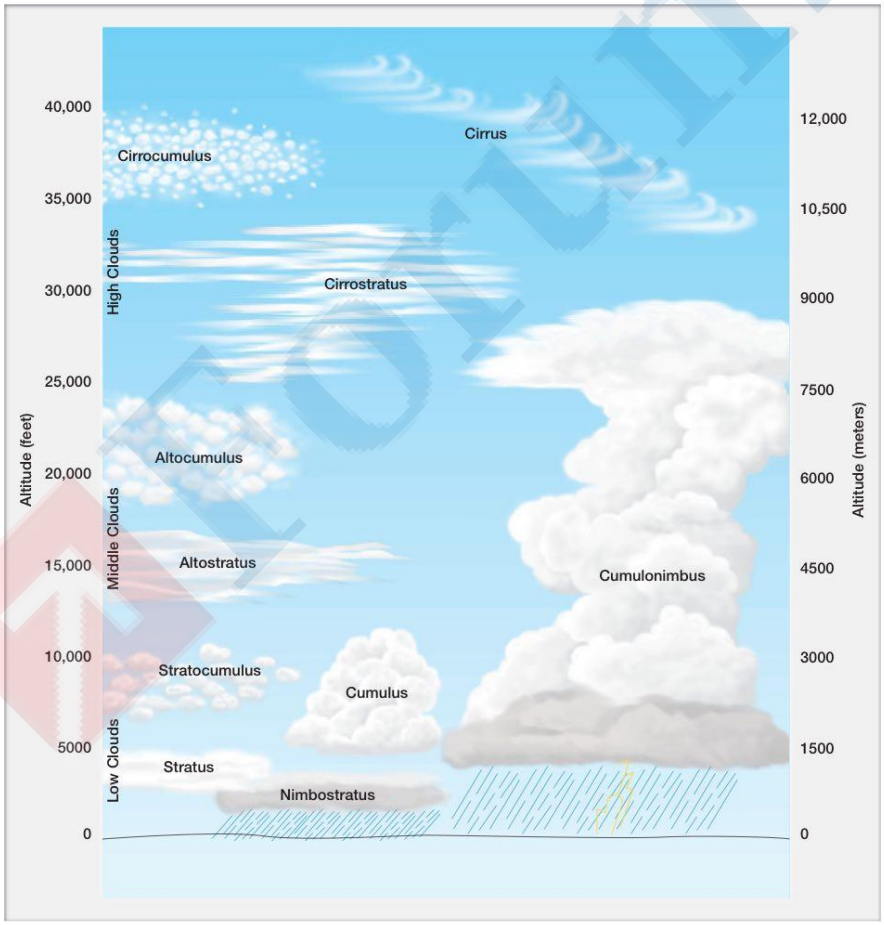
La Niña is simply the opposite of El Niño: the waters off South America become unusually cool the trade winds are stronger than usual; the waters off Indonesia are unusually warm; the southwestern United States is drier than usual while Southeast Asia and northern Australia are wetter. Because El Niño and La Niña conditions are generally identified by sea-

surface temperature trends, sometimes El Niño is referred to as the "warm" phase of ENSO while La Niña is referred to as the "cold" phase.



▶ **Figure 5-38** (a) Normal conditions in the South Pacific. The trade winds carry warm equatorial water across the Pacific from east to west. (b) These conditions either weaken or reverse during an El Niño event. The upwelling of cold water off of South America diminishes, the thermocline boundary between near-surface and cold deep water lowers, and much warmer water than usual is present there.

Clouds and Precipitation -



High clouds are generally found above 6 kilometers (20,000 feet). Because of the small amount of water vapor and low temperature at such altitudes, these clouds are thin, white, and composed of ice crystals. Included in this family are cirrus, cirrocumulus, and cirrostratus. These high clouds often are harbingers of an approaching weather system or storm.

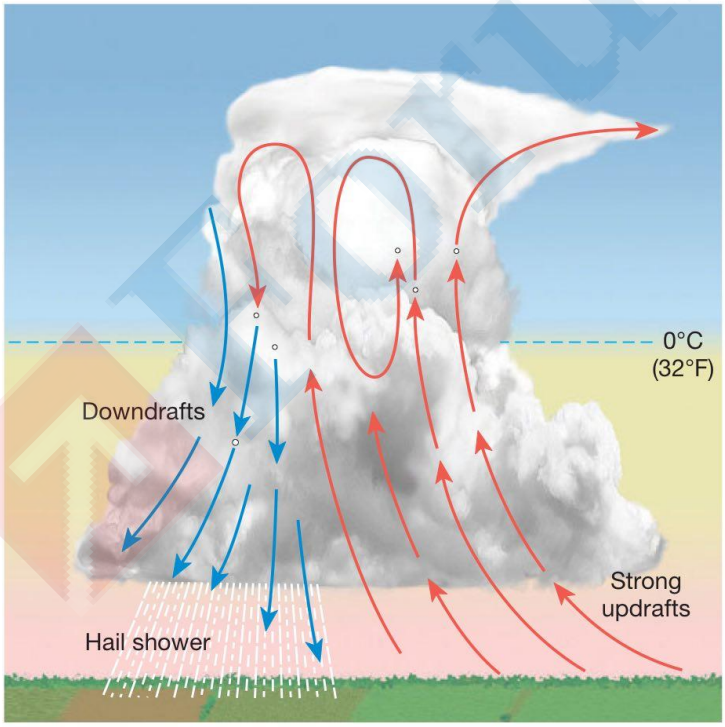
2. Middle clouds normally occur between about 2 and 6 kilometers (6500 and 20,000 feet). They may be either stratiform or cumuliform and are composed of liquid water. Included types are altocumulus and altostratus. The puffy altocumulus clouds usually indicate settled weather conditions, whereas the lengthy altostratus are often associated with changing weather.

3. Low clouds usually are below 2 kilometers (6500 feet). They sometimes occur as individual clouds

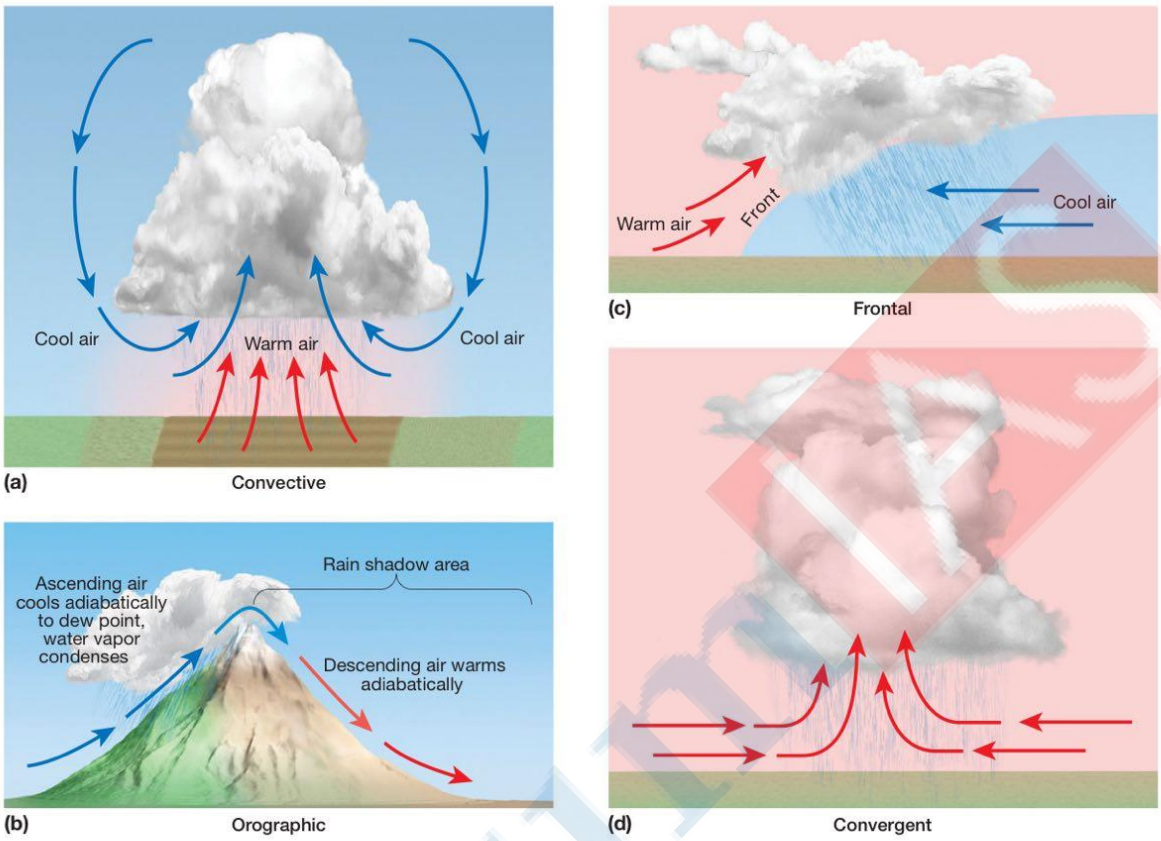
but more often appear as a general overcast. Low cloud types include stratus, stratocumulus, and nimbostratus. These low clouds often are widespread and are associated with somber skies and drizzly rain.

4. A fourth family, clouds of vertical development, grows upward from low bases to heights of as much as 15 kilometers (60,000 feet). Their horizontal spread

is usually very restricted. They indicate very active vertical movements in the air. The relevant types are cumulus, which usually indicate fair weather, and cumulonimbus, which are storm clouds.



▲ **Figure 6-31** Hail is produced in cumulonimbus clouds with strong updrafts that are partly at a temperature above the freezing point of water and partly at a temperature below the freezing point of water. The curved and spiral arrows indicate paths a hailstone takes as it is forming.



▲ **Figure 6-32** The four basic types of atmospheric lifting and precipitation: (a) convective, (b) orographic, (c) frontal, (d) convergent.