Topic 3. : Atmospheric Pressure and Wind System

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Note: This document is only for SYBA student as class notes and not for any commercial purpose.

Introduction:

- air to move *horizontally*— the phenomenon we call **wind**
- *wind is the result of horizontal differences in atmospheric pressure.*
- The continuous bombardment of gas molecules against the sides of the container exerts an outward force called ***air pressure.***
- Instruments used to measure air pressure are**……mercury barometer, aneroid barometer**
- **Instrument barograph** :a **barograph,** provides a continuous record of pressure changes over time

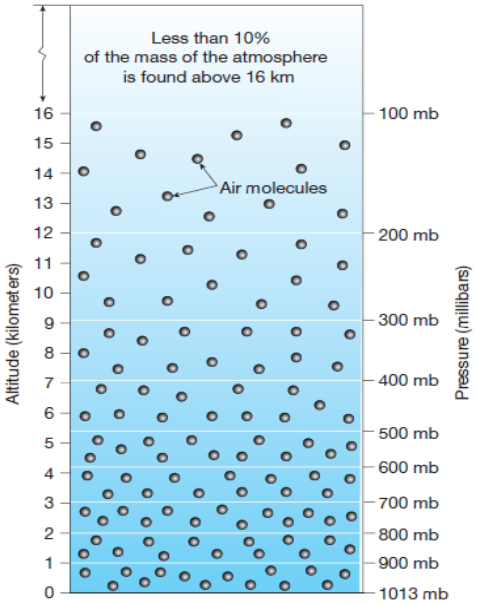
3.1 : Vertical and horizontal distribution of pressure

- **vertical pressure changes are important**
- In the lower atmosphere the pressure decreases rapidly with height.
- The decrease amounts to about 1 mb for each 10 m increase in elevation.
- It does not always decrease at the same rate.
- Table gives the average pressure and temperature at selected levels of elevation for a standard atmosphere.

Table 10.1 : Standard Pressure and Temperature at Selected Levels

Level	*Pressure in mb*	*Temperature °C*
Sea Level	1,013.25	15.2
1 km	898.76	8.7
5 km	540.48	-17. 3
10 km	265.00	- 49.7

Vertical Distribution of Temperature shown in figure……



- The vertical pressure gradient force is much larger than that of the horizontal pressure gradient.
- But, it is generally balanced by a nearly equal but opposite gravitational force.
- Hence, we do not experience strong upward winds.

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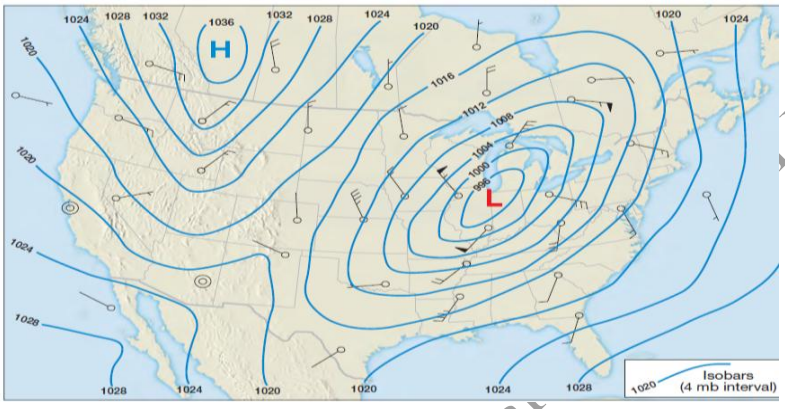
Horizontal Distribution of Pressure

- vertical pressure changes are important,
- meteorologists are much more interested in the horizontal pressure differences that occur daily from place to place around the globe.
- Pressure differences from place to place are relatively small.
- Small differences in pressure are highly significant in terms of the wind direction and velocity.
- Horizontal distribution of pressure is studied by drawing **isobars** at constant levels.
- **Isobars** are lines connecting places having equal pressure.



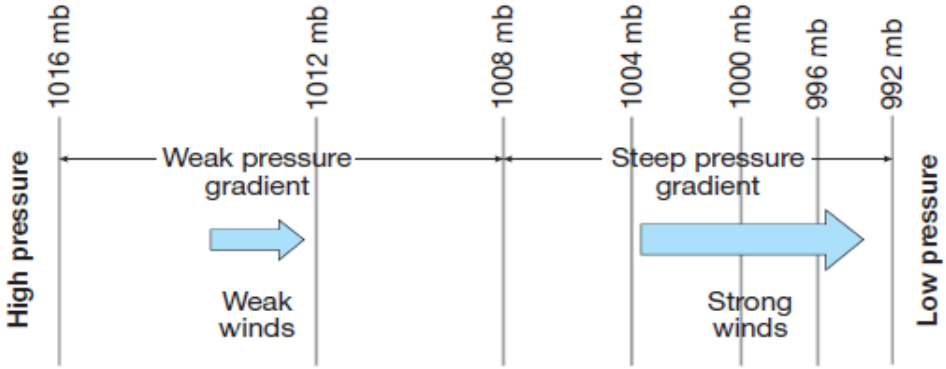
Isobar Pattern on Map

3.3: Important Concepts to be understand:

1. Pressure gradient:

- Variations in air pressure over Earth's surface are determined from barometric readings taken at hundreds of weather stations.
- These pressure measurements are shown on surface weather maps using isobars (*iso* = "equal," *bar* = "pressure") lines connecting places of equal air pressure
- (Figure 6-9). The *spacing* of the isobars indicates the amount of pressure change occurring over a given distance and is called the pressure gradient force.

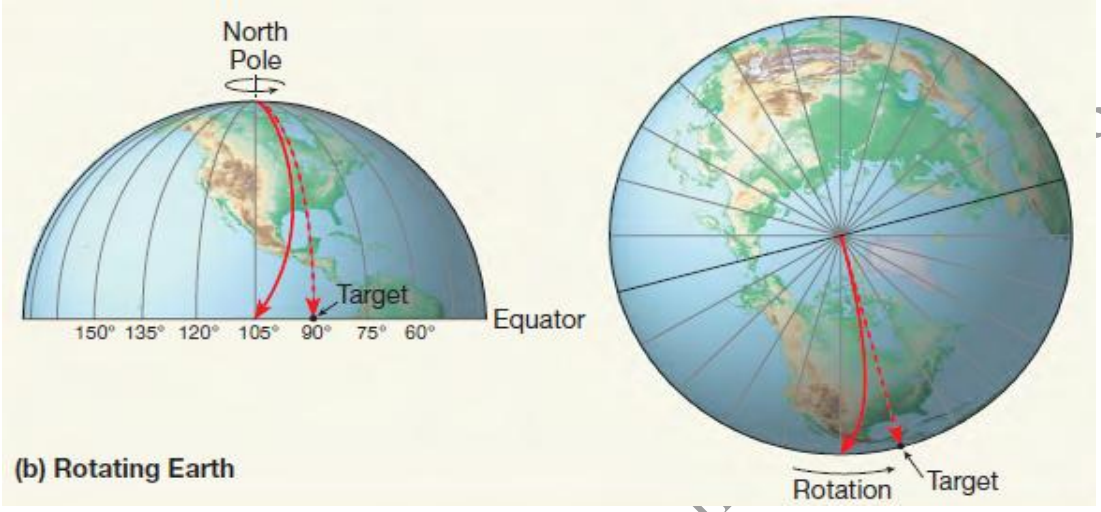
Closely spaced isobars indicate a steep pressure gradient and strong winds;
Widely spaced isobars indicate a weak pressure gradient and light winds.



Coriolis Force:

- This deviation is the result of Earth's rotation and has been named the **Coriolis force,** after the French scientist Gaspard-Gustave Coriolis, who first expressed its magnitude quantitatively.

- It is important to note that the Coriolis force cannot generate wind; rather, *it modifies airflow.*
- The Coriolis force causes all free moving objects, including wind, to be deflected
- to the *right* of their path of motion in the Northern Hemisphere and to the *left* in the Southern Hemisphere.



Friction

- Earlier we stated that the pressure gradient force is the primary driving force of the wind.
- it causes air to accelerate from regions of higher pressure toward regions of lower pressure.
- Thus, we might expect wind speeds to continually increase (accelerate).
- But we know from personal experience that winds do not become faster indefinitely.
- **Friction, which acts to slow moving objects, comes into play.**
- Although friction significantly influences airflow near Earth's surface, its effect is negligible above a height of a few kilometres

3.2 Formation of pressure belts and their relation with winds

Pressure Zones Drive the Wind

- Earth's global wind patterns are derived from a distinct distribution of surface air pressure.
- To simplify understanding of this relation ,
- examine the idealized pressure distribution that would be expected if Earth's surface were uniform—that is, composed entirely of water or smooth land.

Idealized Zonal Pressure Belts

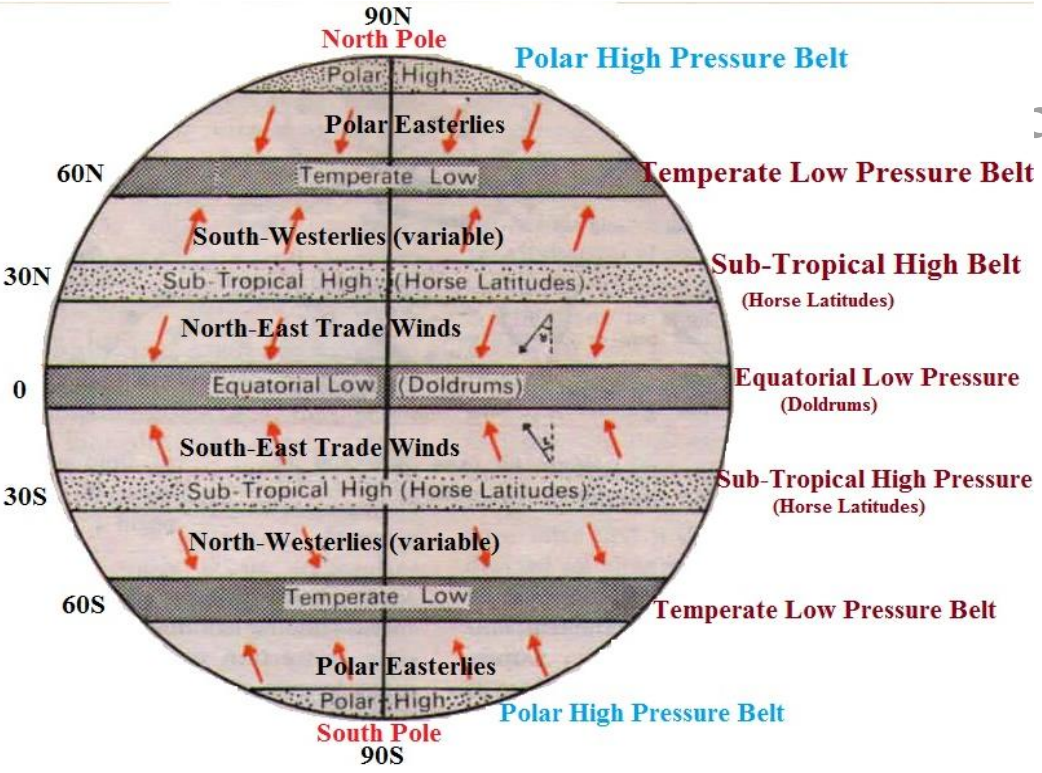
- If Earth had a uniform surface, each hemisphere would have two east-west oriented belts of high pressure and two of low pressure
- Actually 4 pressure belts are developed on the earth.

1. Equatorial low

- Near the equator, the warm rising branch of the Hadley cells is associated with the low-pressure zone known as the **equatorial low.**

- This region of ascending moist, hot air is marked by abundant precipitation.
- Because this region of low pressure is where the trade winds converge,
- it is also referred to as the **intertropical convergence zone (ITCZ).**
- the ITCZ is visible as a band of clouds near the equator.
- Belt called as "Doldrums"

2.



The Distribution of World Pressure Belts and Planetary Winds

Sub-tropical High Pressure Belt:

- In the belts about 20° to 35° (30° N & S) on either side of the equator,
- where the westerlies and trade winds originate and go their separate ways,
- are the high-pressure zones known as the **subtropical highs.**
- **Sub-tropical (Northern Hemisphere)**
- **Sub-tropical (Southern Hemisphere)**
- In these zones a subsiding air column produces weather that is normally warm and dry.
- Belt called as "Horse Latitude"

3.Temprate/ Subpolar Low Pressure belt:

- Another low-pressure region is situated at about 50° to 60° latitude, in a position corresponding to the polar front.
- Here the polar easterlies and the westerlies clash in the lowpressure convergence zone known as the **subpolar low.**
- this zone is responsible for much of the stormy weather in the middle latitudes, particularly in the winter.

4. Polar High Pressure Belt:

- near Earth's poles are the **polar highs pressure belt,**

- From which the polar easterlies originate .
- The polar highs exhibit high surface pressure mainly because of surface cooling.
- Because air near the poles is cold anddense, it exerts higher-than-average pressure.

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3.4. Type of winds-

- **Planetary winds,**
- **Periodic winds (Monsoon winds),**
- **Local winds –**
  - **land and sea breezes,**
  - **mountain and valley winds**

Introduction:

Wind is defined as air moving horizontally over the Earth's surface.

- Horizontal movement of Air from high pressure to low pressure is known as wind.
- The wind systems can group in three major(3M) categories of atmospheric circulation:
  - Microscale,
  - Mesoscale, and
  - Macroscale.

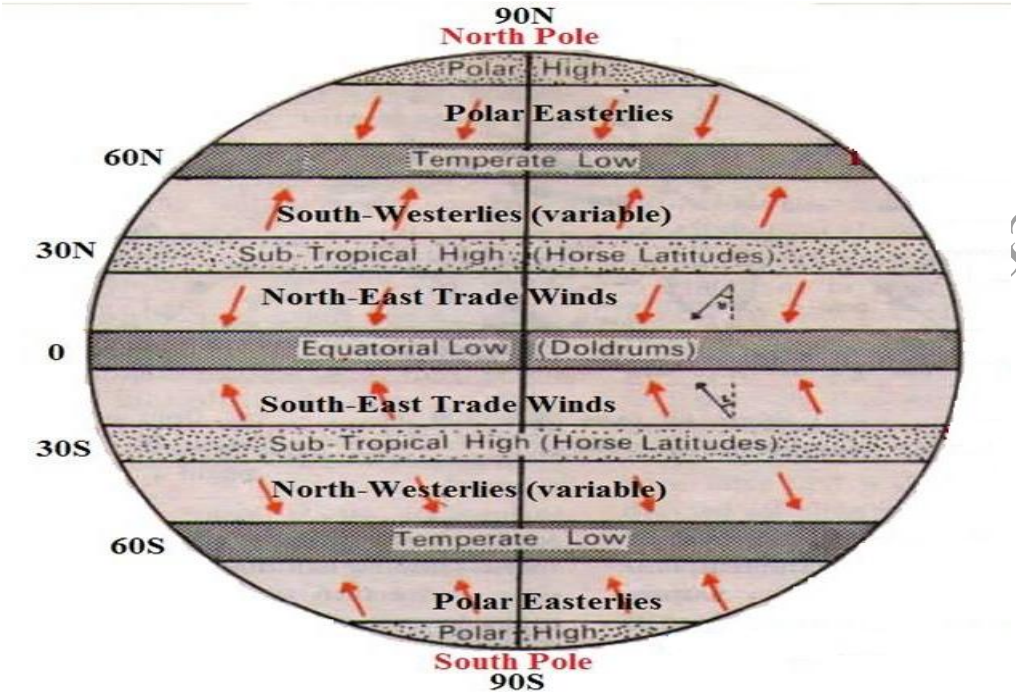
Name of the Scale	Time Scale	Length Scale	Example
1.Macroscale a. Planetary Scale	Weeks to Years	1000 to 40,000km	Westerlies, Easterlies, Trade Winds
b. Synoptic Scale	Days to Weeks	100 to 5000km	Cyclones, Anti-cyclone, Hurricanes
2.Mesoscale	Minutes to Days	1 to 100km	Land Sea Breezes, Thunderstorms,Tornadoes
3.Microscale	Seconds to Minutes	Less than 1 km	Turbulence

The Planetary Winds:

- Within the pattern of permanent pressure belt on the globe, winds tend to blow from the high pressure belt to low pressure belts as the planetary winds.
- Instead of blowing directly from one pressure belt to another, however, the effect of the rotation of the earth (Coriolis Force) tends to deflect the direction of the winds.
- In the northern hemisphere, winds are deflected to their right and in the southern hemisphere to their left.
- This is known as Ferrel's Low of Deflection.
- The Coriolis Force is absent along the equator but increases progressively towards the pole.
- 1.Trade Wind
  - a. North East Trade Wind
  - b. South-East-Trade Wind
- 2. Westerlies

- a. South-Westerlies
- b. North-Westerlies

- 3.Polar Easterlies Wind



The Distribution of World Pressure Belts and Planetary Winds

Trade Winds:

- Winds blow out from the Subtropical High Pressure Belt in the northern Hemisphere towards the Equatorial Low become **North-East trade winds,**
- And those in the southern hemisphere become the ***South- East Trade winds***
- Trade winds are the most regular of all planetary winds
- Blow great force and a constant direction.
- They were thus helpful to easy traders who depended on the wind when sailing the high seas, hence the name trade winds.
- Blow from the cooler sub-tropical latitudes to the warmer tropics, they have great capacity for capacity for holding moisture.
- In their passage across the open oceans, they gather more moisture and bring Heavy Rainfall to the East Coast of continents within the tropics.
- As they are off-shore on the west coast, these regions suffer from great aridity and forms the Trade Wind Hot Deserts of the World…
- Sahara, Kalahari, Atacama and Great Australian Deserts.

The Westerlies Winds

- the great wind system of the midlatitudes, commonly called the **Westerlies**,
- From the Sub tropical high pressure belts winds blow towards the temperate low pressure belts as the variable Westerlies

- Under effects of Coriolis Force, they become the South-Westerlies in the northern hemisphere and north-Westerlies in southern hemisphere
- flow from west to east around the world in the latitudinal zone between about 30° and 60° both north & south of the equator.
- They are more variable in the northern hemisphere,
- but they play a valuable role in the carrying warm equatorial water and winds to western coasts of temperate land.
- Result variable climate-cyclone and anticyclone
- In southern hemisphere, where large expanse of Ocean (from 40 S to 60 S) –Westerly blow with much greater force and regularity throughout the year.
- They bring much precipitation to the western cost of continents
- Weather is damp and cloudly, and seas are violent and stormy.
- For Seafarers to refer to the Westerlies as the…
    - Roaring Forties, 40N
    - Furious Fifties, 50N
    - Shrieking or Stormy Sixties 60N

According to the varying degree of storminess in the latitudes in which they blow

Polar Easterlies

The third broad-scale global wind system occupies most of the area between the polar highs and about 60° of latitude (Figure 5-26). The winds move generally from east to west and are called the **polar easterlies**. They are typically cold and dry but quite variable.

- It blow out from the Polar High Pressure
- Belts towards the Temperate Low Pressure Belts.
- These are extrimely cold wind as they comes from the tundra and ice-cap regions.
- They are more regular in the south than n the north

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ii. Periodic winds (Monsoon winds),

Monsoons

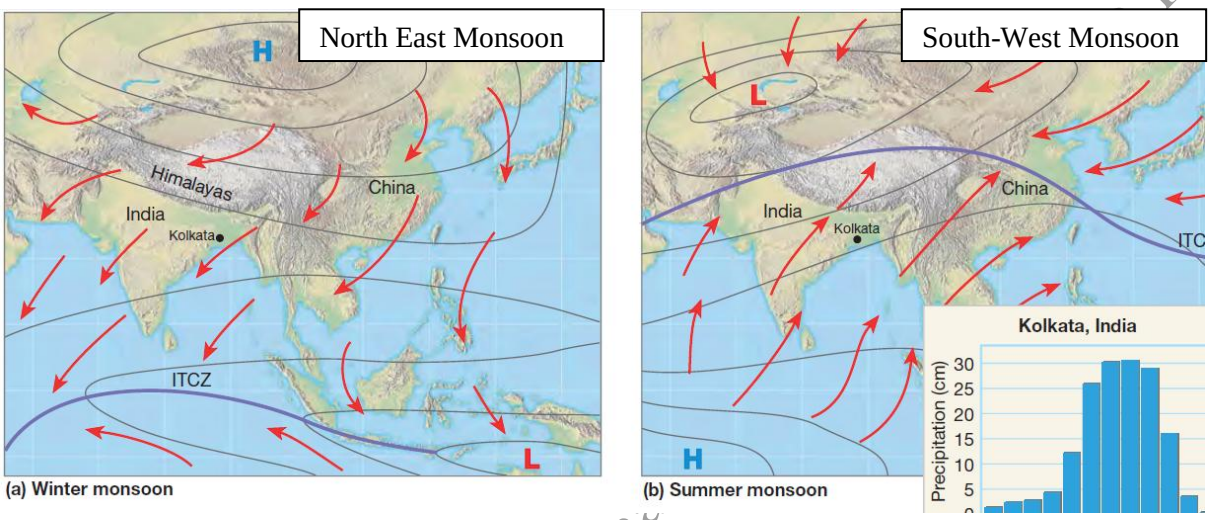
- Large *seasonal* changes in Earth's global circulation are called monsoons.
- **monsoon** does not mean "rainy season"; rather,
- it refers to a particular wind system that reverses its direction twice each year.
- In general, winter is associated with winds that blow predominantly off the continents, called the ***winter monsoon*.**
- In contrast, in summer, warm moisture-laden air blows from the sea toward the land. Thus, the ***summer monsoon*** is usually associated with abundant precipitation over affected land areas and is the source of the misconception.
- The pattern of wind circulation is modified in different seasons due to the shifting of regions of maximum heating, pressure and wind belts.

- The most pronounced effect of such a shift is noticed in the monsoons, especially over southeast Asia.

The Asian Monsoon

- The best-known and best-developed monsoon circulation occurs in southern and southeastern Asia—affecting India and the surrounding areas as well as parts of China, Korea, and Japan.

the Asian monsoon is driven by pressure differences that are generated by unequal heating of Earth's surface



(a) Winter monsoon (b) Summer monsoon

iii. Local winds –

a) Land and sea breezes,

b) Mountain and valley winds

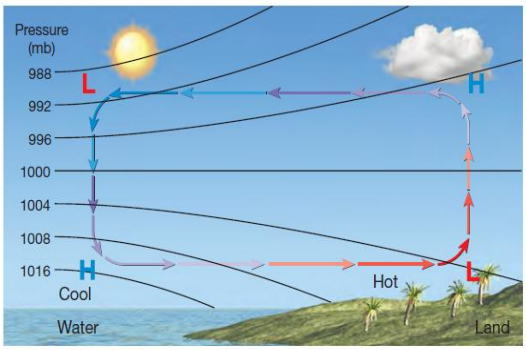
- *Local winds* are driven by local effects.
- Local winds are examples of mesoscale winds (time frame of minutes to hours and size of 1 to 100 kilometers).
- causes: pressure differences that arise because of temperature differences caused by unequal heating of Earth's surface.
- Most local winds are linked to temperature and pressure differences
    - that result from variations in topography or in local surface conditions.
- *Differences in the heating and cooling of earth surfaces and the cycles those develop daily or annually can create several common, local or regional winds*

Sea and *land breezes*, *mountain* and *valley winds* are simple examples of local winds.

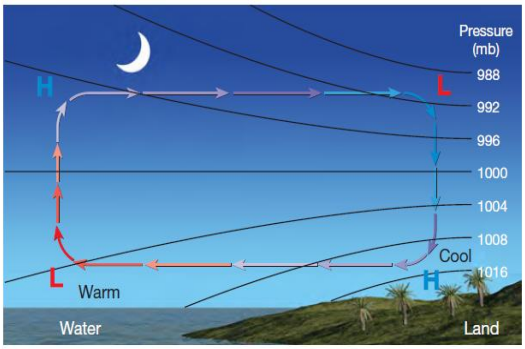
Land and Sea Breezes

Sea Breezes

- the land and sea absorb and transfer heat differently.
- During the day the land heats up faster and becomes warmer than the sea.
- Therefore, over the land the air rises giving rise to a low pressure area, whereas the sea is relatively cool and the pressure over sea is relatively high.
- Thus, pressure gradient from sea to land is created and the wind blows from the sea to the land as the sea breeze.



(a) Sea breeze



(b) Land breeze

- ***Land Breezes***
- In the night the reversal of condition takes place.
- The land loses heat faster and is cooler than the sea.
- The pressure gradient is from the land to the sea and hence land breeze results

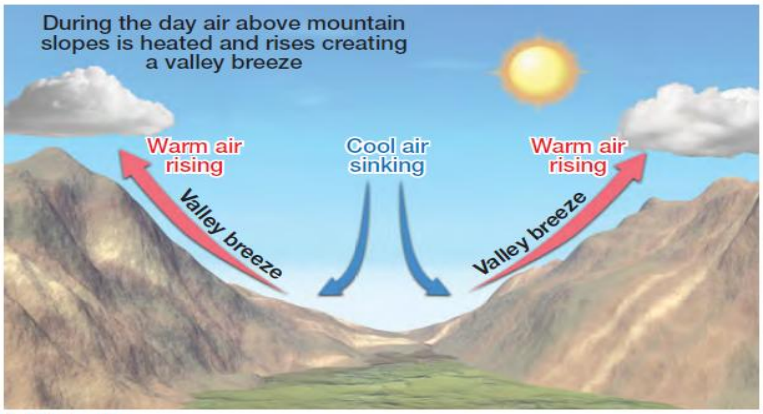
  - The intensity and extent of land and sea breezes vary by location and season.
  - Tropical areas where intense solar heating is continuous throughout the year experience more frequent and stronger sea breezes than midlatitude locations.
  - The most intense sea breezes develop along tropical coastlines adjacent to cool ocean currents.
  - In the middle latitudes, sea breezes are best developed during the warmest months, but land breezes are often missing because at night the land does not always cool below the temperature of the ocean surface.

Mountain and Valley Breezes

- A daily wind similar to land and sea breezes occurs in mountainous regions.
- During the day, air along mountain slopes is heated more intensely than air at the same elevation over the valley floor.

Valley Breeze

- This warmer air glides up the mountain slope and generates a **valley breeze.**

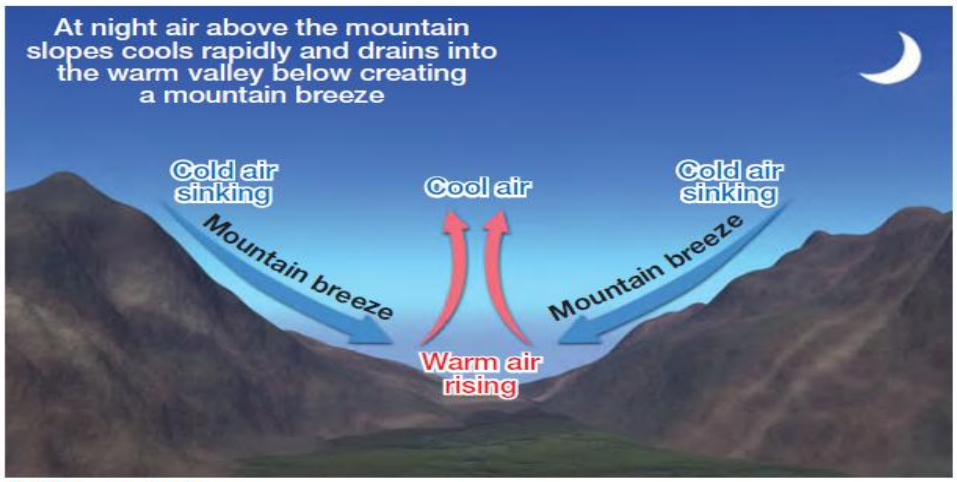


(a) Valley breeze

Mountain breeze

- After sunset the pattern is reversed. Rapid heat loss along the mountain slopes cools the air, which drains into the valley and causes a **mountain breeze.**
- Similar cool air drainage can occur in hilly regions that have modest slopes.

- The result is that the coldest pockets of air are usually found in the lowest spots.



(b) Mountain breeze

- Like many other winds, mountain and valley breezes have seasonal preferences.
- Valley breezes are most common during warm seasons, when solar heating is most intense,
- whereas mountain breezes tend to be more frequent during cold seasons.

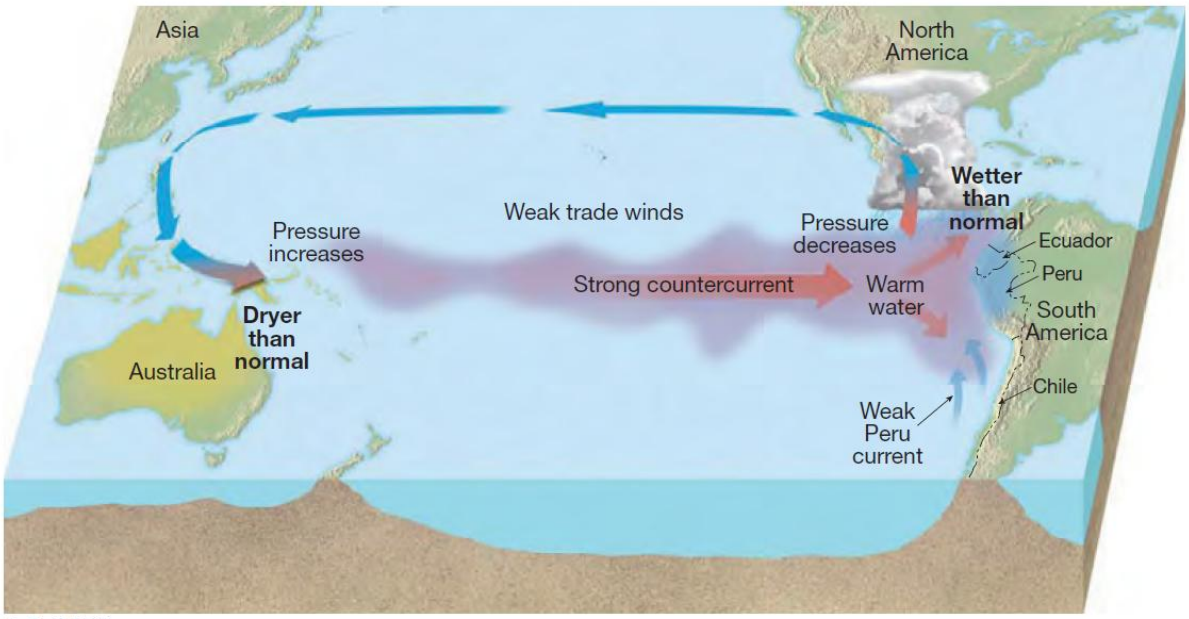
5. El Niño and La Niña

Introduction:

El Niño Southern Oscillation (ENSO) is a fluctuation of the ocean–atmosphere system that originates in the tropical Pacific. The warm phase is known as El Niño and the cold phase La Niña.

El Niños are a regional phenomenon , but their 'footprint' is global. In general, the tropical Pacific Ocean is characterized by warm surface water (29–307C) in the west but much cooler temperatures in the east (22–247C).

- **El Nino**
  - El Nino is a natural phenomenon wherein the ocean temperatures rise especially in parts of the Pacific ocean.
  - a periodic development along the coast of Peru.
  - This development is a temporary replacement of the cold current along the coast of Peru.
- El Nino is a Spanish word. The term El Nino basically means 'the child'.
- This is due to the fact that this current starts to flow around Christmas and hence the name referring to baby Christ.
- **El Niño** was first recognized by **fishermen** from **Ecuador and Peru**, who noted a **gradual warming of waters** in the **eastern Pacific in December or January.**
- warming usually occurred near the **Christmas season**, the event was named ***El Niño—"little boy," or "Christ child,"*** in Spanish.
- irregular intervals of **two to seven years** and usually persist for **spans of nine months to two years.**

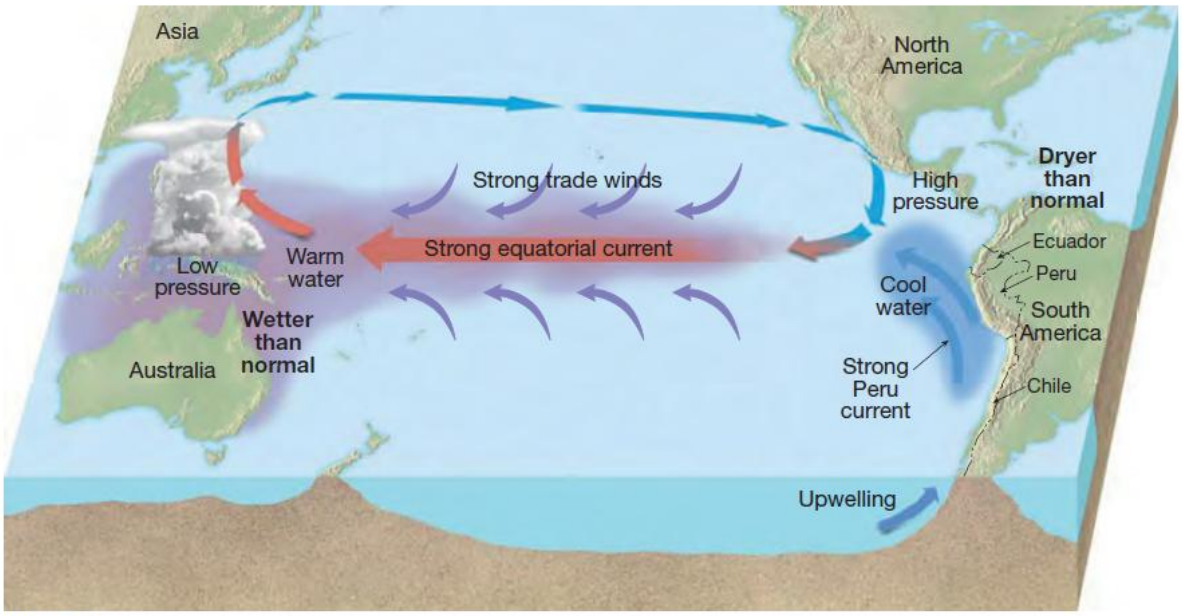


(b) El Niño

(**b) When the Southern Oscillation** occurs, the pressure over the eastern and western Pacific flip-flops. This causes the trade winds to diminish, leading to an eastward movement of warm water along the equator and the beginning of an El Niño. As a result, the surface waters of the central and eastern Pacific warm, with far-reaching consequences for weather patterns.
(Source: Trujillo,2016)

❖ La Nina

- ❖ Another natural phenomenon, similar to El Nino is the La Nina, which is also in news these days.
- ❖ The term La Nina literally means ‘ little girl’.
- ❖ It is termed as opposite to the phenomenon of El Nino as it results in the ‘cooling’ of the ocean water in parts of the Pacific ocean.
- ❖ **La Niña**, which means **“little girl,”** is the opposite of **El Niño** and refers to **colder-than-normal sea-surface temperatures** along the **coastline of Ecuador and Peru.**



(a) La Niña

(a) During a La Niña event, strong trade winds drive the equatorial currents toward the west. At the same time, the strong Peru Current causes upwelling of cold water along the west coast of South America.

- See Animation of El Nino and La Nino here: http://esminfo.prenhall.com/science/geoanimations/animations/26_NinoNina.html

Southern Oscillation

- Major **El Niño and La Niña events** are intimately related to the **large-scale atmospheric circulation**.
- Each time an El Niño occurs,
- the barometric pressure drops over large portions of the eastern Pacific and rises in the western Pacific.
- Then, as a major El Niño event comes to an end, the pressure difference between these two regions swings back in the opposite direction, triggering a La Niña event.

This seesaw pattern of atmospheric pressure between the eastern and western Pacific is called the **Southern Oscillation** .

Impact of El Niño:

- El Niño is noted for its potentially catastrophic impact on the weather and economies of Peru, Chile, and Australia, among other countries.
- during an El Niño, strong equatorial countercurrents amass large quantities of warm water that block the upwelling of colder, nutrient-filled water along the west coast of South America.
- As a result, the anchovies, which support the population of game fish, starve, devastating the fishing industry.
- some inland areas of Peru and Chile that are normally arid receive above-average rainfall, which can cause major flooding.

- These climatic fluctuations have been known for years, but they were considered local phenomena.
- Scientists now recognize that El Niño is part of the global atmospheric circulation pattern that affects the weather at great distances from Peru.
- One of the most severe El Niño events on record occurred in 1997–1998 and was responsible for a variety of weather extremes in many parts of the world.
- During the 1997– 1998 El Niño episode, ferocious winter storms struck the California coast, causing unprecedented beach erosion, landslides, and floods.
- Inthe southern United States, heavy rains also brought floods to Texas and the Gulf states.

Effects wit India :

- El Nino results in the rise of sea surface temperatures
- It also weakens the trade winds of the affected region
- In India, Australia, it can bring about drought conditions.
  - This affects the crop productivity largely.
  - It has been also observed certain times, that EL Nino may not bring drought but cause heavy rainfall.
  - In both the cases, it causes heavy damage.
- However, in some other countries it may result in a complete reversal, i.e., excessive rainfall.

The consequences:

- El Niños are a regional phenomenon, but their 'footprint' is global.
- They are usually accompanied by severe drought over Australia and Indonesia, together with a weakened summer monsoon rainfall over South Asia.
- Catastrophic flooding often occurs along the Pacific coast of South America and
- fish stocks disappear as ocean upwelling, containing high-nutrient cold water, diminishes.
- For societies where the impacts of El Niño are most direct, homes might be flooded, or destroyed by forest fire, and crops destroyed and fisheries ruined.
- Distinct disease patterns follow the waxing and waning of an event, through the contamination of water supplies by flooding and the creation of increased breeding areas for vectors such as mosquitoes.
- Water-borne diseases (hepatitis, dysentery, typhoid and cholera) have cycles associated with El Niño, as do vector-borne diseases (malaria, dengue and yellow fever, encephalitis, plague, hantavirus and schistosomiasis).
- El Niño also influences tropical cyclones, reducing their frequency in the Atlantic, but increasing it in parts of the Pacific.
- Moreover, the climate of the extratropical regions remote from the Pacific may be affected by 'teleconnections'
- Beyond thesesevere regional impacts there is a broad influence on the global economy.
- Many of the commodities that are sensitive to El Niño, such as cereal crops**,** are traded on the world markets.
- Finally, the insurance industry is affected by the changing location of severe

storms and hurrican

- Scientists now recognize that El Niño is part of the global atmospheric circulation pattern that affects the weather at great distances from Peru.

MITIGATION OF EFFECTS:

Keeping a check on the sea surface temperatures…

- Maintain sufficient buffer stocks of food grains and ensuring their smooth supply
- Ensuring relevant support to the farmer community including economic help
- to be promoted such as the practice of sustainable agriculture

References:

1. Essentials of Oceanography by Alan P. Trujillo, Harold V. Thurman
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3. Oceanography by D S Lal
4. Oceanography BY Savindar Sing
5. **http://esminfo.prenhall.com/science/geoanimations/animations/26_NinoNina.html**
6. **WHO website**

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