1. Details of Module and its structure

Module Detail	
Subject Name	Geography
Course Name	Geography 02 (Class XI, Semester - 2)
Module Name/Title	Monsoon Climate: Mechanism and Nature of the Indian Monsoon – Part 2
Module Id	kegy_20402
Pre-requisites	Basic Concept about temperature, pressure and wind
Objectives	After reading this lesson, learners will be able to: • Acquire knowledge and understanding about the mechanism of weather in the winter season. • Acquire knowledge and understanding about the mechanism of weather in the summer season. • Understand the nature of Indian monsoon. • Learn about the concept of break in Monsoon. • Know the role of El-Nino in Indian monsoon.
Keywords	Jet Stream, Upper Air Circulation, Western Cyclonic Disturbance, Tropical Cyclones, Inter Tropical Convergence Zone, Easterly Jet Stream, onset of the monsoon, EI-Nino, Break in the Monsoon

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Table of Content:

Introduction

In the previous module of climate, you have read about the difference between weather and climate, seasonal and diurnal variations in the atmospheric conditions and factors affecting the climate of India. In this module we will discuss about the mechanism of weather in the winter season and the summer season and the nature of the Indian monsoon. This module will let you know the whole procedure of Indian monsoon during the winter and summer season. Have you ever noticed the direction of wind in different months of the year? Have you ever noticed that which month of the year gets the maximum and minimum amount of rainfall? Have you ever thought for the reason behind the dry spells during the advancing monsoon? Have you ever thought for the reason behind the cyclones that is experienced in the coastal regions of the eastern coast? This module will definitely help you out in knowing the answer of these questions. Let us begin with the mechanism of weather in the winter season.

Mechanism of Weather in the Winter Season

To understand the mechanism of weather in the winter season we have to know the role of pressure and surface winds, jet stream, upper air circulation, western cyclonic disturbances and tropical cyclone during the winter season. Let us start with the role of Surface Pressure and Winds during the winter season.

Surface Pressure and Winds: During the winter season the sun's position is in the southern hemisphere. Therefore, Southern Hemisphere experience high temperature and low pressure and vice-versa in the northern hemisphere. In winter months, the weather conditions over India are generally influenced by the distribution of pressure in Central and Western Asia.

A high pressure develops in the region lying to the north of the Himalayas during winter. This Centre of high pressure gives rise to the flow of air at the low level from the north towards the Indian subcontinent, south of the Himalayan mountain range. The surface winds blowing out of the high pressure Centre over Central Asia reach India in the form of a dry continental air mass.

Map: Surface and Pressure Winds During Winter

Source: https://mapswire.com/maps/world/world-physical-map-blank-mercator-large.jpg

These continental winds come in contact with trade winds over northwestern India. The position of this contact zone is not, however, stable. Occasionally, it may shift its position as far east as the middle Ganga valley with the result of that the whole of the northwestern and northern India up to the middle Ganga valley comes under the influence of dry northwestern winds.

Jet Stream and Upper Air Circulation: The pattern of air circulation discussed above is witnessed only at the lower level of the atmosphere near the surface of the earth. Higher up in the lower troposphere, about three km above the surface of the earth, a different pattern of air circulation is observed.

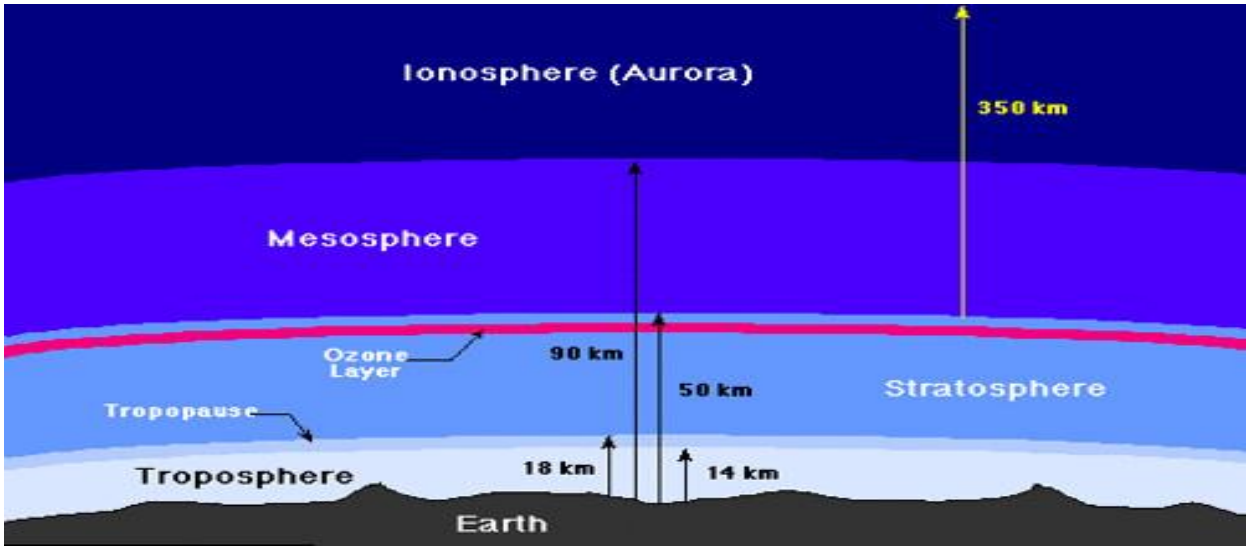
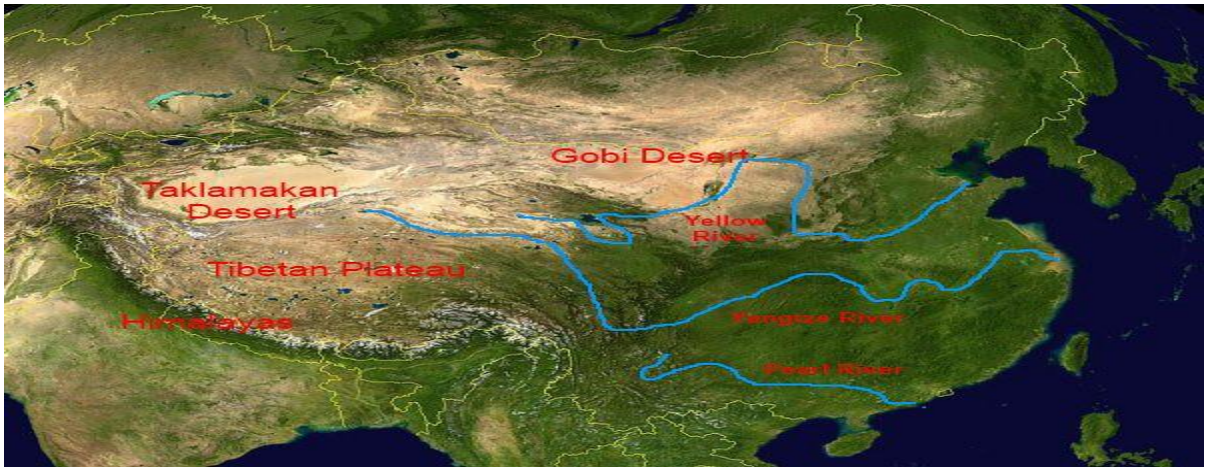


Fig 1: Troposphere

Source: https://www.flickr.com/photos/114042825@N07/15487576309

The variations in the atmospheric pressure closer to the surface of the earth have no role to play in the making of upper air circulation. All of Western and Central Asia remains under the influence of westerly winds along the altitude of 9-13 km from west to east. These winds blow across the Asian continent at latitudes north of the Himalayas roughly parallel to the Tibetan highlands. These are known as jet streams.



Map: Tibetan highlands

Source: https://www.flickr.com/photos/114042825@N07/15488908258

Tibetan highlands act as a barrier in the path of these jet streams. As a result, jet streams get bifurcated. One of its branches blows to the north of the Tibetan highlands, while the southern branch blows in an eastward direction, south of the Himalayas. It has its mean position at 25°N in February at 200-300 mb level. It is believed that this southern branch of the jet stream exercises an important influence on the winter weather in India.

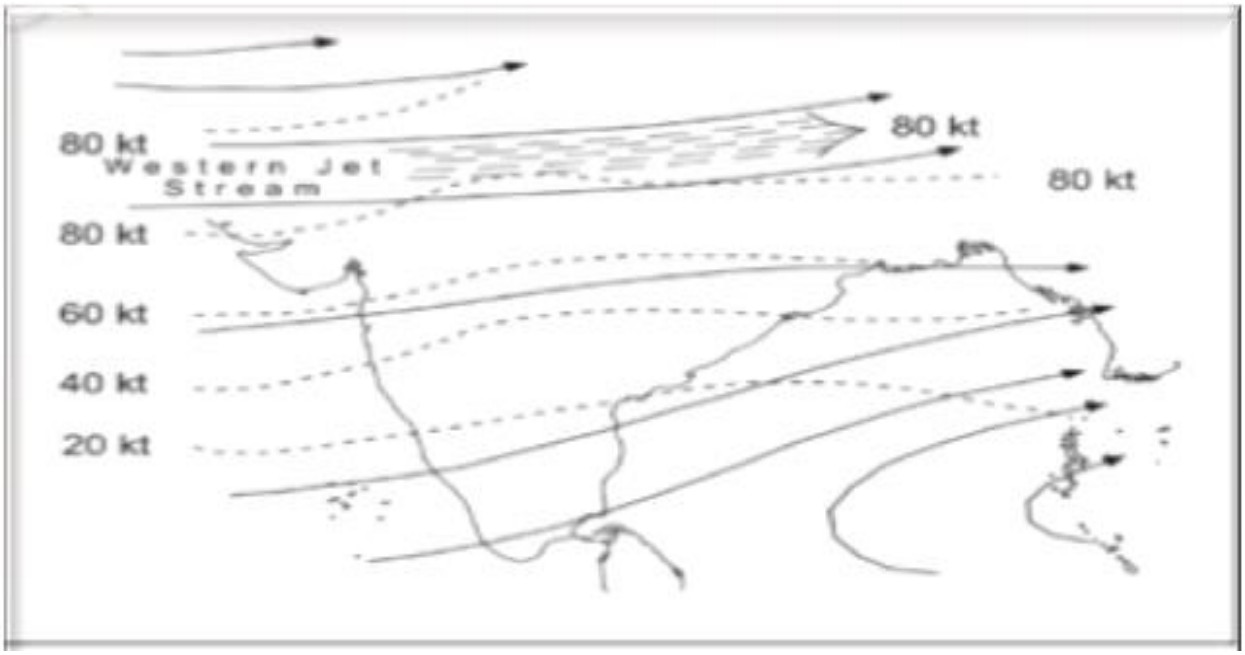


Fig 2: Direction of winds in India in winter at the height of 8.13 km

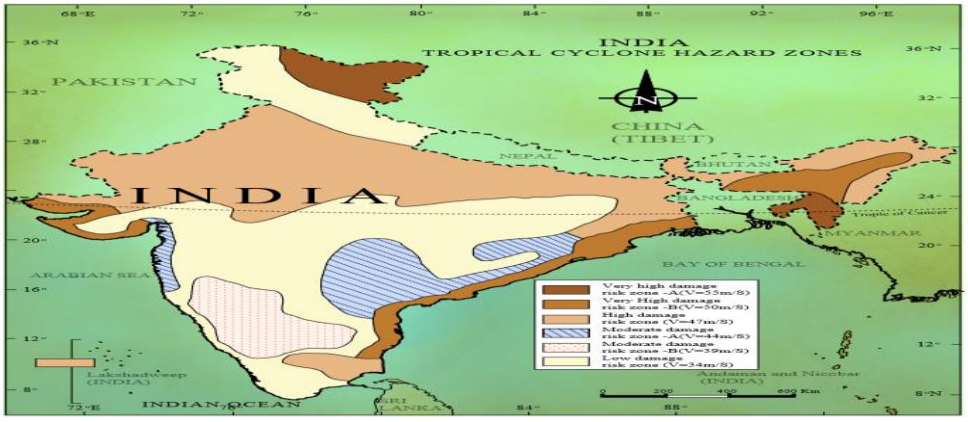
{Knot is the measuring unit for wind speed. It is abbreviated as Kt. Kt means knot 1kt=1.85km/hr.}

Western Cyclonic Disturbance and Tropical Cyclones: The western cyclonic disturbances which enter the Indian subcontinent from the west and the northwest during the winter months, originate over the Mediterranean Sea and are brought into India by the westerly jet stream. An increase in the prevailing night temperature generally indicates an advance in the arrival of these cyclones disturbances.

Map: Inflow of Western Cyclonic Disturbances and Tropical Cyclones

Source**:** https://mapswire.com/world/physical-maps/

Tropical cyclones originate over the Bay of Bengal and the Indian Ocean. These tropical cyclones have very high wind velocity and heavy rainfall and hit the Tamil Nadu, Andhra Pradesh and Orissa coast. Most of these cyclones are very destructive due to high wind velocity and torrential rain that accompanies it. Have you seen their movement in the weather report in the television?



Map: Tropical Cyclone Areas In India

Source: https://nroer.gov.in/55ab34ff81fccb4f1d806025/file/57cff60716b51c038dedcb67

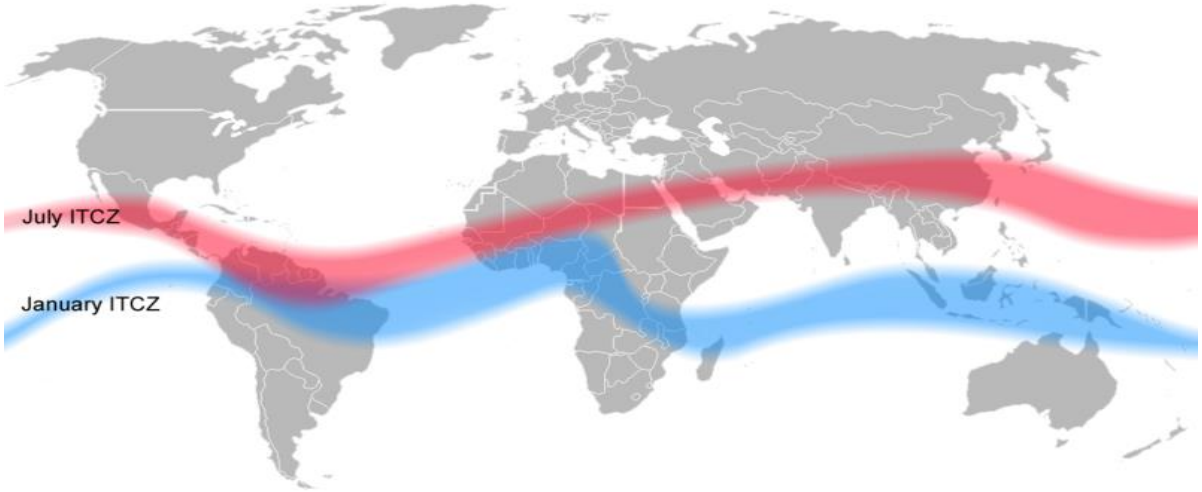
Mechanism of Weather in the Summer Season

Surface Pressure and Winds: As the summer sets in and the sun's position shifts northwards, the wind circulation over the subcontinent undergoes a complete reversal at both, the lower (surface) as well as the upper levels (upper air circulation).

FIG 3: ITCZ ZONE

Source:
https://en.wikipedia.org/wiki/Horse_latitudes#/media/File:Atmospheric_circulation.svg

By the middle of July, the low pressure belt nearer the surface [termed as Inter Tropical Convergence Zone (ITCZ)] shifts northwards, roughly parallel to the Himalayas between 20° N and 25° N. By this time, the westerly jet stream withdraws from the Indian region. In fact, meteorologists have found an interrelationship between the northward shift of the equatorial trough (ITCZ) and the withdrawal of the westerly jet stream from over the North Indian Plain. It is generally believed that there is a cause and effect relationship between the two. The ITCZ being a zone of low pressure, attracts inflow of winds from different directions. The maritime tropical air mass (mT) from the southern hemisphere, after crossing the equator, rushes to the low pressure area in the general southwesterly direction. It is this moist air current which is popularly known as the southwest monsoon.



Map: ITCZ

Source: https://commons.wikimedia.org/wiki/File:ITCZ_january-july.png

Inter Tropical Convergence Zone (ITCZ): The Inter Tropical Convergence Zone (ITCZ) is a low pressure zone located at the equator where trade winds converge, and so, it is a zone where air tends to ascend. In July, the ITCZ is located around 20°N-25°N latitudes (over the Gangetic plain), sometimes called the monsoon trough. This monsoon trough encourages the development of thermal low over north and northwest India. Due to the shift of ITCZ, the trade winds of the southern hemisphere cross the equator between 40° and 60°E longitudes and start blowing from southwest to northeast due to the Coriolis force. It becomes southwest monsoon. In winter, the ITCZ moves southward, and so the reversal of winds from northeast to south and southwest, takes place. They are called northeast monsoons.

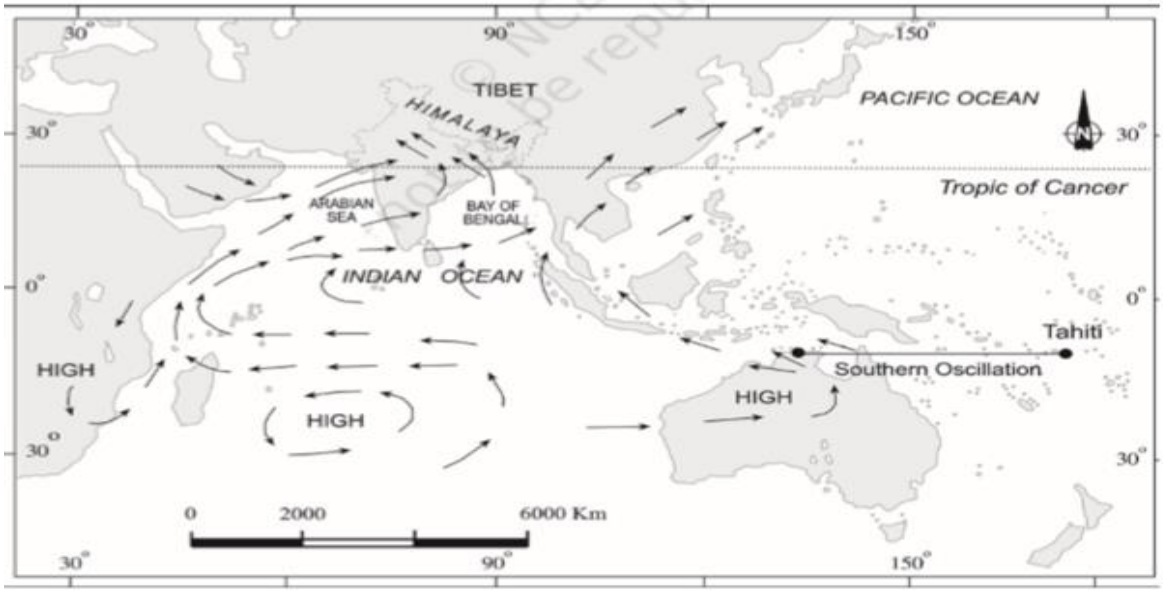


Fig 4: Summer Monsoon Winds: surface circulation

Jet Streams and Upper Air Circulation: The pattern of pressure and winds as mentioned above is formed only at the level of the troposphere. An easterly jet stream flows over the southern part of the Peninsula in June, and has a maximum speed of 90 km per hour (Figure 4.3). In August, it is confined to 15°N latitude, and in September up to 22°N latitudes. The easterlies normally do not extend to the north of 30°N latitude in the upper atmosphere.

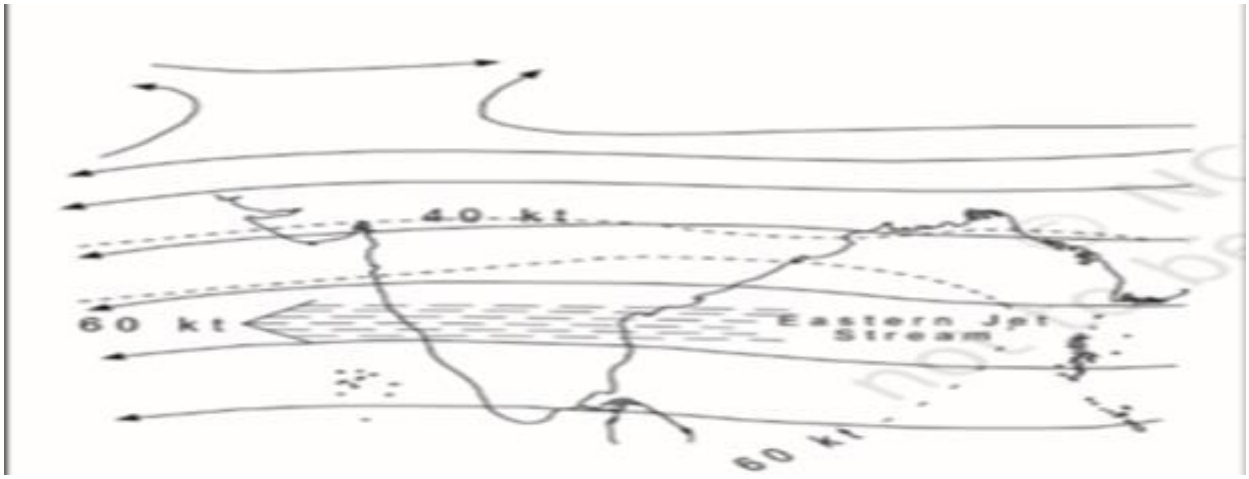


Fig 4: The direction of wind at 13km

Easterly Jet Stream and Tropical Cyclones: The easterly jet stream steers the tropical depressions into India. These depressions play a significant role in the distribution of monsoon rainfall over the Indian subcontinent. The tracks of these depressions are the areas of highest rainfall in India. The frequency at which these depressions visit India, their direction and intensity, all go a long way in determining the rainfall pattern during the southwest monsoon period.

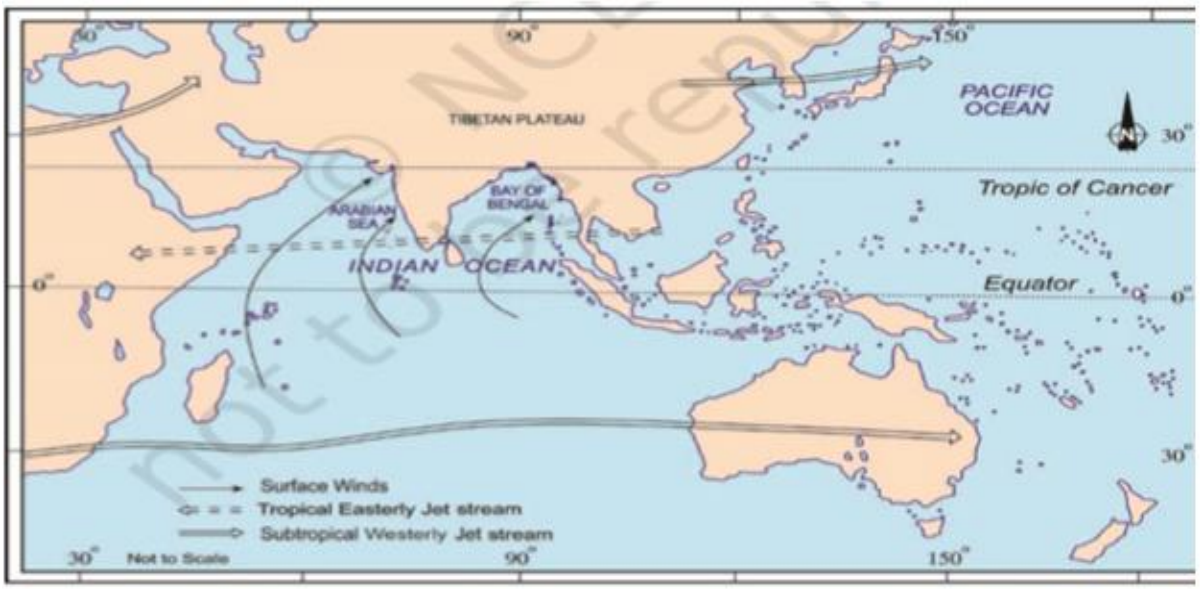


Fig 5: Atmospheric condition over the Indian subcontinents in the month of June

Factors important to understand the mechanism of monsoon:

The monsoon is experienced in the tropical area roughly between 20° N and 20° S. To understand the mechanism of the monsoons, the following facts are important.

(a) The differential heating and cooling of land and water creates low pressure on the landmass of India while the seas around experience comparatively high pressure.
(b) The shift of the position of Inter Tropical Convergence Zone (ITCZ) in summer, over the Ganga plain (this is the equatorial trough normally positioned about 5°N of the equator. It is also known as the monsoon trough during the monsoon season).
(c) The presence of the high-pressure area, east of Madagascar, approximately at 20°S over the Indian Ocean. The intensity and position of this high-pressure area affects the Indian Monsoon.
(d) The Tibetan plateau gets intensely heated during summer, which results in strong vertical air currents and the formation of low pressure over the plateau at about 9 km above sea level.
(e) The movement of the westerly jet stream to the north of the Himalayas and the presence of the tropical easterly jet stream over the Indian peninsula during summer.

Apart from this, it has also been noticed that changes in the pressure conditions over the southern oceans also affect the monsoons.

The Nature of Indian Monsoon

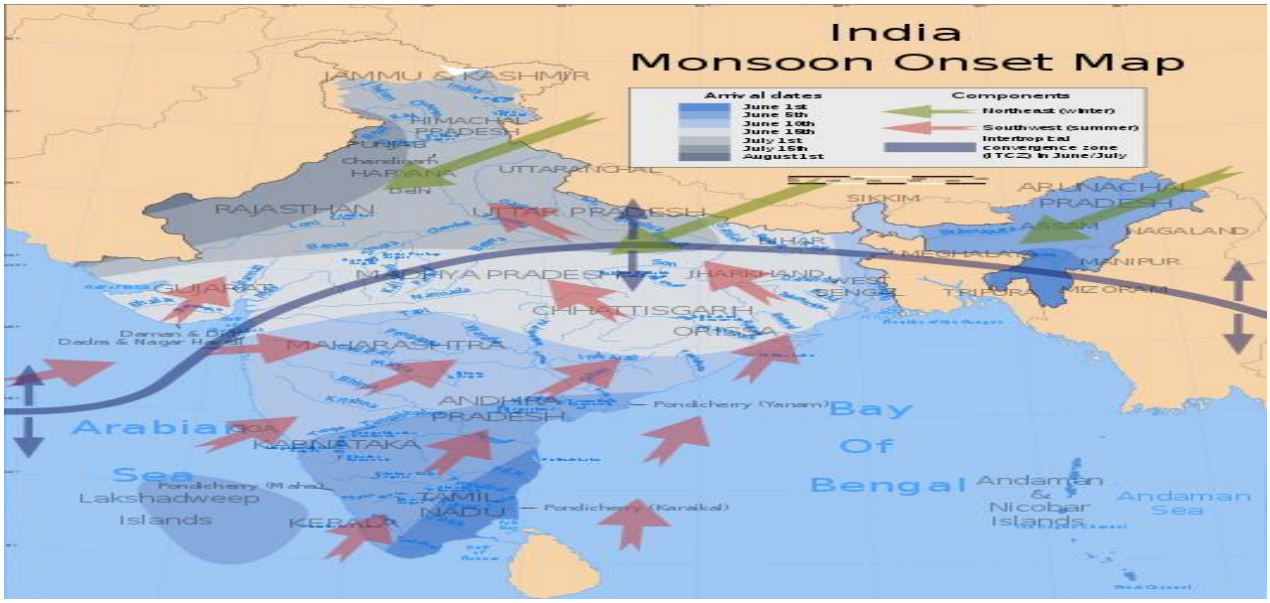
Monsoon is a familiar though a little unpredictable climatic phenomenon. Despite the observations spread over centuries, the monsoon continues to puzzle the scientists. Many attempts have been made to discover the exact nature and causation of monsoon, but so far, no single theory has been able to explain the monsoon fully. A real breakthrough has come recently when it was studied at the global rather than at regional level. Systematic studies of the causes of rainfall in the South Asian region help to understand the causes and salient features of the monsoon, particularly some of its important aspects, such as:

A. The onset of the monsoon.
B. Rain-bearing systems (e.g. tropical cyclones) and the relationship between their frequency and distribution of monsoon rainfall.
C. Break in the monsoon.

A. Onset of the Monsoon

Towards the end of the nineteenth century, it was believed that the differential heating of land and sea during the summer months is the mechanism which sets the stage for the monsoon winds to drift towards the subcontinent. During April and May when the sun shines vertically over the Tropic of Cancer, the large landmass in the north of Indian Ocean gets intensely heated. This causes the formation of an intense low pressure in the northwestern part of the subcontinent.

Since the pressure in the Indian Ocean in the south of the landmass is high as water gets heated slowly, the low pressure cell attracts the southeast trades across the Equator. These conditions help in the northward shift in the position of the ITCZ. The southwest monsoon may thus, be seen as a continuation of the southeast trades deflected towards the Indian subcontinent after crossing the Equator. These winds cross the Equator between 40°E and 60°E longitudes. The frequency of the tropical depressions originating from the Bay of Bengal varies from year to year. Their paths over India are mainly determined by the position of ITCZ which is generally termed as the monsoon trough. As the axis of the monsoon trough oscillates, there are fluctuations in the track and direction of these depressions, and the intensity and the amount of rainfall vary from year to year. The rain which comes in spells, displays a declining trend from west to east over the west coast, and from the southeast towards the northwest over the North Indian Plain and the northern part of the Peninsula.



Map: Onset of Monsoon

Source:
https://commons.wikimedia.org/wiki/File:India_southwest_summer_monsoon_onset_map_en.svg

The shift in the position of the ITCZ is also related to the phenomenon of the withdrawal of the westerly jet stream from its position over the north Indian plain, south of the Himalayas. The easterly jet stream sets in along 15°N latitude only after the western jet stream has withdrawn itself from the region. This easterly jet stream is held responsible for the burst of the monsoon in India.

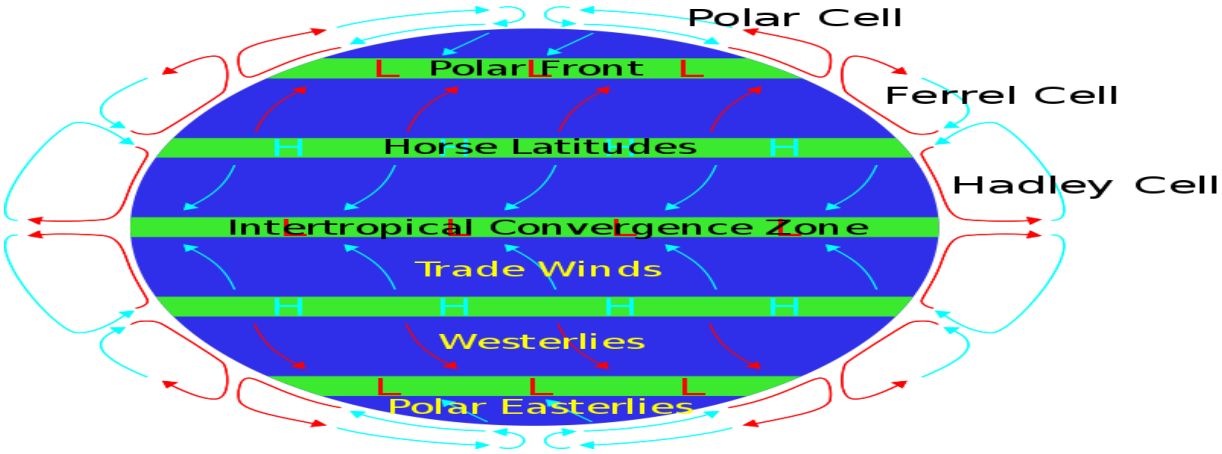
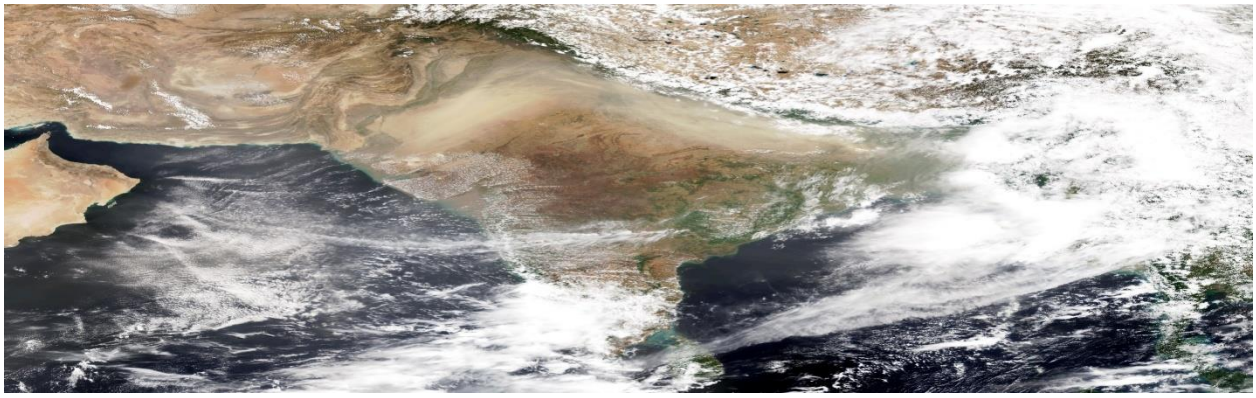


Fig 5: ITCZ

Source:

https://en.wikipedia.org/wiki/Horse_latitudes#/media/File:Atmospheric_circulation.svg

The Monsoon, unlike the trades, are not steady winds but are pulsating in nature, affected by different atmospheric conditions encountered by it, on its way over the warm tropical seas. The duration of the monsoon is between 100 to 120 days from early June to mid-September. Around the time of its arrival, the normal rainfall increases suddenly and continues constantly for several days. This is known as the **'burst' of the monsoon**, and can be distinguished from the pre-monsoon showers.



Map: Burst of Monsoon

Source:

https://upload.wikimedia.org/wikipedia/commons/5/59/North_India_dust_vir_2018165_large.jpg

Mango showers is a colloquial term to describe the occurrence of pre-monsoon rainfall. Sometimes these rains are referred to generically as ‘April rains’ or ‘summer showers’. They are notable across much of South and Southeast Asia, including India and Cambodia.In southern Asia, these rains greatly influence human activities because the control the rains have on crops that are culturally significant like mangoes and coffee.

These rains normally occur from March to April, although their arrival is often difficult to predict. Their intensity can range from light showers to heavy and persistent thunderstorms. Towards the close of the summer season, pre-monsoon showers are common, especially in Kerala, Karnataka and parts of Tamil Nadu in India. They help in the early ripening of mangoes and are often referred to as "Mango showers."

Entry of Monsoon into India: The monsoon arrives at the southern tip of the Indian peninsula generally by the first week of June. Subsequently, it proceeds into two – the Arabian Sea branch and the Bay of Bengal branch.

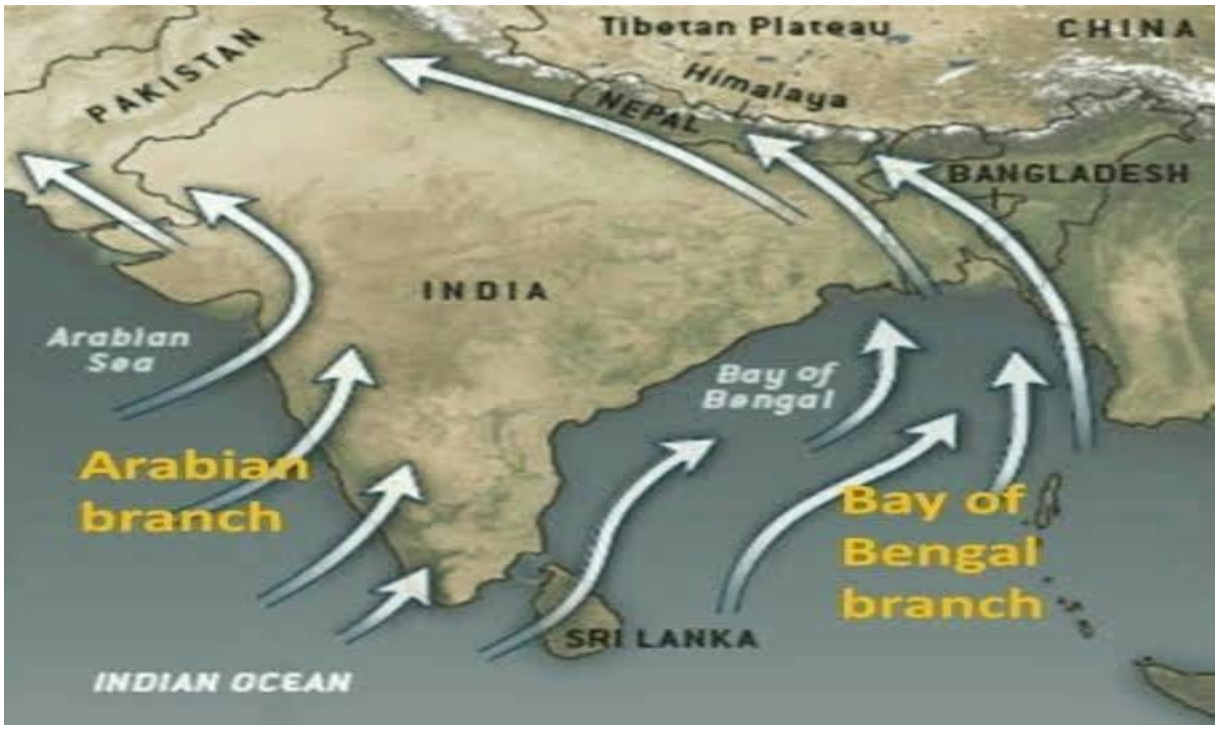


Fig 6: Branches of Southwest Monsoon

Source: https://www.quora.com/What-is-the-Bay-of-Bengal-branch-of-SW-monsoon

The Arabian Sea branch reaches Mumbai about ten days later on approximately the 10th of June. This is a fairly rapid advance. The Bay of Bengal branch also advances rapidly and arrives in Assam in the first week of June. The lofty mountains causes the monsoon winds to deflect towards the west over the Ganga plains. By mid-June the Arabian Sea branch of the monsoon arrives over Saurashtra-Kuchchh and the central part of the country. The Arabian Sea and the

Bay of Bengal branches of the monsoon merge over the northwestern part of the Ganga plains. Delhi generally receives the monsoon showers from the Bay of Bengal branch by the end of June (tentative date is 29th of June).

By the first week of July, western Uttar Pradesh, Punjab, Haryana and eastern Rajasthan experience the monsoon. By mid-July, the monsoon reaches Himachal Pradesh and the rest of the country. Withdrawal or the retreat of the monsoon is a more gradual process. The withdrawal of the monsoon begins in northwestern states of India by early September. By mid-October, it withdraws completely from the northern half of the peninsula.

Fig 7: Southwest Monsoon in India

B. Rain-bearing Systems and Rainfall Distribution

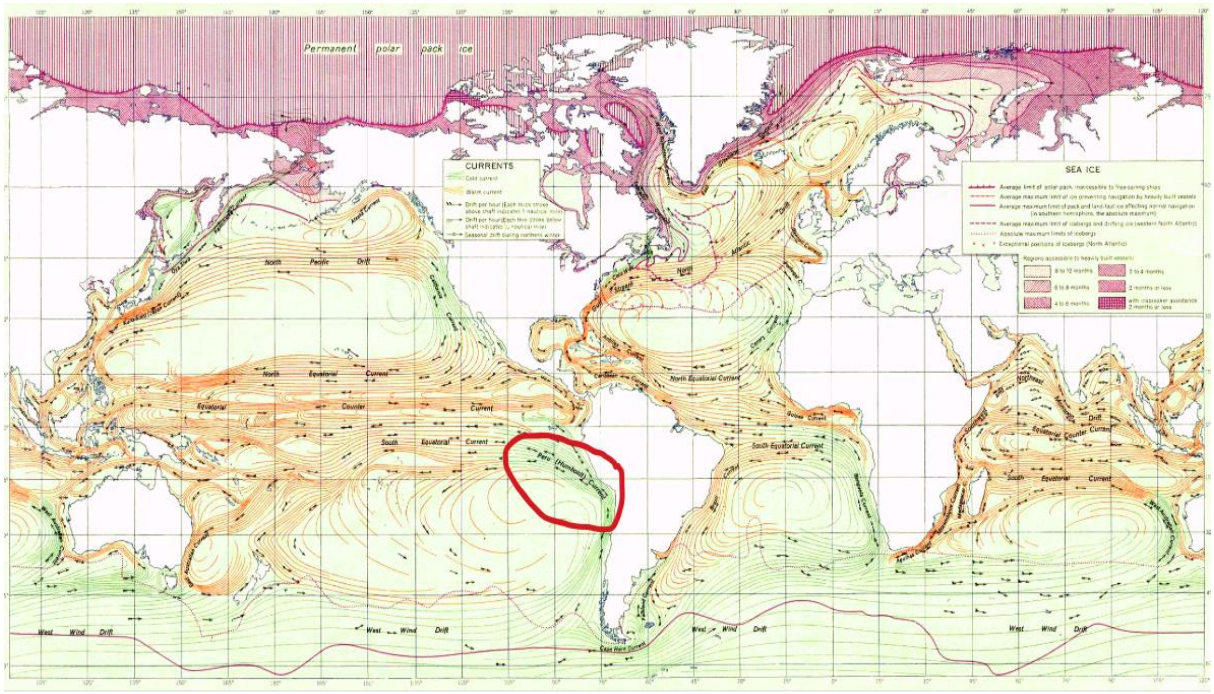
There seem to be two rain-bearing systems in India. First originate in the Bay of Bengal causing rainfall over the plains of north India. Second is the Arabian Sea current of the southwest monsoon which brings rain to the west coast of India. Much of the rainfall along the Western Ghats is orographic as the moist air is obstructed and forced to rise along the Ghats. The intensity of rainfall over the west coast of India is, however, related to two factors:

(i) The offshore meteorological conditions.

(ii) The position of the equatorial jet stream along the eastern coast of Africa.

EI-Nino and the Indian Monsoon

EI-Nino is a complex weather system that appears once every three to seven years, bringing drought, floods and other weather extremes to different parts of the world. The system involves oceanic and atmospheric phenomena with the appearance of warm currents off the coast of Peru in the Eastern Pacific and affects weather in many places including India. EI-Nino is merely an extension of the warm equatorial current which gets replaced temporarily by cold Peruvian current or Humbolt current.



Map: Humbolt Current

Source:
https://upload.wikimedia.org/wikipedia/commons/6/67/Ocean_currents_1943_%28borderless%293.png

December is a summer month in Peru (Southern Hemisphere). This current increases the temperature of water on the Peruvian coast by 10°C. This results in:

(i) the distortion of equatorial atmospheric circulation;

(ii) irregularities in the evaporation of sea water;

(iii) Reduction in the amount of planktons which further reduces the number of fish in the sea.

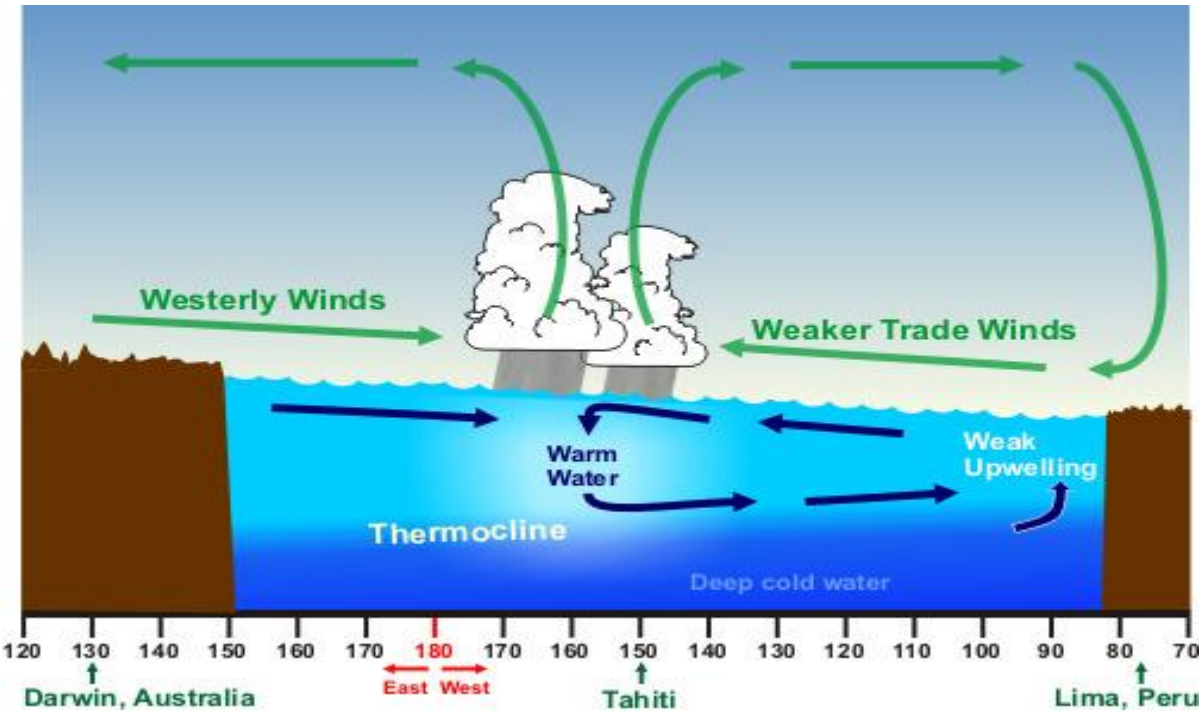


Fig 8: El Nino

Source:
https://upload.wikimedia.org/wikipedia/commons/9/9b/El_Ni%C3%B1o_Conditions.jpg

Normally, when the tropical eastern South Pacific Ocean experiences high pressure, the tropical eastern Indian Ocean experiences low pressure. But in certain years, there is a reversal in the pressure conditions and the eastern Pacific has lower pressure in comparison to the eastern Indian Ocean. This periodic change in pressure conditions is known as the **Southern Oscillation** or SO. The difference in pressure over Tahiti (Pacific Ocean, 18°S/149°W) and Darwin in northern Australia (Indian Ocean, 12°30'S/131°E) is computed to predict the intensity of the monsoons. If the pressure differences were negative, it would mean below average and late monsoons. A feature connected with the SO is the El Nino phenomenon in which a warm ocean current that flows past the Peruvian Coast, in place of the cold Peruvian current, every 2 to 5 years. The changes in pressure conditions are connected to the **El Nino**. Hence, the phenomenon is referred to as **ENSO** (El Nino Southern Oscillations).

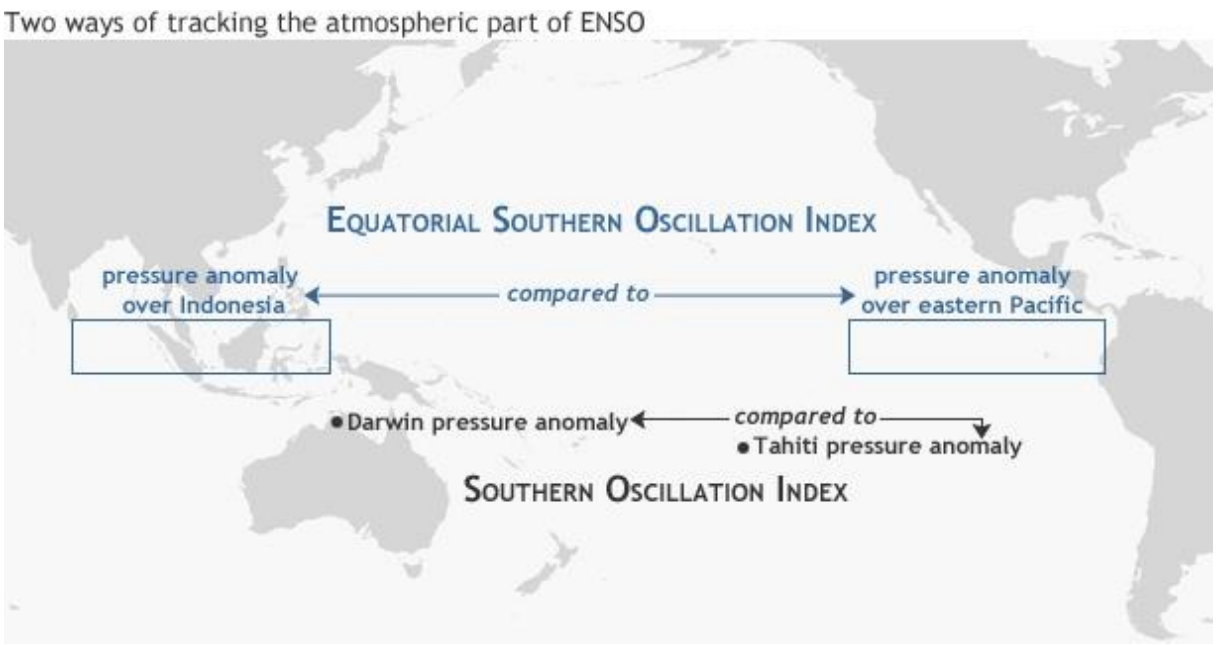


Fig 9: Southern Oscillation

Source: https://commons.wikimedia.org/wiki/File:SOI_map.jpg

El Nino is a name given to the periodic development of a warm ocean current along the coast of Peru as a temporary replacement of the cold Peruvian current. 'El Nino' is a Spanish word meaning 'the child', and refers to the baby Christ, as this current starts flowing during Christmas in December. The presence of the El Nino leads to an increase in sea-surface temperatures and weakening of the trade winds in the region.

EI-Nino is used in India for forecasting long range monsoon rainfall. In 1990-91, there was a wild EI-Nino event and the onset of southwest monsoon was delayed over most parts of the country ranging from five to twelve days.

C. Break in the Monsoon

Another phenomenon associated with the monsoon is its tendency to have 'breaks' in rainfall. Thus, it has wet and dry spells. In other words, the monsoon rains take place only for a few days at a time. They are interspersed with rainless intervals. These breaks in monsoon are related to the movement of the monsoon trough.

For various reasons, the trough and its axis keep on moving northward or southward, which determines the spatial distribution of rainfall. When the axis of the monsoon trough lies over the plains, rainfall is good in these parts. On the other hand, whenever the axis shifts closer to the Himalayas, there are longer dry spells in the plains, and widespread rain occur in the

mountainous catchment areas of the Himalayan Rivers. These heavy rains bring in their wake, devastating floods causing damage to life and property in the plains.

The frequency and intensity of tropical depressions too, determine the amount and duration of monsoon rains. These depressions form at the head of the Bay of Bengal and cross over to the mainland. The depressions follow the axis of the "monsoon trough of low pressure". The monsoon is known for its uncertainties. The alternation of dry and wet spells varies in intensity, frequency and duration. While it causes heavy floods in one part, it may be responsible for droughts in the other. It is often irregular in its arrival and its retreat. Hence, it sometimes disturbs the farming schedule of millions of farmers all over the country. These breaks in the different regions are due to different reasons:

(i) In northern India rains are likely to fail if the rain-bearing storms are not very frequent along the monsoon trough or the ITCZ over this region.

(ii) Over the west coast the dry spells are associated with days when winds blow parallel to the coast.

Understanding the Monsoon

Attempts have been made to understand the nature and mechanism of the monsoon on the basis of data collected on land, oceans and in the upper atmosphere. The intensity of southwest monsoon winds of southern oscillation can be measured, among others, by measuring the difference in pressure between Tahiti (roughly 20°S and 140°W) in French Polynesia in East Pacific and port Darwin (12°30'S and 131°E) in northern Australia. Indian Meteorological Department (IMD) can forecast the possible behaviour of monsoons on the basis different indicators.

In the end of this module it can be concluded that the Indian monsoon has a complex mechanism as it is determined by a number of factors. The unifying influence of the monsoon on the Indian subcontinent is quite perceptible. The seasonal alteration of the wind systems and the associated weather conditions provide a rhythmic cycle of seasons. Even the uncertainties of rain and uneven distribution are very much typical of the monsoons.