

Concept, Mechanism and Behaviour of Indian Monsoon

Abstract

Monsoon is a complex meteorological and atmospheric circulation phenomenon where a large number of concepts and theories have been proposed and put forth by experts and specialists from different backgrounds to understand and explain its origin, mechanism and behavior. Earlier, it was considered to be a simple atmospheric circulation caused by seasonal unequal heating and cooling of large land and water bodies alternatively.

But over a period of time experts through researches at various levels try to prove this complex phenomenon through scientific experiments as more accurate and regular data of upper air circulation available and retrieved. But the origin, mechanism and behavior of this complex wind and air circulation system, is still mystery and whose prediction is eluding the experts. G.B.Cressey has rightly observed that although every school boy understands the Indian Monsoon but the official meteorological department is still in doubt as regards its origin.

Keyword: Atmospheric circulation, Origin and Mechanism, Complexity, Understanding, Experts.

Introduction

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Monsoon is a complex meteorological and atmospheric circulation phenomenon where a large number of concepts and theories have been proposed and put forth by experts and specialists from different backgrounds to understand and explain its origin, mechanism and behavior. Earlier, it was considered to be a simple atmospheric circulation caused by seasonal unequal heating and cooling of large land and water bodies alternatively. But over a period of time experts through researches at various levels try to prove this complex phenomenon through scientific experiments as more accurate and regular data of upper air circulation available and retrieved. But the origin, mechanism and behavior of this complex wind and air circulation system, is still mystery and whose prediction is eluding the experts. G.B.Cressey has rightly observed that although every school boy understands the Indian Monsoon but the official meteorological department is still in doubt as regards its origin.

Aims and Objectives of the study

The aims and objectives of this paper are to

1. Understand the complexity and complications of the concept of Indian monsoon system.
2. Understand and study the mechanism and behavior of Indian monsoon.
3. Study and discuss the different theories and views of explanation of Indian monsoon system.
4. Discuss the prediction and warning system of Indian monsoon system.
5. Discuss the implications and applications of Indian monsoon system.

Tools and Methods

This study and discussion is based on wide and extensive readings of standard text books, magazines, newspapers, articles etc. Besides, participation in seminars and conferences, TV knowledge channels, programmes at radio, group discussion and interaction with specialists also help to understand the concept, mechanism and behavior of Indian monsoon system.

Discussions and Analyses

There are however various views and theories to through light and understand the origin, mechanism and behavior of the Indian monsoon. Some of them are followings mentioned and explained below.

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Thermal or classical concept of the Indian Monsoon

This classical theory of Indian monsoon proposed and put forth by Admand Hally in 1686 to understand and explain the origin of Indian monsoon which was earlier proposed by Arab Geographer Siddique Ali after experiencing the behavioral pattern of Asiatic wind system on his Indian visit. According to the classical concept of Indian monsoon, monsoonal winds are land and sea breezes on a large scale which are produced and controlled by unequal and differential heating of contiguous continental and oceanic areas of the Indian subcontinent. Under this process, during the northern winter when sun rays fall vertically over tropic of Capricorn the gigantic land mass of Asia cools rapidly than the sounding ocean generating a high pressure area over Asia while there is low pressure centre on the Indian ocean. As a result of this air pressure differentials over land and ocean there is an out flow of air from high pressure to low pressure, consequently the surface winds started to flow from land to sea. This wind pattern is commonly known as **north-east monsoon** which is often dry due to lack of moisture and hence do not precipitate.

On other side of this, the temperature and pressure conditions are reversed during the northern summer season on the occasion of summer solstice. In this time period sun rays fall vertical on tropic of cancer which passes through the middle of Indian subcontinent. Due to excess heating of huge land mass of Asia a low pressure area develop over it. However, presence of the Himalayas bifurcate this low pressure areas into northwest Indian low and Baikal low. Conversely, high pressure centre is developed in the Indian Ocean due comparative low thermal conditions here. As a result of this winds started flowing from high pressure area over ocean to low pressure area over Indian subcontinent. This pattern of wind flow is popularly known as southwest monsoon in India and as simple monsoon throughout the world. Due to on shore nature of southwest monsoon it bears and produces rainfall wherever it is obstructed by various topographical barriers.

The thermal and classical theory proposed by Edmund Hally and Siddi Ali got wide popularity and support of the scholars throughout the world due its simplicity to explain the Indian monsoon but over a period of time a number of doubts have been emerged and expressed regarding the reliability of this concept in the explanations of onset, breaks and spatial distribution of rainfall over the Indian subcontinent. It was mainly due to scientific development in observations, collection and analyses of different nature of atmospheric data that thermal concept of monsoon does not describe the complexity in the prediction of monsoon. As a result of this new researches were conducted to predict Indian monsoon more accurately and timely.

Aerological Concept of Indian Monsoon

R. Scherhag, a German meteorologist proposed the Aerological concept of origin of Indian monsoon in 1948. He observed that the changes in

the direction of winds at all levels in the atmosphere are directly related to the temperature changes in the air above the friction layer.

He said that upper air monsoon phenomenon is not so localized and controlled as it is on the surface which is mostly controlled by the annual oscillation of temperatures and pressures. The continents in particular, are more affected by this monsoon although it appears over the entire earth.

A monsoon circulation is observed in upper parts of troposphere which lacks complete reversal of zonal flow over the earth. The monsoon circulation in the free troposphere is very opposed to the thermal monsoon on the surface which is borne out by formation and existence of anticyclones and depressions over the surface of Indian subcontinent in the winter and summer seasons respectively. The monsoon of the free atmosphere influences the monsoon circulation in the surface layers by superimposing a strong and very different type of circulation above it.

Dynamic Concept of Indian Monsoon

This concept was proposed and presented by Flohn in 1951 which is based on dynamic origin of Indian monsoon that say monsoon is none other than and is only the seasonal migration of planetary winds and pressure belts following the position of sun in relation to earth.

It opined that during summer solstice sun rays fall vertical over tropic of cancer hence all wind and pressure belts of globe shift towards north. At this time the zone of inter tropical convergence (ITC or Doldrum) moves northwards and its northern boundary is extended upto 30 degree north that is south and southeast Asia. It is due to relatively larger changes of seasonal temperature and pressure conditions over the land in these areas which help in shifting of these belts. Due to this shifting major part of Indian subcontinent comes under impact of equatorial westerlies blowing in doldrum which are called southwest monsoon in India. Since NITC is associated with tropical disturbances which dominate the surface weather. On the other hand in winter planetary wind system and pressure belts move to southwards due southward movement of vertical sun rays. As a result of this northeast trade winds reestablished over the Indian subcontinent which are often dry and devoid of rain as they come from land

Recent Concepts of Origin of Indian Monsoon

Recent concepts of origin of Indian monsoon is amalgamate of various concepts and viewpoints of recent origin which are based on the findings of researches conducted after 1950 using several computer enabled analyses of the observed and collected data. These concepts mainly rely on the role of Jet streams, Tibet Plateau and atmosphere-ocean circulation in explaining of origin of Indian monsoon.

Role of Jet Streams

Jet stream is a high speed wind blowing system of cyclones and anticyclones in a meandering course at and around 10 to 12 KM from the earth surface which was discovered during Second World War in middle latitudes of sub tropical to temperate

areas of the globe. Their position in summer is 35 to 45 degree north and in winter is 20 to 35 degree north. Jet Streams is a worldwide phenomenon which are observed from polar to tropical areas of the globe although in subtropical areas is great variations in their position and intensity.

There are two types of jet streams in this area. First is westerly jet stream which is generally an extension of circum polar whirl during the northern winter season and it is obstructed by the mighty Himalayas and the Tibetan plateau. The southern branch of the westerly jet stream passes through Indian Gangetic plain and it brings western disturbances (Temperate cyclones) of Mediterranean Sea and Persian Gulf to the great plains of India.

Second is the easterly jet stream which originates only in the northern summer season due to regional conditions of the subcontinent. The most important and leading among these is Tibet plateau. The mighty Tibet plateau act as a heat engine at the altitude of 5000 meters and it spreads in the area of more than 2 lakh square kilometers.

During this summer season the vertical sun rays at tropic of cancer the circum polar whirl along with westerly jet stream weakened and shifted northward of the Himalayas and southern branch of this jet stream disappeared by 6-10 June. This removal of westerly jet stream to the north of Tibet plateau leads to reversal of curvature of flow of free air to the north and northwest of the subcontinent.

It further leads to development of dynamic depression overlying the thermal depression already established at the surface of northwest Indian subcontinent which ultimately help to trigger the burst of Indian monsoon along with it vigorous advance over the Indian subcontinent.

It must be kept in mind that so long as the position of upper air jet stream is maintained above the surface low pressure to the south of the Himalayas the dynamic anticyclonic conditions persist in the northwestern part of Indian subcontinent which obstruct the ascent of air from the surface low as the air is continuously descending from the above. This is the reason why the months of April, May and June are dry inspite of high temperature and evaporation while upper air low pressure in the east of the Himalayas over Myanmar, Assam and Bangladesh helps in ascend of air and produce rainfall.

It may be remembered that during northern summer there is winter in the southern hemisphere where southern polar whirls or jet streams is more developed and extended upto the equator which pushed the inter tropical convergence and southeasterly trade winds to cross over the equator and flow in southwesterly direction due to coriolis force of rotation of earth.

Indeed pulsations in monsoon are dynamically induced waves and not the frontal cyclones, after coming over India become cyclone vortices which cause summer monsoon rains in India. While development of cyclonic vortices produces wet weather, their occlusion brings dry weather which continues till new vortices are formed.

Role of Tibet Plateau

Role of the Tibet plateau in the origin and mechanism of Indian monsoon is a recent development and advancement in the researches conducted for accurate prediction of its behavior. For which monsoon expedition so called Monex was organized with Russian partnership to collect weather data from the Indian and Arabian Sea to identify the role played by the mighty Tibetan highland in the origin of Indian monsoon.

It was Dr. P. Koteswaram, Director General of Indian Observatories who firstly proposed the role of Tibet plateau in the origin of Indian monsoon at the eve of international symposium on monsoon of world. He said that the mighty Tibet plateau with its peculiar location at an altitude of 5000 meters acts as a heat engine in the northern summer season. Due to its protruded height it receives 3 to 4 degree C more insolation than its surroundings. The mighty plateau affects the atmosphere in two ways.

Firstly, it acts as a mechanical barrier as mentioned by N. Maung Tun Yin that in the month of June the subtropical westerly jet stream is completely withdraw from India mainly due to hydrodynamic effect of the mighty plateau which ultimately help in onset and burst of Indian monsoon.

Secondly, it acts as a high level heat source under which during the summer time high level heating produces a thermal anticyclone in mid troposphere over this region. This anticyclone weakens the western subtropical jet stream to the south of Himalayas but produces tropical easterly jet on the southern side of the anticyclone.

This tropical jets first develop in longitudes east of India and then extends westward across India, over the Arabian Sea and to eastern Africa. Air under this jet stream blowing along Kolkata-Bangalore axis, the air descends over Indian Ocean and intensify it high pressure cell which moves southwest monsoon swiftly towards Indian subcontinent. Data collected and researches conducted under Monex support that the high pressure cell over Indian Ocean responds positively to a stronger tropical easterly jet and consequently a stronger southwest monsoon in India. In October the conditions are reversed as the middle and upper tropospheric anticyclone over the Tibet plateau disintegrate and tropical easterly jet disappear and a subtropical westerly jet reestablished in place of it.

Ocean Bodies and Air Circulations

Under this head experts have tried to find out relationships among Indian monsoon and El Nino, Southern Oscillation, Walker Cell and the Somali Ocean current.

El Nino and Indian monsoon

El Nino is Warm Ocean current appearing along the Peru coast in the month of December which replaces the Peru/Humboldt cold ocean current in this region. In normal conditions mixed layer over eastern pacific (Peru and Ecuador) is cool and shallow while over the western pacific (Indonesia and Western Australia) it is warm and deep which is helpful for strong southwest monsoons. The appearance of El

Nino so called El Nino anomaly reverses the conditions as warm conditions over eastern pacific and cold in western pacific. Since El Nino represent large atmospheric perturbations to which the ocean responds with warmer and colder surface temperatures which leads to extreme weather events such as shortage of rainfall and draughts in Indian monsoon region and excess of rainfall and floods over Peru and Ecuador coasts.

The southern Oscillation and Indian Monsoon

The southern oscillation refers to a seesaw pattern of atmospheric/meteorological changes observed between pacific and Indian oceans. It is observed that whenever surface pressure is high over the pacific the pressure over Indian ocean is tend to low and good monsoon develop and vice versa. This oscillation was discovered by Sir Gilbert Walker who observed that as pressure are inversely related to rainfall that means when low prevails over Indian Ocean in December (positive SOI) there are chances of good monsoon rain in the summer.

The oscillation period varying from 2 to 7 years and intensity of southern oscillation is measured by the difference in sea level pressures of Tahiti in mid pacific and Darwin in north Australia. A negative value of Southern Oscillation Index implies higher pressure over north Indian Ocean and poor monsoon and a positive value of the same means good monsoon in India. There is a close relationship between a negative oscillation and appearance of El Nino. This low and negative phase of SOI in combination with an El Nino is called an ENSO event.

Walker Circulation and Indian Monsoon

Walker circulation and southern oscillation are closely interlinked and to it Indian monsoon responds. Walker circulation is a meridional high and low pressure systems over the surface of oceans and lands.

A high positive SOI would be zone of low atmospheric pressure over Australia and Indonesian archipelago and it will be accompanied by large convective clouds, heavy rainfall and rising or ascending air currents/motions. This air eventually turns eastward and traversing the pacific as high level westerlies it descends over South America. Thus according to walker circulation there is a rising limb over the Southeast Asia with a descending branch over the South America. In case of global winds the walker circulation supports a strong belt of convergence between the trade winds of both hemispheres slightly to the north of the Equator. These trade winds piles up large quantity of warm water in western pacific, producing equatorial counter current from the Indonesian coast and help upwelling of cold water from below near Peru coast giving rise cold Humboldt current. Meteorological observations indicate that the circulation of air over the tropics is dominated by two gigantic cells. First is known as Hadley cell which is oriented in north-south direction and during the summer monsoon its ascending limb is over the plateau of Tibet which moves southwards as tropical easterly jet and eventually descends over the Indian Ocean. The second cell is known as Walker

cell that is oriented as east-west direction and its ascending and descending limbs are closely linked to sea surface temperatures (SST). Temperatures at the surface of the sea are usually cool in the regions of descending motions (Peru coast) they are warm in the zones of ascent (Indonesia-Australia coast).

During El Nino effect or negative SOI, the descending limbs of walker cell are moved eastward and hence a large area over India now become a zone of descent rather than ascent leading to poor monsoon and draught conditions.

Somali Current and Indian Monsoon

The Somali current is a warm ocean current which flow in the western parts of Indian Ocean. It reverses its direction in response to over lying winds. During the northern summer it flows from south of equator to 10 degree north before turning towards the Indian coast while during winter it flows southwards following the northeast winter monsoon or trades. This current is the western limb of a gigantic whirl over the Arabian Sea called 'gyre'. Recent observations suggest the current is made of two gyres; firstly, northern gyre between 5-9 degree north latitudes and secondly, southern gyre between equator and 4 degree north latitudes. As the southern monsoon sets over India, the southern gyre moves northwards and finally coalescence with the northern gyre.

In fact the southern gyre is more prominent in years of good monsoon while in years of weak monsoon it is either weak or absent. The area lying between these two gyres is a wedge or region of intense upwelling which may leads to thermal anomaly between the coast of Somalia (June, 15 degree C) and Mumbai (30 degree C). This gradient of temperature influences the radiation balance of the monsoon air (Das, P.K., 1990, p.15).

Some findings of the Study

Some of the major findings and concluding remarks of the present paper are presented below

1. Undoubtedly, Indian monsoon is a very complex phenomenon which is widely popular but less explored till date.
2. There are a number of concepts and theories of explanation of origin, mechanism and behavior of Indian monsoon.
3. It is clearly an interdisciplinary concept, so a cooperative and supportive discussion and analysis is needed to launch, internationally.
4. Thermal concept that is alternatively heating and cooling of land and water bodies is most widely accepted but a vague concept to explain origin, mechanism and behavior of Indian monsoon.
5. The dynamic concept of Indian monsoon is an aggregative and representative way of expression of different sub-concepts of Indian monsoon as discussed in this paper separately.
6. The land-air circulation of our earth system is very dynamic and unstable which needs to understand and study more precisely right from local to global levels.
7. The lower and upper atmospheric circulations have vital significance which should be analyzed both traditionally and scientifically.

8. In the end both the implied and applied meanings and perspectives of complex nature of origin, mechanism and behavior of Indian monsoon along with precise prediction and warning system of Indian monsoon should be strengthened globally as well as locally.

Conclusion

At the end it can be concluded that Indian monsoon system is not as easy to describe and explain as it seems to appear. However it is a popular concept among the large mass of people on which anyone or a layman can easily speak for a long time. Sometimes these predictions and explanations seem to happen but this a casual approach to describe the mechanism of the monsoon which being an expert must be avoided and ignored.

It is also said that the mechanism of Indian monsoon is widely known yet less explored concept from a scientifically point of view. Over a period of time with the advancement of science and technology to observe and generate diversified nature of data new models and theory building have been proceeded in this field. The classical theory of thermal explanation of Indian monsoon provides the base of this vague system of air circulation. But viewing this complex system of monsoonal wind patterns from different and varied angles, it is surely possible to understand and predict it more accurately and timely as it is happening nowadays. The real time data provided by different types of satellites, Indians and foreign are very useful in explanation and prediction of cyclone genesis, cloud formation and direction, speed and intensity of rain bearing clouds and wind patterns with no time lag. The role of differential heating of land and water bodies along with jet streams, Tibet plateau, El Nino and southern oscillation etc is being changing year to year so more researches and studies really need to be promoted and supported not only in India but throughout the world on mutual share bases.

The role of Indian monsoon is vital as huge population of human, plants and animals and other organism directly and indirectly either influenced or controlled by distribution of monsoonal rain. Finally, it can be narrated that Indian monsoon is indeed

backbone of not only Indian economy but to every walks of life.

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