A FIELD BASED STUDY ON THE RAINFALL ANALYSIS

MINI PROJECT REPORT SUBMITTED

TO

THE DEPARTMENT OF PHYSICS

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ACKNOWLEDGEMENT

For the past few months we were engaged in a fruitful exercise, which we must admit, leaves us richer in knowledge and experience which is mainly due to the valuable guidance, encouragement and assistance given from many cognizant resources. It was a group effort and a number of personalities greatly helped us for the completion of the project.

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DECLARATION

We hereby declare that the project report entitled **“Impact of El Nino in the parametrisation of rainfall”** submitted to the Department of Physics, Alphonsa College, Pala for the partial fulfilment of the requirement for the award of Bachelor of Science in Physics is a bona fide record of the original project work carried out by us under the guidance and supervision of Dr. Veena Suresh Babu, Assistant Professor, Department of Physics, All Saints College, Thiruvananthapuram.

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ABSTRACT

The study of precipitation trends is critically important for a country like India whose food security and economy are dependent on the timely availability of water. In this study an attempt has been made to identify epochs of increasing and decreasing trends of the annual rainfall during the 11-year period from 2007 to 2017 for South Peninsular India. An important aspect of the present study is to report the long term trends in the south west monsoon rainfall. The average monthly rainfall during different seasons like Pre-monsoon, monsoon and post monsoon over South Peninsular were also reported. Strong regional dependency can be considered to exist for the secular variation or the amounts of seasonal rainfall in India for the study regions. The variability and trends in the rain fall pattern are also discussed in detail. There was a major shift in rainfall pattern temporarily during recent years. An attempt has been made to estimate possible link on the Southern peninsular India fall to the temperature of eastern pacific. Thus we can infer that the temperature of east-central tropical Pacific is a driving factor of Indian Monsoon. El-Nino years are resulting in maximum rainfall while La-Nina years are resulting in less rainfall.

CHAPTER I
INTRODUCTION

1.1 Earth's Atmosphere

Earth is the only planet in the solar system with an atmosphere that can sustain life. It warms the planet by day and cools it at night. Earth's atmosphere is about 300 miles (480 kilometers) thick. Air pressure decreases with altitude. At sea level, air pressure is about 14.7 pounds per square inch (1 kilogram per square centimeter). At 10,000 feet (3 km), the air pressure is 10 pounds per square inch (0.7 kg per square cm). There is also less oxygen to breathe. Earth's atmosphere has a series of layers each with its own specific traits. Moving upward from ground level, these layers are named the troposphere, stratosphere, mesosphere, thermosphere, and exosphere.

In general air pressure and density decreases with altitude in the atmosphere .However temperature has a more complicated profile with altitude and many remain relatively constant or even increases with altitude in some regions. Because the general pattern of the temperature altitude profile is constant and measurable by means of instrumented Balloon sounding the temperature behavior provides a useful metric to distinguish layers. These include;

- Troposphere
- Stratosphere

- Mesosphere
- Thermosphere
- Exosphere

TROPOSPHERE

The layer of the atmosphere closest to the Earth is the troposphere. It begins at the surface of the Earth and extends out to about 6 to 20 km. This layer is known as the lower atmosphere. It's where weather happens and contains the air humans breathe. The temperature of the troposphere decreases with height. Although variations do occur, the temperature usually declines with increasing altitude in the troposphere because the troposphere is mostly heated through energy transfer from the surface. Thus, the lowest part of the troposphere is typically the warmest section of the troposphere. The troposphere contains roughly 80% of the mass of Earth's atmosphere. The troposphere is denser than all its overlying atmospheric layers because a larger atmospheric weight sits on top of the troposphere and causes it to be most severely compressed.

STRATOSPHERE

The stratosphere is the second-lowest layer of Earth's atmosphere. It lies above the troposphere and is separated from it by the tropopause. This layer extends from the top of the troposphere at roughly 12 km above Earth's surface to the stratopause at an altitude of about 50 to 55 km. The atmospheric pressure at the top of the stratosphere is roughly 1/1000

the pressure at sea level. It contains the ozone layer, which is the part of Earth's atmosphere that contains relatively high concentrations of that gas. The stratosphere defines a layer in which temperatures rise with increasing altitude. This rise in temperature is caused by the absorption of ultraviolet radiation from the Sun by the ozone layer, which restricts turbulence and mixing. Although the temperature may be −60 °C at the tropopause, the top of the stratosphere is much warmer, and may be near 0 °C.

MESOSPHERE

The mesosphere is the third highest layer of Earth's atmosphere, occupying the region above the stratosphere and below the thermosphere. It extends from the stratopause at an altitude of about 50 km to the mesopause at 80–85 km above sea level. Temperatures drop with increasing altitude to the mesopause that marks the top of this middle layer of the atmosphere. It is the coldest place on Earth and has an average temperature around −85 °C. Just below the mesopause, the air is so cold that even the very scarce water vapor at this altitude can be sublimated into polar-mesospheric noctilucent clouds. These are the highest clouds in the atmosphere and may be visible to the naked eye if sunlight reflects off them about an hour or two after sunset or a similar length of time before sunrise.

THERMOSPHERE

The thermosphere is the second-highest layer of Earth's atmosphere. It extends from the mesopause (which separates it from the mesosphere) at an altitude of about 80 km up to the thermopause at an altitude range of 500–1000 km. The height of the thermopause varies considerably due to changes in solar activity. Because the thermopause lies at the lower boundary of the exosphere, it is also referred to as the exobase. The lower part of the thermosphere, from 80 to 550 kilometres above Earth's surface, contains the ionosphere. The temperature of the thermosphere gradually increases with height. Unlike the stratosphere beneath it, wherein a temperature inversion is due to the absorption of radiation by ozone, the inversion in the thermosphere occurs due to the extremely low density of its molecules. The temperature of this layer can rise as high as 1500 °C, though the gas molecules are so far apart that its temperature in the usual sense is not very meaningful. The air is so rarefied that an individual molecule (of oxygen, for example) travels an average of 1 kilometre between collisions with other molecules. Although the thermosphere has a high proportion of molecules with high energy, it would not feel hot to a human in direct contact, because its density is too low to conduct a significant amount of energy to or from the skin. This layer is completely cloudless and free of water vapor.

EXOSPHERE

The exosphere is the outermost layer of Earth's atmosphere (i.e. the upper limit of the atmosphere). It extends from the exobase, which is located at the top of the thermosphere at an altitude of about 700 km above sea level, to about 10,000 km where it merges into the solar wind. This layer is mainly composed of extremely low densities of hydrogen, helium and several heavier molecules including nitrogen, oxygen and carbon dioxide closer to the exobase. The atoms and molecules are so far apart that they can travel hundreds of kilometers without colliding with one another.

Thus, the exosphere no longer behaves like a gas, and the particles constantly escape into space. These free-moving particles follow ballistic trajectories and may migrate in and out of the magnetosphere or the solar wind colliding with one another. Thus, the exosphere no longer behaves like a gas, and the particles constantly escape into space. These free-moving particles follow ballistic trajectories and may migrate in and out of the magnetosphere or the solar wind.

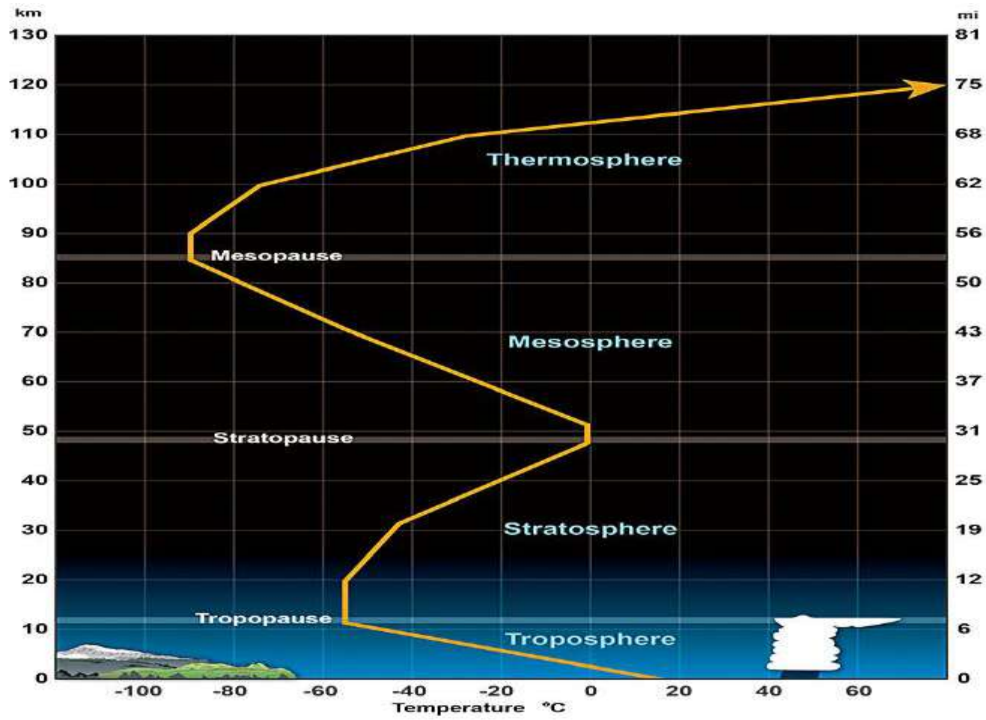


Figure 1.2. Variation of atmospheric temperature with altitude

1.2 Tropospheric weather systems

The troposphere is the layer where most of the world's weather takes place. The troposphere contains almost all the atmospheric water vapor, in fact it contains about 70 to 80 per cent of the total mass of the Earth's atmosphere and 99 per cent of the water vapor. Temperature and water vapor content in the troposphere decrease rapidly with altitude and thus most of the water vapor in the troposphere is concentrated in the lower, warmer zone. Water vapor concentrations vary with latitude. They are greatest above the tropics and decrease toward the Polar Regions.

In the troposphere air temperature on average decreases with height at an overall positive lapse rate of about 6.5°C/km, until the tropopause, the boundary between the troposphere and stratosphere is reached. The tropopause, extending from 11 to 20 km, is an isothermal layer in the atmosphere where temperature remains constant over a distance of about 9 km. Troposphere and tropopause are also known as the lower atmosphere. It is also the layer in the atmosphere where the winds increase with height and jet streams usually occur in the upper troposphere, just below the tropopause. Since temperature decreases with altitude in the troposphere, warm air near the surface of the Earth can readily rise, being less dense than the colder air above it. Such vertical movement or convection of air generates clouds and ultimately rain from the moisture within the air, and gives rise to much of the weather which we experience. The troposphere is capped by the tropopause, a region of stable temperature. Air temperature then begins to rise in the stratosphere. Such a temperature increase prevents much air convection beyond the tropopause, and consequently most weather phenomena, including towering, cumulonimbus thunderclouds, are confined to the troposphere.

However, lapse rate variations that sometimes occur within the troposphere include inversions (temperature increase with height within some limited layer). In the upper troposphere temperature falls below about -50°C and only little moisture is present or condensing out as ice crystals. So, weather disturbances don't go higher than the tropopause, besides for some severe thunderstorms which have an "overshooting top" that punches its way into the stratosphere. The stratosphere contains ozone gas which is heated by the sunlight. There isn't much convection (rising air currents that transport heat) going on in the stratosphere. Also, the stratosphere contains very little moisture.

The thickness of the troposphere varies from about 7 to 8 km (5 mi) at the poles to about 16 to 18 km (10 to 11 mi) at the Equator. In addition, it varies in height according to season, being thinner in winter when the air is densest. This seasonal effect is strongest at the mid-latitudes, where it varies around 11 km (7 mi). Increasingly, it is understood that air movements in the upper troposphere greatly influence weather systems in the lower troposphere.

AIR MASSES

Air masses represent large regions (1,000s km2) of the lower troposphere with relatively uniform properties (temperature, moisture content). The characteristics of individual air masses are dependent upon the attributes of a source area and the modification of the air mass that occurs as a result of movement from the source region. Weather in any region is influenced by the changes that occur in the air mass over time and the interactions that occur at fronts, the boundaries between contrasting air masses.

An air mass develops when the atmosphere is located above a relatively uniform land or water surface for several days. The lower atmosphere assimilates some of the properties of the underlying surface. Air masses are identified by their temperature (polar/tropical) and the character of the underlying surface (continental/maritime). The latter property is a proxy for moisture content. Air masses that develop above oceans contain much more moisture than those formed over land. The distribution of air masses is relatively intuitive. Arctic and polar air masses are located at high latitudes in the Northern Hemisphere and tropical air masses are located closer to the equator. Continental air masses are found over land, maritime air masses over ocean. The boundaries between individual air masses vary with seasons.

FRONTAL SYSTEMS

Frontal systems represent the meteorological battle that ensues when air masses of contrasting properties clash along their boundaries. As air masses move across Earth's surface they inevitably interact to create relatively narrow, curvilinear zones that mark a front, a transition from one air mass to another. Advancing frontal systems bring clouds and precipitation and are accompanied by changes in moisture, temperature, pressure, and wind direction..

Cold, dense continental polar air replaces moist, warm maritime tropical air across the cold front. People living downwind from the front experience decreasing temperature and humidity and increasing atmospheric pressure with the passage of the cold front. Changes following the passage of the warm front are more benign than the storms that travel with the cold front. Friction at Earth's surface causes the warm front to slope gently toward the warm air mass. Warm, humid air is transported upward over a distance of approximately 1,000 km (625 miles). Rain associated with a warm front may last longer than precipitation that accompanies a cold front because the warm front typically moves more slowly and extends over a larger area. Temperatures and humidity rise and winds typically shift direction (from south to southwest) with the passage of the warm front. The cold front moves more rapidly than the warm front (~ 10 km per hour faster) and will eventually close the gap between the fronts, forcing the intervening warm air upward generating additional precipitation. An occluded front is represented by a combination of warm and cold front. The occluded front juxtaposes two bodies of cold air; the warmer of the two masses is forced up and over the other. Occluded fronts may be marked by the occurrence of nimbostratus clouds.

1.5 Scope of the Study

Rainfall is the important element of Indian economy. Although the monsoons effect most part of India, the amount of rainfall varies from heavy to scanty on different parts. There is great regional and temporal variation in the distribution of rainfall. Over 80% of the annual rainfall is received in the four rainy months of June to September. Attempts were made to study temporal variation in monthly, seasonal and annual rainfall over Kerala, India, during the period from 2007-2017.. In view of the importance of variability in rainfall, as indicated above, it would be of interest to study the long-term variation of monthly, annual and seasonal rainfall during south west monsoon over peninsular India which is known as the ‘‘Gateway of summer monsoon’’ over India

CHAPTER II
DATA AND METHODOLOGY

2.1 Indian Meteorological Department - IMD

The Indian Meteorological Department (IMD) is an agency of the Ministry of Earth Sciences of the Government of India. It is the principal agency responsible for meteorological observations, weatherforecasting and seismology. IMD is headquartered in Delhi and operates hundreds of observation stations across India and Antarctica. IMD is also one of the six Regional specialized Meteorological Centres of the World Meteorological Organization. It has the responsibility for forecasting, naming and distribution of warnings for tropical cyclones in the Northern Indian Ocean region, including the Malacca Straits, the Bay of Bengal, the Arabian Sea and the Persian Gulf.

Data and observations are also reported into the IMD network from meteorological instruments on board Indian merchant marine and Indian Navy ships. IMD was the first organization in India to deploy a message switching computer for supporting its global data exchange. IMD collaborates with other agencies such as the Indian Institute of Tropical Meteorology, National Centre for Medium Range Weather Forecasting and the National Institute of Ocean Technology. IMD also operates seismic monitoring centres at key locations for earthquake monitoring and measurements.

IMD undertakes observations, communications, forecasting and weather services. In collaboration with the Indian Space Research Organisation, the IMD also uses the IRS series and the Indian National Satellite System (INSAT) for weather monitoring of the Indian subcontinent. IMD was first weather bureau of a developing country to develop and maintain its own satellite system. It is regional nodal agency for forecasting, naming and disseminating warnings about tropical cyclone in the Indian Ocean north of the Equator. The two types of data collected by IMD are the Manually Observed Data and the Automatic Weather Data. The Manual surface observatories are located almost one in each district so as to meet the requirements of weather forecasting, agriculture and other operations of the country. The observations taken manually are air temperature, relative humidity, sunshine duration, solar radiation, wind speed and direction, precipitation, evaporation and cloud cover, etc. Automatic Weather Station (AWS) and Automatic Rain Gauge (ARG) data are increasingly becoming the ideal method for collection of meteorological data world over. The AWS and ARG data are collected at hourly frequencies and transmitted to the data receiving center located at Pune. These data are automatically quality checked before transmission on GTS for operational use. The parameters collected are air temperature, relative humidity, wind speed, barometric pressure, rainfall, soil temperature, leaf wetness and soil moisture.

2.2 Methodology

The mechanism of Indian Monsoon and the factors affecting its deviation were analyzed. Then the monthly analysis of rainfall as a data over South Peninsular India was collected from the official website of the IMD. The data was inserted into the Microsoft Excel in rows and columns**.** Our aim was to analyze the variation in the amount of rainfall in India during 10 years, from 2007 to 2017. The amount of rainfall during the study period was available in monthly and annual basis. Similarly the mean rainfalls of all the other months were determined.

From the data of mean rainfall of each month, standard deviation of each month for each year was determined separately. The standard deviations corresponding to twelve such months are calculated. Finally rainfall anomalies are represented the over the whole period of study. Recognizing the rainfall shifts, the Oceanic Niño Index values were accessed from National Oceanic and Atmospheric Administration and were studied. Further, the factors responsible for shift in the rainfall patterns were examined and studied.

CHAPTER III

RESULTS AND DISCUSSION

3.1 Annual Variability of Monsoon

The annual variability of rainfall over study period over South Peninsular India is examined. In order to have a detailed structure of the rainfall pattern we have taken the year wise rainfall anomalies which can be depicted and are shown in Figure 3.1. From figure it is evident that rainfall anomaly shows large year to year variability. The anomaly is found to be maximum during 2009 and 2014 - 2015 monsoon season and minimum during 2013.

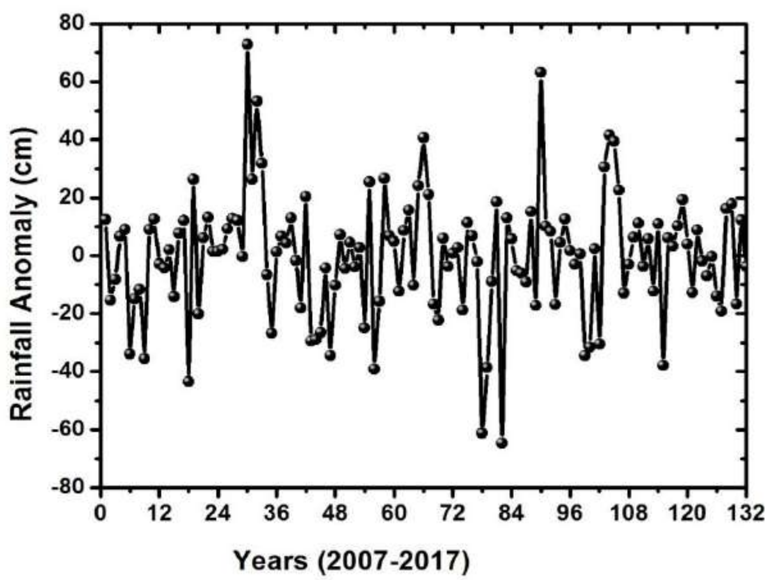


Figure 3.1(a). Annual rainfall anomalies over South Peninsular India from 2007-2017

The deficient or excess rainfall years are defined for those years when rainfall is less or more than the standard deviation. Pant and Rupa Kumar (1997) reported that Indian monsoon displays multi-decadal variations in which there is clustering of dry or wet anomalies. With reference to the percentage deviation from normal the various rainfall catagories are as follows.

Large Excess : + 60% an Above

Excess : +20 % - +59 %

Normal : +19 % - -19 %

Deficient : -20 % - -59 %

Large Deficient (Scanty) : -60% or less

No rain :-100%

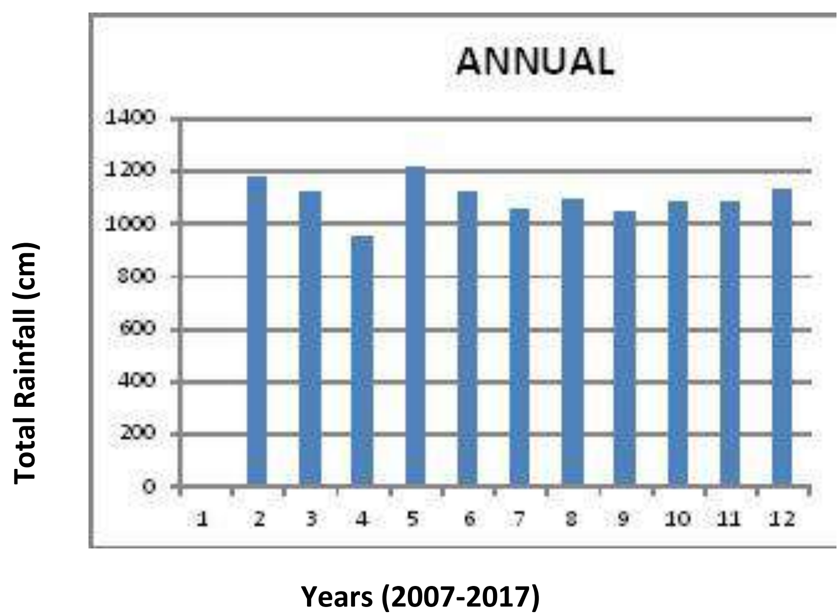


Figure 3.1(b). Total annual rainfall over South Peninsular India from 2007-2017

Figure 3.2 (b) represents total annual rainfall during the study period for South peninsular India. The annual rainfall is found to be maximum during 2010 and minimum during 2009.

3.2 Monthly Variability of Monsoon

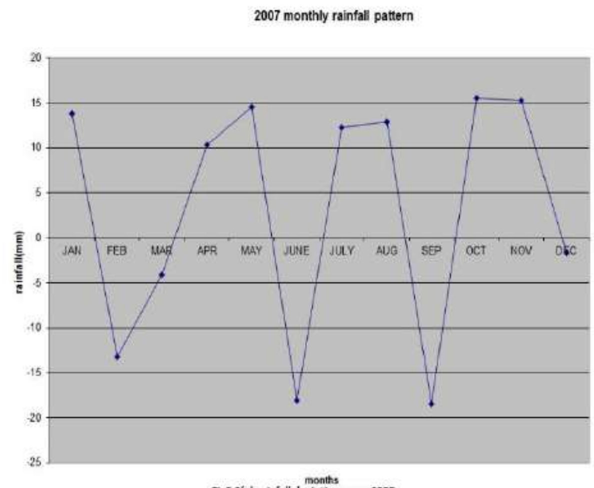


Fig3.2(a);rainfall deviations over 2007

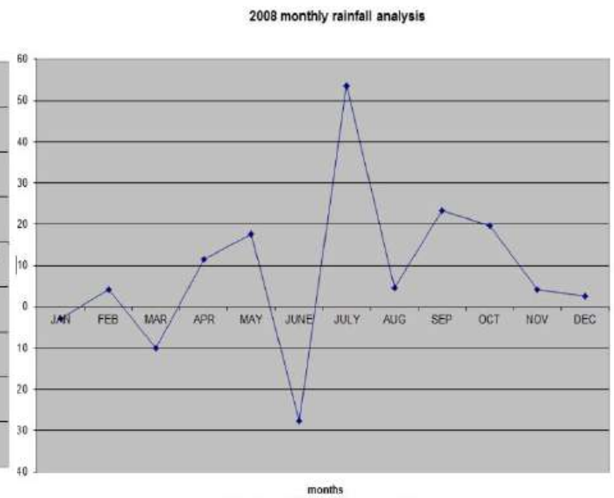


Fig 3.2(b);rainfall deviations over 2008

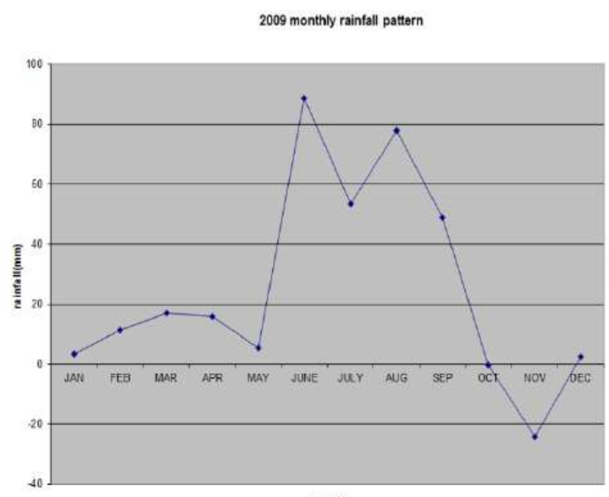


Fig3.2(c);rainfall deviation over 2009

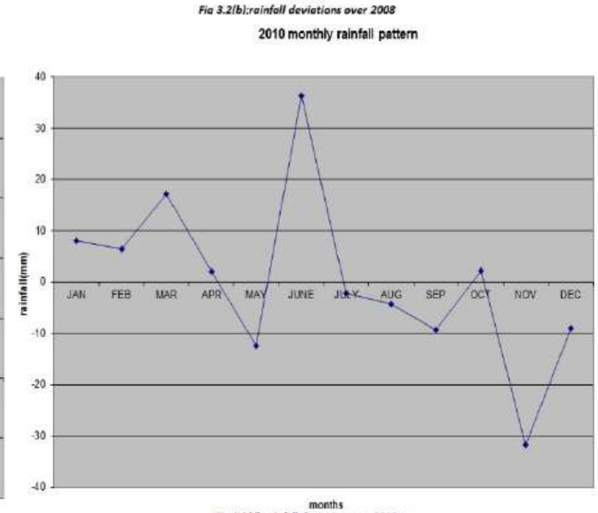


Fig 3.2(d);rainfall deviation over 2010

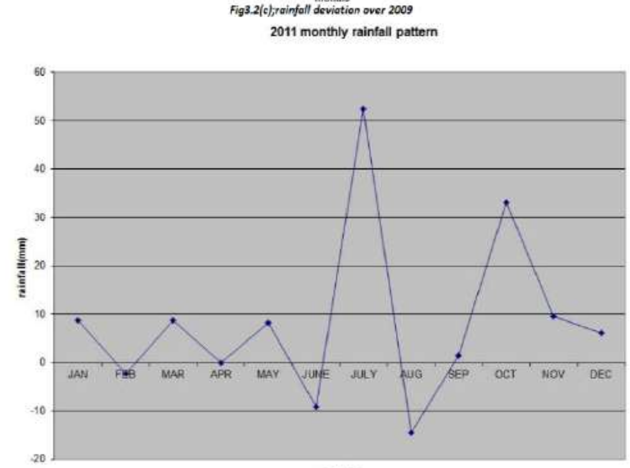
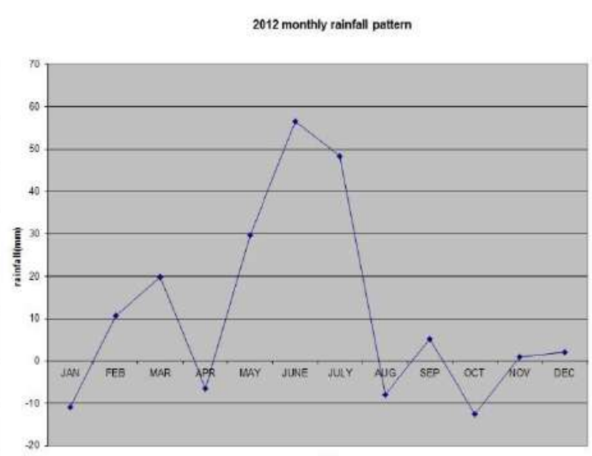


Fig3.2(e);rainfall deviations over 2011



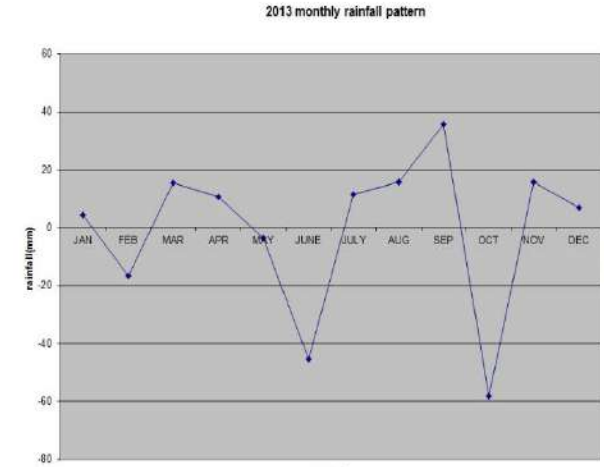


Fig3.2(g);rainfall deviations over 2013

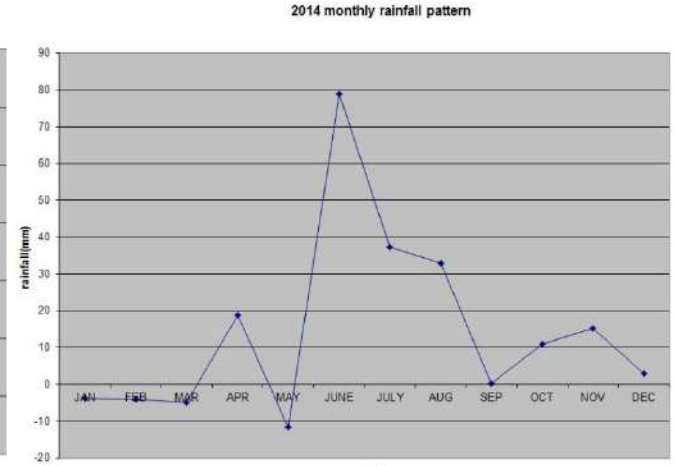


Fig3.2(h);rainfall deviations over 2014

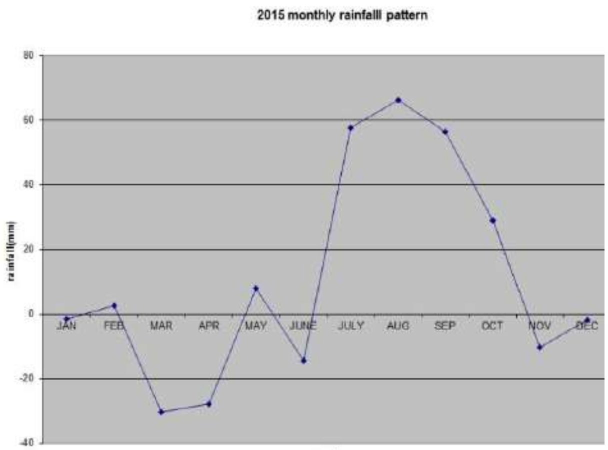


Fig3.2(i);rainfall deviations over 2015

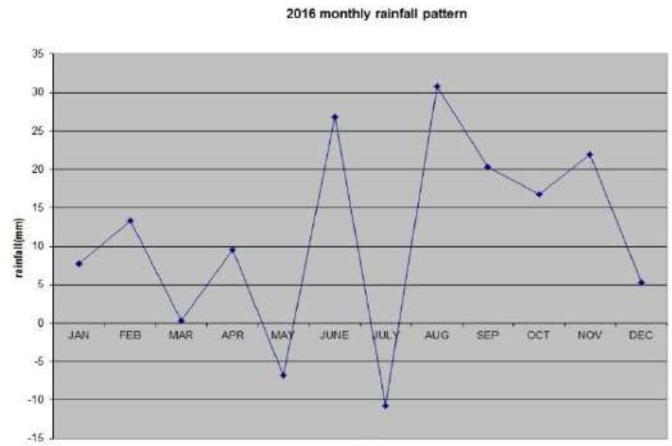


Fig3.2(j);rainfall deviations over 2016

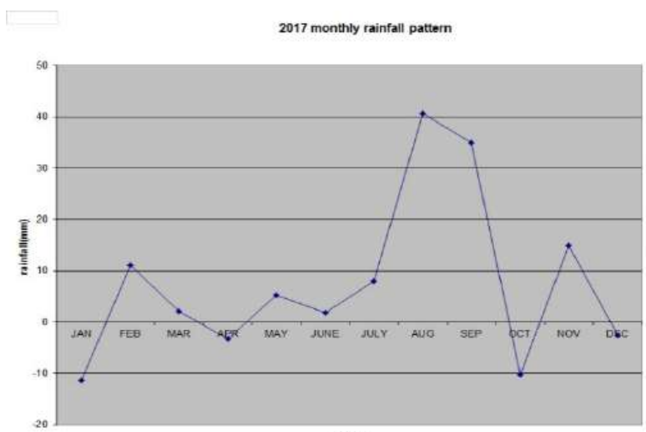


Fig3.2(k);rainfall deviations over 2017

Figure 3.2 (a - j). Annual rainfall deviations over South Peninsular India from 2007-2017

The annual rainfall deviations over South Peninsular India from 2007-2017 are calculated and demonstrated in figure 3.2 (a-j). Amongst the eleven years of study, year 2007 showed the maximum deviation. October received the maximum rainfall (15.54 cm) and June received the minimum rainfall (-18.110cm) respectively. The monsoon began by the end of the June and experienced a high peak thereafter lasting up to August. Year 2008 showed a negative trend in June. The monsoons advanced by the beginning of July. July received the highest rainfall (53.48cm) and June received the lowest rainfall (-27.61cm) respectively. Similar to 2007, the post monsoon period also showed a positive trend in rainfall.

The year 2009 showed the minimum number of negative deviations amongst the all eleven years. But unlike 2007 and 2008, the monsoon began in the early June with the maximum positive deviation in June. This year received more monsoon rains than usual. The post monsoon period showed a negative trend with zero deviation in October. November received the least rainfall (-24.05cm).Year 2010 shows a maximum positive deviation for June (36.29cm) and negative deviation for November (-31.75 cm) similar to 2009.But by July the monsoon weakened, and decreased thereafter. It can also be noted that the pre monsoon periods of 2009 and 2010 showed an increasing trend in rainfall.

Year 2011 showed a maximum deviation in July (52.48cm) and the maximum negative trends in August (-14.57cm) respectively. January and March accounted for the same deviation values indicating that the rainfalls were higher than the normal but by the same amount. The post monsoon period also showed an increase in rainfall. In the year 2012, June received the highest rainfall (56.59) and September received the lowest rainfall (-5.18cm) respectively.. The rainfall patterns showed an increasing positive trend from May and it continued up to July. Over the four consecutive years, from 2009-2012, August experienced negative deviations. The increased peak width over June –Aug indicates the wider span of the monsoon.

In 2013 September showed the maximum positive deviations (35.62cm) and October showed the minimum deviations (-58.16cm). After about four years, June began to see a decreasing trend in the rainfall patterns. In 2014 June received the maximum rainfall (78.99 cm) and May received the minimum rainfall (-11.56 cm) respectively. The span of the monsoon is also very higher. The year also has a characteristic that both the pre monsoon and the post monsoon experienced a positive deviation in the rainfall. The next three consecutive years, 2015, 2016 and2017 showed a maximum positive deviation in August. In 2015 it was (66.13cm). In 2016 and in 2017 (30.73cm, 40.73cm) respectively. This meant that August experienced more than the normal rainfall rains over these consecutive years. This is also an indication of the shift in the monsoon from June July to Aug September .2015 March obtained the lowest rainfall (-30.270cm) 2016 it was July (-10.72cm) and in 2017 it was January (-11.73 cm) respectively.

3.4 Seasonal Variability of Monsoon

In order to have a detailed analysis about the rainfall patterns, separate graphs of all the twelve months were considered. The study period is divided into 1)Pre monsoon 2)Monsoon and 3) Post monsoon. The months February, March, April and May constituted the pre monsoon months. June July August and September the monsoon and October, November, December and January constituted the post monsoon months respectively.

3.5 El Nino Southern Oscillations - ENSO

The tropical pacific is an important factor in climatology because of the processes of tropical convection: the tendency for warm air and moisture to rise high into the atmosphere. Atmospheric convection in the tropics rises up to a height of 5-10 km above the ocean taking the warmth to the mid to upper troposphere. One of the major climate shifting patterns is associated with the tropical pacific and is termed as ENSO – El Nino Southern Oscillation. It is an irregularly periodic variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean, affecting the climate of much of the tropics and subtropics. The warming phase of the sea temperature is known as *El Niño* and the cooling phase as *La Niña*. The *Southern Oscillation* is the accompanying atmospheric component, coupled with the sea temperature change: the Southern Oscillation, a “seesaw of atmospheric pressure between the eastern equatorial Pacific and Indo–Australian areas”, is closely linked with El Niño. During an El Niño–Southern Oscillation (ENSO) event, the Southern Oscillation is reversed. Generally, when pressure is high over the Pacific Ocean, it tends to be low in the eastern Indian Ocean, and vice versa (Maunder, 1992). It is measured by gauging sea-level pressure in the east (at Tahiti) and west (at Darwin, Australia) and calculating the difference. This is then put into an index called the Southern Oscillation Index (SOI) or Tahiti–Darwin Index. High negative values of the SOI represent an El Niño, or “warm event”. *El Niño* is accompanied by high air surface pressure in the tropical western Pacific and *La Niña* with low air surface pressure there. The two periods last several months each and typically occur every few years with varying intensity per period.

Intensity of El Nino can be classified based on sea surface temperature anomalies exceeding a pre-selected threshold in a certain region of equatorial pacific sea. Sea Surface Temperature is the water temperature close to ocean's surface. The warming phase of sea temperature is El Nino and the cooling phase is La Nina. This means that El Nino is accompanied with warmer ocean surface than average ocean water temperatures. La Nina results in a cooler ocean temperature in the central and eastern Pacific Ocean. The sea surface temperature will be lower than the normal by 3-5 degree Celsius. The Oceanic Nino Index (ONI) is one of the primary indices used to monitor the El Nino-Southern Oscillation (ENSO). The ONI is calculated by averaging sea surface temperature anomalies in an area of the east-central equatorial Pacific Ocean.

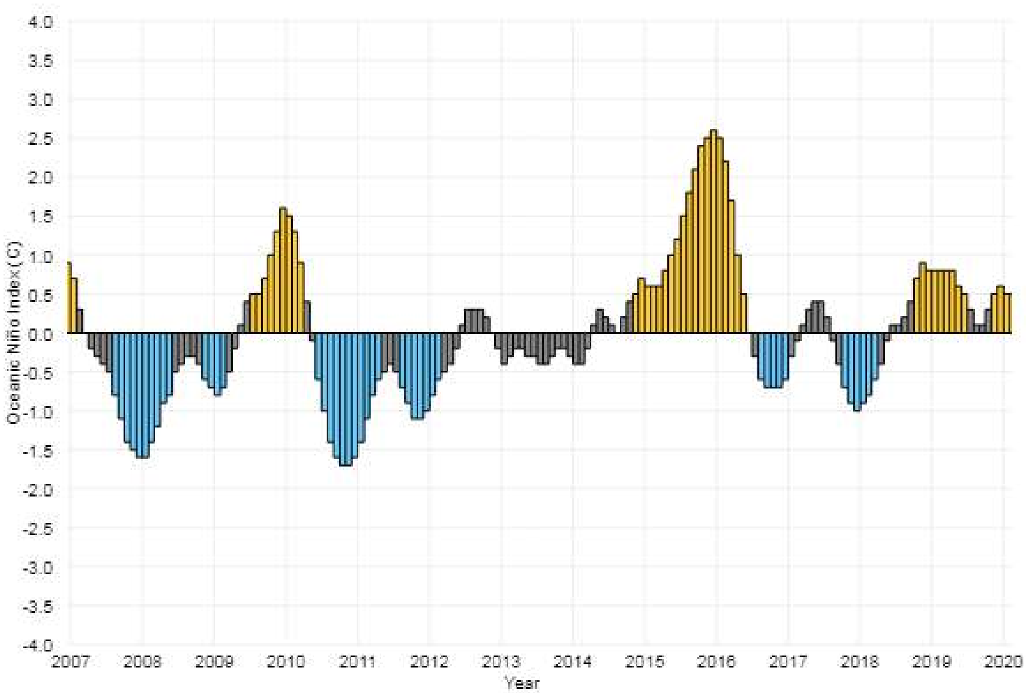


Figure 3.6. Oceanic Nino Index for the study period (Courtesy – NOAA)

NOAA (National Oceanic and Atmospheric Administration) considers El Niño conditions to be present when the Oceanic Niño Index is +0.5 or higher, indicating the east-central tropical Pacific is significantly warmer than usual. La Niña conditions exist when the Oceanic Niño Index is -0.5 or lower, indicating the region is cooler than usual. NOAA has established and now operates an array of moored buoys in the equatorial Pacific Ocean. These buoys measure temperature, currents, and winds in this region on a daily basis. The data is available to scientists around the world in real time, enabling them to use the data for both research and forecasting. This network is very valuable in that the first stages of an ENSO event occur in this region. By monitoring data from past episodes and the data from the months leading up to an episode, scientists can use numerical models (similar to but not as reliable as those used in weather forecasting) to help them predict and/or simulate ENSO events. The predictive models are becoming more sophisticated and more effective in many respects.

The ONI is found to be more than +0.5 during 2009 and 2015, indicating east-central tropical Pacific is significantly warmer than usual. From our observation we got maximum rainfall during 2009 and 2014 - 2015 monsoon season over Southern Peninsular Indian Region. Similarly Oceanic Niño Index is -0.5 or lower, indicating the region is cooler than usual where we got minimum rainfall (2013). So we can infer that the temperature of east-central tropical Pacific is a driving factor of Indian Monsoon. El Nino years are resulting in maximum rainfall while La Nina years are resulting in less rainfall.

The term Indian Ocean Dipole or IOD means two opposite sides of Indian Ocean with respect to surface temperatures Indian Ocean lie in the Tropical region. The western side of the ocean lies near the African continent and the eastern side lies near the Australian continent. There is an irregular shift of temperature from the western side to the eastern side of the ocean and vice versa. That means when the western part of the Indian Ocean is warmer, the eastern side becomes cooler and vice versa. This is referred as the Indian Ocean Dipole.

Indian Ocean is the warmest ocean. It is surrounded by land masses on three sides. At the eastern side the Pacific Ocean mixes up with the Indian Ocean flowing towards it through the Australian land mass. Tropical easterly makes this happen. It blows from northeast in the northern hemisphere and from southeast of the southern hemisphere. The flow of Pacific Ocean into the Indian Ocean results in the temperature difference. The Indian Ocean Dipole varies between positive negative and neutral phase. During the positive and negative IODs, there is a pressure difference between the eastern and western region of Indian Ocean. Air always flow from higher pressure region to lower pressure region. This leads to global wind belts. Wind belts are responsible for the climate change in areas which lie in its path. India lies in between the western and eastern Indian Ocean. Hence the flow of air during positive and negative IODs will affect the climate of India. Positive IOD is beneficial to India because it pushes rain towards India. Negative IOD brings drought in India.

CHAPTER IV

CONCLUSION

4.1. Conclusion

Indian Monsoons are dynamic and complex. The monsoon climate is affected by various factors such as latitudinal position, altitudinal variations, Himalayas, Distribution of land and sea, amount of humidity etc. There for a high level of accuracy is required in the fore casting and prediction of monsoon to provide stability and sustainability to Indian Economy. Understanding that climate is changing globally, we must make our system to cope with these changes. Recognizing that monsoon is very complex and that a lot of factors are included in it, what we now require is a model that will easily fit with the climatic changes.

In this context monthly, seasonal and annual trends of rainfall have been studied using monthly data series of during 2007-2017 for over the south peninsular region over India. In India, the monsoon months of June to September account for more than 80% of the annual rainfall. In this study, we defined homogeneous regions based on rainfall seasonality. Homogeneous regions were defined as regions with similar climatological seasonality of rainfall. We then analyzed both the long-term trend of rainfall for two homogeneous region .An important aspect of the present study is to report the long term trends in the south west monsoon rainfall over India. Rainfall is more predominant in July in the south peninsular region. Unlike in June and July, the contribution of rainfall during August and September are stable. The all India rainfall during June and September are found to be stable and in July and August showed an increasing trend. The average monthly rainfall during June – September over South Peninsular and all India were also reported. Strong regional dependency can be considered to exist for the secular variation or the amounts of seasonal rainfall in India for the study. The anomaly is found to be maximum during 2009 and 2014 monsoon season and minimum during 2013. The span of the monsoon is also very higher. The year also has a characteristic that both the pre monsoon and the post monsoon experienced a positive deviation in the rainfall. There is an observed shift as indicated in monsoon from June July to Aug September 2015-17. 2009 and 2014-2015 June showed a record minimum rainfall. The ONI is found to be more than +0.5 during 2009 and 2015, indicating east-central tropical Pacific is significantly warmer than usual. From our observation we got maximum rainfall during 2009 and 2014 - 2015 monsoon season over Southern Peninsular Indian Region. Both these years were marked with El Nino. Similarly, Oceanic Niño Index is -0.5 or lower, indicating the region is cooler than usual where we got minimum rainfall (2013). So we can infer that the temperature of east-central tropical Pacific is a driving factor of Indian Monsoon. El nino years are resulting in maximum rainfall while La-nina years are resulting in less rainfall.

4.2. Future Scope

Although the subject area of climate change is vast, the changing pattern of rainfall is a topic within this field that deserves urgent and systematic attention, since it affects both the availability of freshwater and food production. Rainfall is an important meteorological parameter, which has direct application to agricultural production and other aspects such as water resources. Investigations into different aspects of the rainfall are essential for a country such as India whose economy is dependent on agricultural production. During the last few decades climate change has assumed importance owing to an identified increase in tropospheric temperatures. Associated with the climate change, the spatial and temporal distribution of rainfall is also subjected to variations. As a result of a wide range of applications, study of the long-term trends and periodicities in annual rainfall is an important problem which needs to be investigated.

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