COMPARATIVE STUDY OF RAINFALL FROM AWS AND MANUAL RAINGAUGE NETWORKS OVER ANDHRA PRADESH AND TELANGANA STATES

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IN

SATELLITE METEOROLOGY & WEATHER INFORMATICS

By

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I/we certify that the Dissertation entitled "**COMPARATIVE STUDY OF RAINFALL FROM AWS AND MANUAL RAINGAUGE NETWORKS OVER ANDHRA PRADESH AND TELANGANA STATES**" submitted by B.VINODH KUMAR bearing H.T.NO: 13031G2320 in partial fulfillment of requirement of the Master's degree in "Satellite Meteorology and Weather Informatics" of the Department is bonafide work and may be placed before the examination board for their consideration.

Head of the Department

Internal examiner **External Examiner**

DECLARATION

The work entitled **"COMPARATIVE STUDY OF RAINFALL FROM AWS AND MANUAL RAINGAUGE NETWORKS OVER ANDHRA PRADESH AND TELANGANA STATES "** is a bonafide work which was carried out by me under the supervision of P.V.Ramanamurthy, Deputy Executive Engineer, APSDPS, AP Secretariat in Hyderabad is submitted to centre for Earth, Atmosphere and Weather Modification Technologies (CEA&WMT), Institute of science and technology (IST), Jawaharlal Nehru Technological University Hyderabad (JNTUH).This work is original and has not been submitted for any other degree or diploma of this or any other university.

Date: **B.VINODH KUMAR**

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ABSTRACT

Most of the people in Andhra Pradesh and Telangana States depend on agriculture. Rainfall is the only major source that meets the water needs of living beings on earth including for agriculture. Over the recent years the changing of climatic conditions leading to drought & floods. Understanding the rainfall situation across-the state has become an important aspect to understand its impact on agriculture. Specifically the study made on attempt to investigate the relationship between rainfall data obtained from Automatic Weather Station (AWS) and traditional (conventional) surface observation system. It was hypothesised that a significant relationship exists between data sets from the two observation methods. India Meteorological Department station was chosen for this study due to availability of data for both observation systems.

Assessment of rainfall situation based on IMD & DRMS manual Rain gauges is contrasted with densely installed AWS network. Similarly the variation in the various methods used to understand the rainfall across the states using point rainfall observations from two networks are also contrasted. Although AWS & IMD stations are not co-terminus geographically AWS station data nears to IMD stations are used to study correlation between AWS data and IMD&DRMS manual gauge data.

It is expected that the outcomes of this study when read with agriculture drought assessments would help the authorities in adopting suitable methodology for converted point rainfall to areal rainfall so that a realistic rainfall situation can be assessed across the state.

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CHAPTER-1

INTORDUCTION

The states of Andhra Pradesh and Telangana are situated in the eastern side of south India. Andhra Pradesh lies between12°41' and 19°20'N latitude and 77° and 84°40'E longitude. And Telangana lies between 15°80' and 19°90'N latitude and 77°30' and 81°85'E longitude. Andhra Pradesh and Telangana States having significant variation in geological, geographical and meteorological features. The geographical and geological features affect the weather and climate of place to large extend. 70% off people depends on Agricultural production which is determined by climate as one of the key factors. In Andhra Pradesh the east coast is affected by cyclones and floods, while some of the districts in Rayalaseema and Telangana state face extreme drought conditions. The problem has caused so many agriculture farmers and human beings died. Due to lack of understanding of meteorological information for planning and management purposes. To study the global warming and climate change impacts in Andhra Pradesh and Telangana there is a need to study the change in hydrological cycle incorporating in rainfall data.

1. 1 Why to study Rainfall?

Accurate estimation of rainfall is crucial for crop yield for assessment, water resources management and flood and drought monitoring. Excess rainfall causes severe flooding leading to property and human loss. Extended absence of rainfall lead to drought, which can deviation state crop yield. Since the rainfall is most important for agriculture purpose the collection rainfall data and is accuracy is important in this study.

GENERAL

1.2 Precipitation: for general use the terms precipitation and rainfall are used as synonyams with each other. Precipitation is defined as, “Earthward falling of water drops or ice particles that have formed by rapid condensation in the atmosphere” in condensation the water vapour is suspended in the air in different forms but, in the precipitation an appreciable deposit either in solid or liquid form takes place on the earth surface. There are some common forms and different types in precipitation.

1.2.1 Liquid Forms:

1. **Rain**

It is defined as, "precipitation of drops of liquid water". The cloud consists of minute droplets of water and when these droplets combine and forms large drop and can not remain suspended in the air they fall down as rain. These droplets are formed by rapid condensation. The size of rain drop is more than 0.5 m.m. in diameter. The imaginary lines drawn on a map connecting the points of equal rainfall are known as the "Isohytes".

2. Drizzle

It is more or less uniform precipitation of very small and minute rain drops. These drops can be carried away even by light winds. The diameter of drizzle drop is less than 0.5 m.m. It falls from low lying nimbostratus cloud. Fog merges to form drizzle.

3. Shower

It is the precipitation lasting for a short time with relatively clear intervals.

1.2.2 Solid Forms

1. Snow

It is defined as, "Precipitation of water in solid form of small or large ice crystals". It occurs only when the condensing medium has a temperature well below freezing (0^oC) temperature. It is also seen in the form of flakes which are aggregates of many crystals, formed due to sublimation of water vapour at sub-freezing temperatures.

2. Hail

It is a precipitation of solid ice. A strong convective column on a warm sunny day may cause the formation of pellets of spherical shape with concentric layers of ice, which is known as hail. Hail falls from cumulonimbus clouds and is often associated with thunder and storm. The size of hail ranges from peanut to cricket ball. The rainfall associated with the hail is called as the "Hail storm".

1.2.3 Mixed Forms

1. Sleet

It is the simultaneous precipitation of the mixture of rain and snow occasionally, half frozen drops also fall as sleet forms when rain drops are frozen as they fall through a layer of cold air.

2. Glaze

Freezing rain is known as glaze. This is formed at sub-freezing temperatures when rain falls on objects or on ground. It looks like a sheet or coat.

1.3 MEASUREMENT OF RAINFALL:

1.3.1 The India Meteorological Department (IMD) Ordinary (Non-recording) Rain-Gauge:

it is made up galvanized iron sheet of 12 gauge thickness. Of late, fiber glass and plastic makes are also in use. This consists of four parts (a) funnel (b) body (c) Receiver and (d) base. Measurement of rainfall data with Manual rain gauge at 0830 hours IST of day 1 to 0830 hours IST (Indian Standard Time) of day 2.

Principle:

The rain water entering the gauge from the top of the rim of the funnel is lead via funnel to receiver. The rain water thus collected is measured with the help of a measuring cylinder.

Operation and measurement:

1. The diameter of the funnel is 12.7 cm the outer peripheral ring is made up of copper or brass it is called as “Rim”. It is designed in such a way that the rain water does not splash out (fig 1.1).
2. The rain water received by the funnel is emptied into collecting jar which is kept in an jacket or receiver.
3. The outer jacket is a cylindrical vessel closed at one end.
4. Besides housing the collecting jar, the outer jacket also receives the over flow of the rain water from it.
5. The funnel, the collecting jar, and the outer jacket are fitted into a base which has a locking arrangement.
6. The amount of the water is measured with the help of a calibrated glass measuring jar, corrected up to 0.1 mm.
7. The rain gauge should be kept on a hard compact leveled platform partially inserted in the ground in such a way that the rim is at a height of 1 flood (30 cm) above the ground surface (fig1.2).
8. The rim should be positioned on a perfectly horizontal plane. This can be done by using spirit level and rain gauge should be painted grey thought.
9. Rain gauge should be checked for leaks and dust partials. Leaves should be removed from the receiver.
10. The measuring cylinder should be kept clean and a spare measuring cylinder should be available in the observatory.

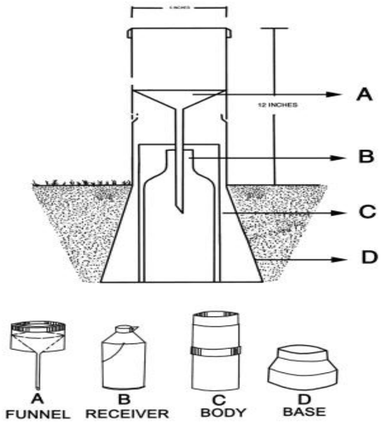


Fig 1.1 Symons Rain Gauge

Fig 1.2 Ground surface installed Symons rain gauge

As per as District wise Rainfall Monitoring Scheme (DRMS) and Directorate of Economics and Statistics (DES) also using Ordinary (Non-recording) Rain-Gauge.

1.3.2 Automatic Weather Station (AWS): WMO defines an automatic weather station (AWS) as a facility that automatically transmits or records observations obtained from measuring instruments. Automatic weather observation refers to the activities involved in converting measurements of meteorological elements into electrical signals through sensors, processing and transforming these signals into meteorological data, and transmitting the resulting information by wire or radio or automatically storing it on a recording medium.

Automatic Weather Stations are equipped with various weather parameter sensors such as Temperature, Humidity, Wind Speed, Wind Direction, Local Pressure, MSLP, Rainfall etc. The weather data from these AWS Stations are received at the APSDPS central servers at any given interval of time. The real-time weather data receives at central server consists of some errors and uneven values, due to sensor problem/some uneven interruptions at AWS site (fig 1.3). For this data, Quality checks are performed to correct erroneous values. These erroneous data are identified and corrected by performing Quality Checks like completeness of data, climatologically consistency, Time Consistency, Internal consistency, spatial and range checks. After performing Quality Checks the accuracy level reached to 95% and during the process of quality checks, the calibration requirements for the AWS is recommended and thereby improving the AWS performance.

Fig 1.3 Automatic Weather Station

Andhra Pradesh Government established an Early Warning Center (EWC) to forewarn people about cyclones and floods based on mathematical models. The Early Warning Center frame work involves running of weather forecasting models supported by real time acquisition of data on a number of weather related parameters.

Andhra Pradesh Government have established the AP State Disaster Mitigation Society (APSDMS) to take up Disaster Mitigation studies relating to Rainfall, Run-off and Flood Forecasting, Cyclone model for Track, Wind and Storm Surge forecast to improve the early warning capabilities of State during natural disasters. The society in course of its working also started studies on Coastal Zone Management, Delta Water management, Preparation of Disaster Management Plans related to Cyclone, Drought and Earthquakes as part of its long term mitigation measures. After almost 10 years of its existence, APSDMS was restructured and re-named as Andhra Pradesh State Development Planning Society (APSDPS) with effect from 01-04-2012, with modified by-laws and structure. To facilitate data collection APSDPS has installed following weather sensors in Andhra Pradesh & Telangana State.

Table 1.1 To facilitate data collection APSDPS and TSDPS has installed following weather sensor in Andhra Pradesh and Telangana State.

Sensors	Andhra Pradesh State	Telangana State
Rainfall	1185	854
Air Temperature	1173	831
Humidity	1173	831
Wind Speed	1173	831
Wind Direction	1173	831
Pressure	713	831
Global Radiation	86	64
Soil Moisture	59	41
River Gauges	93	31
Reservoir Level Sensors	76	1

The AWS measures 6 weather parameters - Rainfall, Wind Speed, Wind Direction, Atmospheric Pressure, Humidity and Temperature at every one hour interval and transmits it in the form of SMS using GSM technology, the values are logged in the internal memory of the data logger, transmitted via GSM transmitter at assigned time to SMPP (Short Message Peer to Peer) Server and data receives at the central data receiving station established at APSDPS, AP Secretariat Hyderabad. In addition to 6 sensors in AWS, Soil Moisture, Solar Radiation & River Gauge Sensors are Inbuilt in AWS at specific locations duly considering Agro-Climatic regions. The data loggers in AWS are pre-programmed to take measurement of meteorological parameters using interfaced sensors at an interval of an hour.

This data is being used by various government agencies like Agriculture Department, Disaster Management, Irrigation department, Energy Department etc., for proper planning and implementation of varied government programs and schemes. AWS data is also being used by Agriculture Insurance Company of India for implementation of Weather Based Crop Insurance Scheme (WBCIS) for various crops in the districts**.**

1.3.3AWS Sensor Specifications

The Automatic Weather Stations in remote areas work on battery backup and solar panels and transmit data on parameters having following ranges and accuracies.

Table 1.2 AWS Sensor specifications. (Source APSDPS)

Sensor Specifications

Sensors	Range	Accuracy	Resolution
Rainfall (mm)	0 to 600mm/Hr	+/- 2.5 %	0.25mm / tip
Temperature (°C)	-30 to 70°C	+/- 0.2°C	0.01°C
Humidity (%RH)	0% to 100%	+/- 3%	0.10%
Wind speed (kmph)		+ / - 1 Kmph up to 20 kmph	0.1 kmph
		+ / - 2% beyond 20 Kmph	
Wind direction (Degree)	0 to 360°	+/- 3°	1°
Pressure (mbar)	0 to 1100 mbar	+/- 0.15%	0.1 mbar
Global Radiation (w/m2)	0 to 1750 W/m2	5W/m2	
Soil Moisture (%)	0 to 100%	+/- 5%	1%
River Water level Gauges (m)	0 to 30m	0-3m -->3mm;	5mm
		3-30m-->0.1% of the reading	
Reservoir water – All Major and medium	0 to 30m	10mm	10mm

The ideal international norm of one AWS for every 100 sq km has been adopted and thus carries an area of 10KM x 10KM grid, presently at least one AWS for each Mandal is installed. The grid spacing for installation of AWS is designed on a scientific basis and the final one adopted is as per the WMO norms.

Similarly for river gauges the norm is based on terrain conditions and for plains it is one river gauge per 1875 Sq KM of catchment area. River Gauge sensors will measure the water levels in the rivers/streams at every one hour interval on real time basis with reference to MSL (Mean Sea Level) which stores in the data logger located at remote location and transmits the same to the APSDPS server. Reservoir water level recorders will measure the water level in reservoirs of major (i.e. Srisailam, Nagarjuna Sagar, Somasila and Mylavaram) and medium irrigation projects in the state at every one hour interval on real time basis.

The different sensors and instruments equipped with Automatic Weather Stations such as Rain Gauge (Tipping Bucket), Data logger, Battery (12 V), Solar Panel, GSM Antenna, GSM transmitter , solar charge controller, Temperature, Humidity, Wind Speed ,Wind Direction and Pressure Sensors are certified by IMD. The stations have been installed in the premises of Electrical Substances, Research institutes, Agricultural universities, district collector offices and colleges**.**

1.3.4 Tipping Bucket Rain Gauge (TBRG)-Rainfall sensor: A stainless steel tipping bucket rain gauge is used for measurement of rainfall volume. The collector diameter is 2 inches and the resolution of the gauge is 0.25 mm rainfall (fig 1.4). The large collector area helps prevent the loss of rainfall due to evaporation. The rain water enters the funnel inside the gauge and is directed to one of the two tipping bucket. Each bucket is calibrated to tip when 15.7 cm3 of rain water is collected in it. At any given time one bucket is always in collection mode. As the bucket tips it causes a 4 magnet to pass by a ruggedized mercury switch, momentarily (0.05 sec) closing the switch. The contact closure initiates event or count accumulation in the data logger. Once the rain is measured, the rain water is directed into drain tubes that allow it to exit through the base of the gauge.

The rainfall sensor is tipping bucket type and can measure 0- 600 mm/hr with accuracy of ±2.5 mm. To make the comparison more meaningful collocated stations data is utilized for the present work. Manual rain gauge data 0830 hours IST of day 1 to 0830 hours IST (Indian Standard Time) of day 2. This 24 hours accumulated rainfall data is compared with the AWS and Manual data From IMD, DES and DRMS of the same accumulation time.

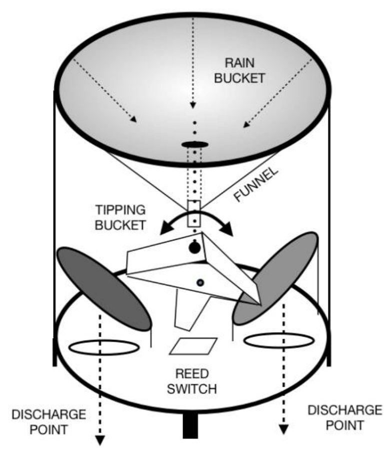


Fig 1.4 Tipping bucket sensor

1.3.5 AWS Data Flow Model

Data from AWS stations are transmitted through GSM Technology in an encrypted form. The received raw data is decrypted in real time and retrieved at APSDPS central server. Quality checks are performed on this raw data to eliminate error values and disseminate to various technical units.

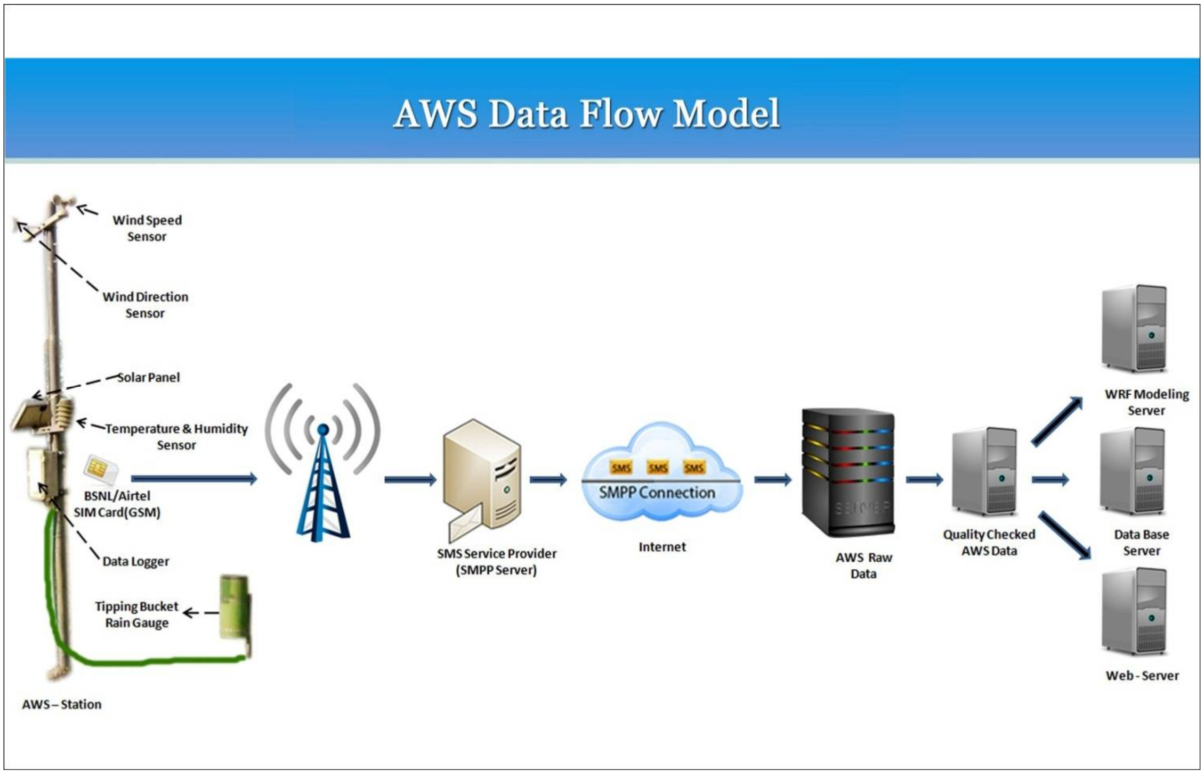


Fig 1.5 AWS Data flow modal

1.3.6 Quality Control Checks:

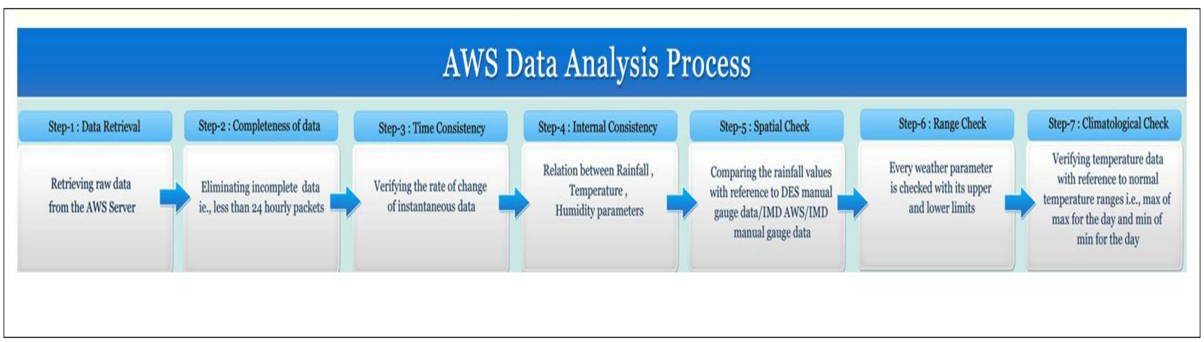


Fig 1.6 AWS Data Analysis Process

Step 1: Data Retrieval

- Raw Data is retrieved from central server of APSDPS by running query.

Step 2: Check for completeness of data reception

Raw data received on hourly basis is checked for time of recording. Only data with time-tags matching with top of the hours are segregated to eliminate erroneous data coming intermittently

- From the above segregated data, Number of packets received from each station/sensor is counted. Normally functioned station shall send 24 hourly packets one each for every hour
- Separating the data received from stations that sent 24 hourly records

Step 3: Time Consistency Check

- The aim of this check is to verify the rate of change of instantaneous data (detection of unrealistic spikes or jumps in values).Check on a maximum allowed variability of an instantaneous value, or a step test: if the current instantaneous value differs from the prior one by more than a specific limit or step, the current instantaneous value does not pass the check and it should be flagged as doubtful or suspect. The possible limits of a maximum variability, the absolute value of the difference between the successive values, are provided below:

Table 1.3 Source: Final Report, CBS/OPAG-IOS ET-AWS-5 (Geneva, Switzerland, 5-9 May 2008)

Parameter	**Limit for suspect**	**Limit for Erroneous**
Air Temperature	3° C	10° C
Ground (surface) Temperature	5° C	10° C
Soil Temperature 5 cm	0.5° C	1° C
Soil Temperature 10 cm	0.5° C	1° C
Soil Temperature 20 cm	0.5° C	1° C
Soil Temperature 50 cm	0.3° C	0.5° C
Soil Temperature 100 cm	0.1° C	0.2° C
Relative Humidity	10%	15%
Atmospheric Pressure	0.5 hPa	2 hPa
Wind Speed (2- minute average)	10 ms-1	20 ms-1
Solar Radiation (irradiance)	800 Wm-2	1000 Wm-2
Rainfall	4.5 cm	10 cm

(http://www.wmo.int/pages/prog/www/OSY/Reports/ET-AWS-5_Geneva_2008.pdf)

Step 4: Internal Consistency Check

- The basic algorithms for checking internal consistency of data are based on the relation between two parameters like when there is rainfall, the temperature will fall and humidity will rise.

Step 5: Spatial Check

- Comparing the rainfall values with reference to Directorate of Economic & Statistics (DES) manual gauge data IMD (Indian Meteorological Department) manual gauge data and IMD AWS data.

Step 6: Range Check

- Every weather parameter is checked with its upper and lower limits

Step 7: Climatologically consistency Check

- Verifying temperature data with reference to normal temperature ranges i.e., with maximum of maximum for the day and minimum of minimum for the day
- If there is any deviation, calculating the anomalies with respect to normal
- Checking the stations with anomalies with other weather guidance provided

CHAPTER 2

REVIEW OF LITERATURE

2.1 Giri R.K., Devendra Pradhan and Sen A.K. et al., The study discusses the comparison of 24 hour accumulated rainfall from manual and automatic rain gauges in 15 collocated stations of Bihar region. Results show that nine stations have bias within ±6 mm except Jahanabad, Monghyr, Rohtas, Muzaffarpur, Darbhanga and Sabour districts which have bias within ±20 mm. The correlation coefficients between two data sets of all the stations are strong and positive. The t test shows that the difference between means of two data sets is not statistically significant at 95 % confidence. The scores of probability of detection (POD) are strong and false alarm rate (FAR) is appreciably low almost for all the stations. It has been observed from the error structure analysis that usability of the rainfall data from AWS in day to day forecasting of all the stations over Bihar region are more than 75 % for all the stations.

2.2 Geeta Agnihotri And Jagabandhu Panda et al., The established of a network of AWS is one of the important components under modernization programme of IMD. This study discusses the comparison of 24hrs accumulated rainfall from ordinary and automatic rain gauges in 11 co-located stations of Karnataka. Results show that Bangalore, Gadag, Honnaver, Dharwad, Havari, Tumkar Bidar and Kodagu have bias within ±5mm exhibiting good performance while Chamarajnagar, Raichur and Bijapur have bias within ±20 mm. The coefficient between two datasets is strong and positive for all the stations except Chamarajnagar, Raichur and Bijapur. The t-test shows that the difference between means of two datasets is not statistically significant at 95% confidence. Durther, AWS data is able to show changes in various meteorological parameters along with the movement of the cyclone. This has highlighted the utility of AWS data in extreme weather event like a tropical cyclone.

2.3 Aribo Lawrence, Bazira Eliphaz, Masinde Moses, Waiswa Milton.et al., Uganda is a country in which, the lives of most of the local communities depend of agriculture apart from nomadic pastoralism. Over the recent years the occurrence of climatic extremes (droughts and floods) has increased in many parts of the country that has caused public outcry for adequate meteorological information for planning and management purposes. The goal of this study is to contribute to provision of reliable meteorological information to the end users (farmers, researchers etc). Specifically the study investigated the relationship between rainfall data obtained from Automatic weather observation system (AWOS) and traditional (conventional) surface observation system. It was hypothesised that a significant relationship exists between data sets from the two observation methods. Namulonge Meteorological station was chosen for this study due to availability of data for both observation systems, on-going agricultural research by NARO-Uganda and being an area of bimodal type of rainfall. The normalised pentad rainfall totals for March-April-May (MAM) and September-October- November (SON) 2005 seasons were analysed. Time series graphs, scatter-grams, Spearman.s rank correlation and Analysis of variance (ANOVA) F-test were used to investigate the relationship. Moderately strong positive correlations were obtained for MAM ($r = 0.59$) and SON ($r = 0.50$). The correlation for MAM was also statistically significant ($p< 0.05$) while for SON ($p > 0.05$) it was not statistically significant at 95% confidence level. More research is still needed since this comparison can also be useful in data quality control and management.

2.4 Anjit Anjan, Rudra Pratap, U.K.Shende& Dr. R.D.Vashistha: et al., an Automatic Rain gauge Station (ARG) is defined as a “meteorological stations at which observations are made and transmitted automatically”. Automatic Rain gauge Stations are used for increasing the number and reliability of real time rainfall data. Rainfall is a highly variable parameter in space and time as the heterogeneities on local scale in land surface features (hills) rivers, vegetation etc. affect its distribution. It is also a very important parameter for agricultural operations, water resource management and as well as result in hydro-climatic disasters on local and regional scales.

A network of 1350 Automatic Rain gauge Stations (JINYANG make) is under installation by IMD during the year 2008-10 across India. Each ARG Station is configured to measure Hourly rainfall and Cumulative rainfall for the day. In addition to rainfall sensor, 500 ARG are equipped with Air temperature sensor. Each ARG station transmits a data stream at an interval of **ONE SECOND** in a Time Division Multiple Access via UHF transmitter and a dedicated meteorological satellite INSAT-3A to the central AWS data receiving Earth Station facility established at IMD, Pune.

A network of 100 ARG Station have been installed during 2008 and its performance have been encouraging during SW Monsoon-2008.After implementation of 1350 ARG network all over India in 2010, real time rainfall data will be very much useful for agricultural operations, water resource management and flood forecast. Another network of 2250 ARG will be established by India Meteorological Department during 2011-2012.

2.5 Branislav Chvíla, Miroslav Ondras and Boris Sevruk: et al**.,** The Questionnaire of the WMO/CIMO on recording precipitation gauges, RPG, shows that almost all WMO Members responding the Questionnaire support the proposed international intercomparison measurements of such gauges. Surprisingly enough one-half of them even agreed to participate in such intercomparisons as can be seen from the paper by Sevruk and Michaeli (2002) published in this volume. Such an intercomparison was also recommended by the CIMO Expert Meeting on Rainfall Intensity Measurements held in Bratislava, Slovakia in April 2001 (WMO, 2001). Having this in mind and being also the host of the upcoming TECO and CIMO-XIII in Bratislava, the Slovak Hydro meteorological Institute, SHMI decided to carry out national intercomparison measurements of RPG. The primary aim was to test the possible method of such an international intercomparison and in such a way to contribute to the numerous activities of the CIMO in the field of precipitation measurement. This decision was not accidental. The SHMI has a long tradition in the precipitation measurement research. It belongs to the first countries worldwide such as the former Soviet Union, Nordic Countries and Switzerland, which developed correction procedures of systematic precipitation measurement errors as recommended many times since more than 30 years by the CIMO (WMO, 1985: Samaj and Lapin, 1985; Sevruk and Hamon, 1984).

CHAPTER-3

DATA AND METHODOLOGY

3.1 DATA

In this chapter June to September, year 2014 Rainfall data was collected from India Meteorological Department (IMD) Manual Data, District wise Rainfall Monitoring Scheme (DRMS) Manual Data, Directorate of Economics and Statistics (DES) Manual Data and Automatic Weather Station (AWS) Data (APSDPS, TSDPS).

3.1.1 India Meteorological Department (IMD) Manual Data: Manual rain gauge data are data Obtained From the India Meteorological Department (IMD). 4 months (June-2014 to September-2014) daily rain rates are collected from the all 31(AP 20, TS 11) stations over Andhra Pradesh and Telangana state (fig 3.1, 3.3) shows the locations of the manual Rain gauge stations.

3.1.2 District wise Rainfall Monitoring Scheme (DRMS) Manual Data: Inspected annually by IMD, these manual rain gauge data are maintained by the Directorate of Economics and Statistics (DES). 4 months (June-2014 to September-2014) daily rain rates collected from the all 185 (AP 114, TS 71) stations over Andhra Pradesh and Telangana State (fig 3.2, 3.4) shows the locations of the manual rain gauge stations.

3.1.3 Directorate of Economics and Statistics (DES) Manual Data: manual rain gauge data are obtained from the Directorate of Economics and Statistics (DES). 4 months (June-2014 to September-2014) daily rain rates collected from the all 1128 (AP 664, TS 464) stations over Andhra Pradesh and Telangana State (fig3.2, 3.4) shows the locations of the manual rain gauge stations.

3.1.4 Automatic Weather Station (AWS) Data (APSDPS, TSDPS): Automatic Weather Station data are obtained from the Andhra Pradesh State Development Planning Society (APSDPS) and Telangana State Development Planning Society (TSDPS). 4 months (June-2014 to September-2014) daily rain rates collected from all 2039 (AP 1185, TS 854) stations over Andhra Pradesh and Telangana State (fig3.1, 3.3) shows the location of the manual rain gauge stations.

3.2 METHODOLOGY:

Daily Rainfall data of AP and Telangana states obtained from IMD, DES, and DRMS to find out the accuracy of APSDPS AWS rainfall data. Among all the stations 13 stations were identified as common best stations for further analysis based on approximately to each other. After identifying common stations Daily, Weekly and Monthly comparison of AWS data with IMD, DES and DRMS has done. After that, correlations between AWS and other sources rainfall data calculated by weekly and monthly time steps.

After that cumulative rainfall of weekly and 15 days over AP and TS calculated by taking entire state as one grid by Inverse Distance Weighting (IDW).

After that, these point observations are transformed into aerial averages using thiessen polygon and arithmetic mean district cumulative rainfall of AWS, DES and DRMS deviations calculated by using Des and IMD district normal rainfall.

Finally to show the usefulness of AWS data to better estimate drought conditions the seasonal cumulative rainfall spatial maps and rainfall deviation maps of Andhra Pradesh and Telangana State by using IMD, DES, DRMS and AWS data.

Arithmetic mean Formula are described below:

$$\bar{X} = \frac{X_1 + X_2 + X_3 \ldots X_N}{N}$$

Where
$\bar{X}$ = the mean
X_1 = the first value
X_2 = the second value
X_3 = the third value
X_N = the last value
N = the number of valuse

Thiessen polygon equation is shown below:

If there are n stations with rainfall values $P_1, P_2, P_3, \ldots\ldots P_n$ *and* $A_1, A_2, A_3, \ldots\ldots A_n$ *are the areas of the respective Thiessen polygons, the average rainfall over the catchment* $\bar{P}$ *is computed as*

$$\bar{P} = \frac{P_1 A_1 + P_2 A_2 + P_3 A_3 + \ldots\ldots\ldots\ldots + P_n A_n}{A_1 + A_2 + A_3 + \ldots\ldots\ldots\ldots + A_n} = \sum_{1}^{n} P_i \frac{A_i}{A}$$

$\frac{A_i}{A}$ *is called the weightage factor*

Inverse Distance Weighting (IDW) Formula are described below:

$$\text{target value} = \frac{\sum_i \frac{e_i}{d_i}}{\sum_i \frac{1}{d_i}}$$

e is the elevation of a neighbouring cell

d is the distance between the neighbouring cell and the target cell.

i is the number of cells

The linear regression (r^2) equation is shown below:

$$Y = a + bX$$

$$b = \frac{N\sum XY - (\sum X)(\sum Y)}{N\sum X^2 - (\sum X)^2} \qquad a = \frac{\sum Y - b\sum X}{N}$$

Where,

N = number of observations, or years

X = a year index (decade)

Y = population size for given census years

Correlation coefficient (r) Formula are described below:

$$r = \frac{N\Sigma xy - (\Sigma x)(\Sigma y)}{\sqrt{[N\Sigma x^2 - (\Sigma x)^2][N\Sigma y^2 - (\Sigma y)^2]}}$$

Where:

N	=	number of pairs of scores
Σxy	=	sum of the products of paired scores
Σx	=	sum of x scores
Σy	=	sum of y scores
Σx^2	=	sum of squared x scores
Σy^2	=	sum of squared y scores

3.3 STUDY AREA

3.3.1Andhra Pradesh

is one of the 29 states of India situated on the southeastern coast of the country. The state is the eight largest state in India covering an area of 160,205 km^2 (61,855 sq mi). as per 2011 census of India, the state is tenth largest by population with 49,386,799 inhabitants. On 2 June 2014, the north-western portion of the state was bifurcated to form a new state of Telangana. In accordance with the Andhra Pradesh Reorganization Act, 2014. Hyderabad will remain the de jure capital of both Andhra Pradesh and Telangana states for a period of time not exceeding 10 years. The new river-front proposed capital in Guntur district is Amravati, which is under the jurisdiction of APCRDA .Economically, the Gross State Domestic Product (GSDP) of Andhra Pradesh at today's prices stood at 2359.3 billion(US$36 billion) and the Gross State Domestic Product at the prices for the 2013 financial year were 4193.91 billion(US$63 billion). The average income of the state rose 62.6% from 25,959 (US$390) (2004–05) to 42,186 (US$640) (2012-13).

The state has a Coastline of 974 km (605 mi), the second longest among all the states of India after Gujarat. It is bordered by Telangana in the north-west, Chhattisgarh in the north, odisha in the north-east, Karnataka in the west, Tamil Nadu in the south and the water body of Bay Of Bengal in the east. A small enclave of 30 km^2 (12 sq mi) of Yanam , a district of Puducherry , lies south of Kakinada in the Godavari delta to the northeast of the state.

There are two regions in the state namely Coastal Andhra and Rayalaseema. These two regions comprise 13 districts, with 9 in Coastal Andhra and 4 in Rayalaseema. Visakhapatnam is the largest city and a commercial hub of the state with a GDP of $26 billion followed by Vijayawada with a GDP of $3 billion as of 2010, and is expected to increase to $17 billion by 2025. There are a total of 28 Cities with a population of 100,000 and above in the state at the 2011 Census, while Visakhapatnam and Vijayawada are the two Million-Plus Cities.

Table 3.1 Andhra Pradesh Stations latitude and longitude points.

ANDHRA PRADESH						
STATION NAME	IMD		AWS		DES &DRMS	
	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
Bapatla	15.903	80.47	15.9033	80.4697	15.903	80.47
Kakinada	16.945	82.25	16.9453	82.2501	16.945	82.25
Nandigama	16.771	80.288	16.7709	80.2881	16.771	80.288
Rentachintala	16.553	79.553	16.553	79.5527	16.553	79.553
Tuni	17.356	82.545	17.3558	82.5448	17.356	82.545
Vijayawada	16.521	80.667	16.5212	80.6674	16.521	80.667
Visakhapatnam	17.734	83.275	17.7338	83.2754	17.734	83.275
Anantapur	14.674	77.604	14.6741	77.6038	14.674	77.604
Tirupathi	13.641	79.513	13.6407	79.5131	13.641	79.513

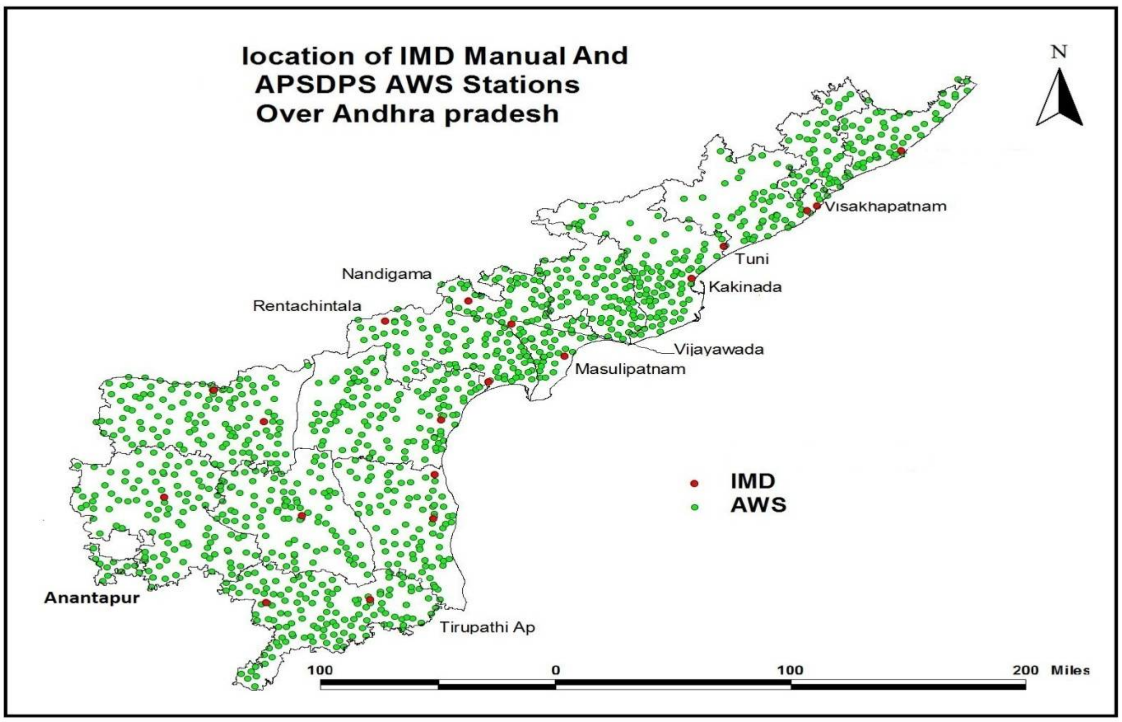


Fig .3.1 IMD and AWS Rainfall Station Locations in Andhra Pradesh

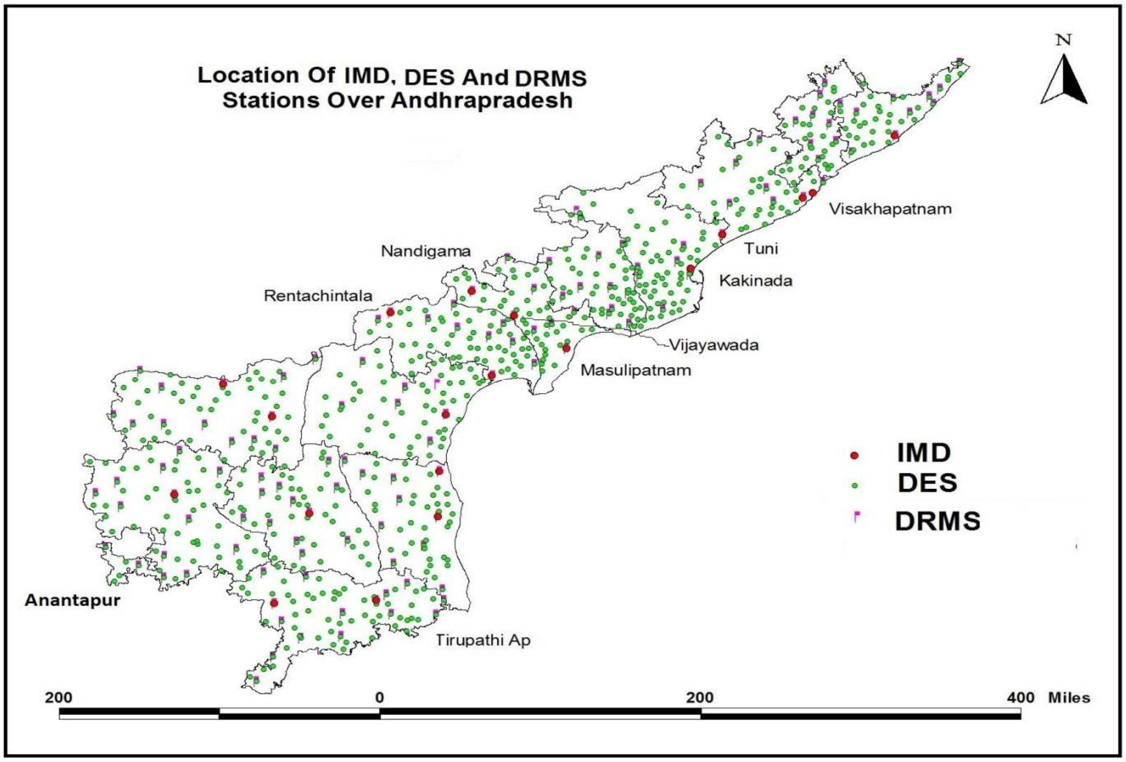


Fig.3.2 IMD, DRMS and DES Rainfall Station Locations in Andhra Pradesh

3.3.2 Geography:

Geographically, Andhra Pradesh is bestowed with two mighty river systems of Krishna and Godavari. Its varied topography ranging from the hills of Eastern Ghats and Nallamalla to the shores of Bay of Bengal supports varied ecotypes, rich diversity of flora and fauna. The state has two regions Coastal Andhra and Rayalaseema. The plains to the east of Eastern Ghats form the Eastern Coastal Plains. The coastal plains are for the most part of delta regions formed by the Godavari, Krishna and Penna Rivers. The Eastern Ghats are discontinuous and individual sections have local names. The Eastern Ghats are a major dividing line in the state's geography. The Kadapa Basin formed by two arching branches of the Eastern Ghats is a mineral-rich area. The Ghats become more pronounced towards the south and extreme north of the coast. Most of the coastal plains are put to intense agricultural use. The Rayalaseema region has semi-arid conditions. Lammasingi (or Lammasingi), a village in the Chintapalli Mandal of Visakhapatnam district is situated at 1000 meters above the sea level. It is the only place in South India which has snowfall and is also nicknamed as Kashmir of Andhra Pradesh. Throughout the year the temperature here ranges from 0 °C to 10 °C.

3.3.3 Andhra Pradesh Climate: the climate of Andhra Pradesh is generally hot and humid. Monsoons play a major role in determining the climate of the state .The summer season in this state generally extends from March to June. During these months the moisture level is quite high. The coastal areas have higher temperatures than the other parts of the state. In summer, the temperature generally ranges between 20 °C and 40 °C. At certain places the temperature is as high as 45 degrees on a summer day.

The summer is followed by the monsoon season, which starts during July and continues till September. This is the season for heavy tropical rains in Andhra Pradesh. The major role in determining the climate of the state is played by South-West Monsoons. About one third of the total rainfall in Andhra Pradesh is brought by the North-East Monsoons around the month of October in the state.

The winters in Andhra Pradesh are pleasant. This is the time when the state attracts most of its tourists. October to February are the winter months in Andhra Pradesh. Since the state has quite a long coastline, the winters are comparatively mild. The range of winter temperatures is generally from 13 °C to 30 °C.

3.3.4 Rainfall the rainfall in Andhra Pradesh is influenced by both South-West and North-East monsoons. Of the normal annual rainfall of 940 mm, 624 mm (66%) is contributed by South-West Monsoon (June- September) followed by 224 mm (24%) during the North-East Monsoon (October-December) and 10% during the winter and summer months.

3.3.5 Agriculture

With an economy mainly based on agriculture and livestock, Andhra Pradesh is an exporter of many agricultural products and is also known as "Rice Bowl of India". Four important rivers of India, the Godavari, Krishna, Penna, and Tungabhadra, flow through the state and provide irrigation. Agriculture is the main occupation and 60 percent of population is engaged in agriculture and related activities. Rice is the major food crop and staple food of the state.

Besides rice, farmers also grow wheat, jowar, bajra, maize, minor millet, coarse grain, many varieties of pulses, oil seeds, sugarcane,cotton,chili pepper, mango nuts and tobacco. Crops used for vegetable oil production such as sunflower and peanuts are popular. There are many multi-state irrigation projects under development, including Godavari River Basin Irrigation Project and Nagarjuna Sagar Dam.

Livestock and poultry is also another profitable business, which involves rearing cattle in enclosed areas for commercial purposes. The state is also a largest producer of eggs in the country and hence, it is nicknamed as “Egg Bowl of Asia”.

Fisheries contribute 10% of total fish and over 70% of the shrimp production of India. The geographical location of the state allows marine fishing as well as inland fish production. The most exported marine exports include Vannamei Shrimp and are expected to cross $1 billion in 2013-14.

3.4.1 Telangana State:

Is a state in South India and one of the 29 States in. It was formed on 2 June 2014 with the city of Hyderabad as its capital. Telangana is bordered by the states of Maharashtra to the north and North West Chhattisgarh to the north east, Karnataka to the west, and Andhra Pradesh to the east and south. As the Twelfth largest state in India, Telangana has an area of 114,840 square kilometers (44,340 sq mi) and a population of 35,286,757 (2011 census). Its major cities include Hyderabad, Warangal, Nizamabad, Karimnagar, Ramagundam and Khammam.

Telangana acquired its identity as the Telugu -speaking region of the Princely State of Hyderabad, ruled by the Nizam of Hyderabad, joining the Union of India in 1948. In 1956, the Hyderabad state was dissolved as part of the Linguistic reorganization of states and Telangana was merged with former Andhra State to form Andhra Pradesh. Following a Popular movement for Separation, it was awarded Separate Statehood on 2 June 2014. Hyderabad will continue to serve as the joint capital city for Andhra Pradesh and Telangana for a period of not more than ten years.

Table3.2 Telangana state Stations latitude and longitude points.

TELANGANA STATE						
STATION NAME	IMD		AWS		DES &DRMS	
Badrachalam	17.669	80.889	17.6694	80.8885	17.669	80.889
Medak	18.045	78.262	18.0448	78.2618	18.045	78.262
Nizamabad	18.674	78.095	18.6736	78.095	18.674	78.095
Ramagundam	18.775	79.447	18.7749	79.4472	18.775	79.447

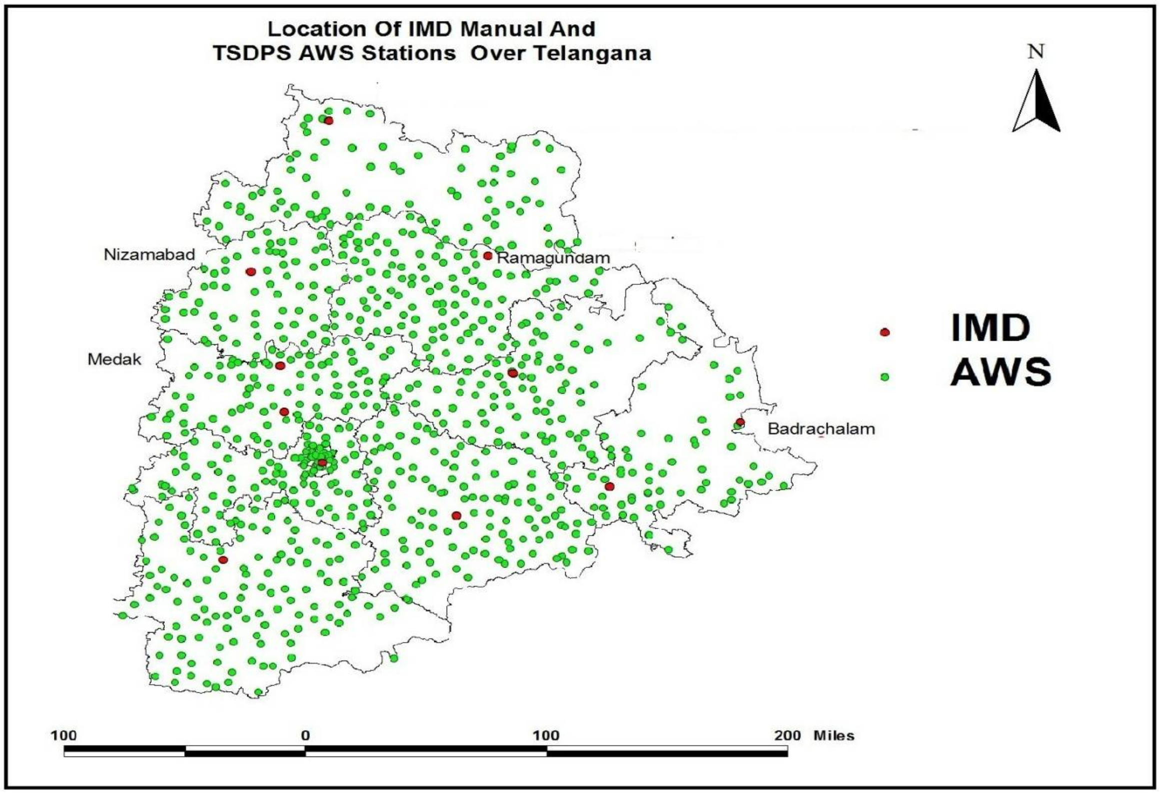


Fig 3.3 IMD and AWS Rainfall Station Locations in Telangana State

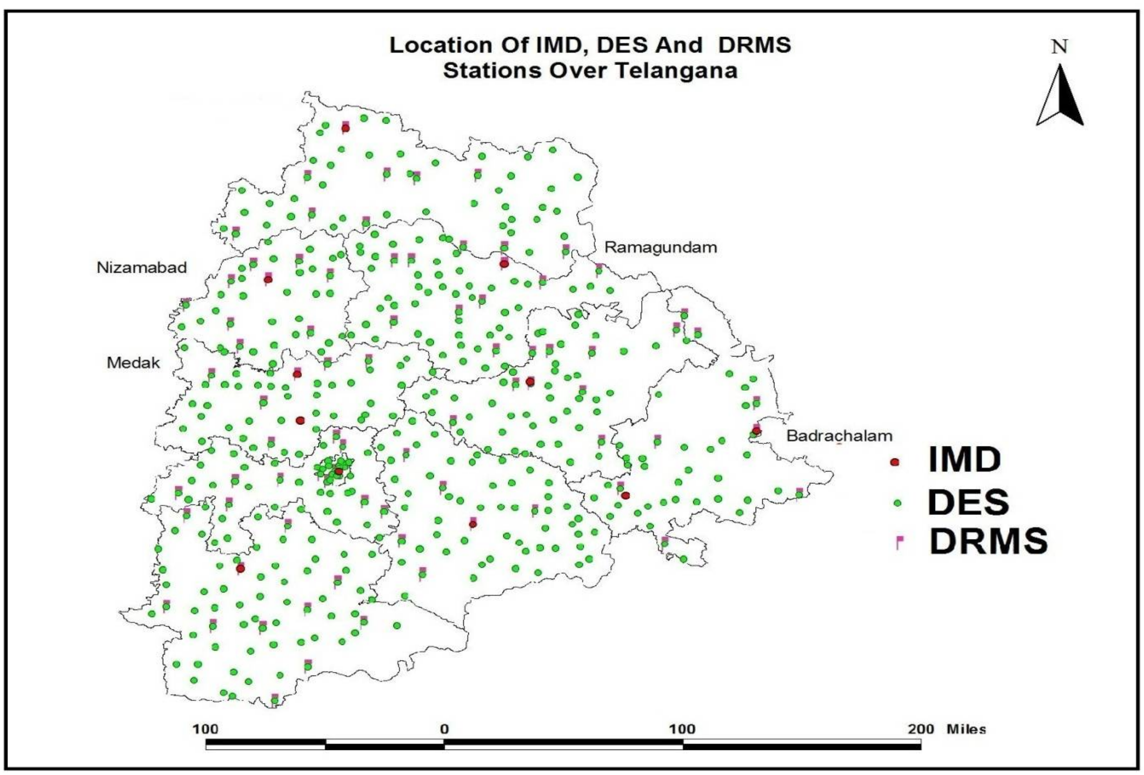


Fig 3.4 IMD, DRMS and DES Rainfall Station Locations in Telangana State

3.4.2 Geography:

Telangana is situated on the Deccan Plateau, in the central stretch of the eastern seaboard of the Indian Peninsula. It covers 114,840 square kilometers (44,340 sq mi). The region is drained by two major rivers, with about 79% of the Godavari River catchment area and about 69% of the Krishna River catchment area, but most of the land is arid. Telangana is also drained by several minor rivers such as the Bhīma, the Manjira and the Musi.

At 965 m Dolui Gutta is possibly the highest mountain peak in the state of Telangana since Chintoor and Vararamachandrapuram mandals of Khammam district

The annual rainfall is between 900 to 1500 mm in northern Telangana and 700 to 900 mm in southern Telangana, from the southwest Monsoons. Various soil types abound, including chalkas, red sandy soils, dubbas, deep red loamy soils, and very deep black cotton soils that facilitate planting mangoes, oranges and flowers.

3.4.3 Telangana Climate

Telangana is a semi-arid area and has a predominantly hot and dry climate. Summers start in March, and peak in May with average high temperatures in the 42 °C (108 °F) range. The monsoon arrives in June and lasts until September with about 755 mm (29.7 inches) of precipitation. A dry, mild winter starts in late November and lasts until early February with little humidity and average temperatures in the 22–23 °C (72–73 °F) range.

3.4.4 Agriculture

Rice is the major food crop and staple food of the state. Other important crops are maize, tobacco, mango, cotton and sugar. Agriculture has been the chief source of income for the state's economy. Important rivers of India, the Godavri, Krishna flow through the state, providing irrigation. Apart from major rivers, there are small rivers as Tunga Bhadra, Bima, Dindi, Kinnerasani, Manjeera, Manair, Penganga, Pranahitha, peddavagu and Taliperu.There are many multi-state irrigation projects in development, including Godavari River Basin Irrigation Projects and Nagarjuna Sager Dam , the world's highest masonry dam. Agri Export Zone For the following produce are proposed at the places mentioned against them.

CHAPTER-4

RESULTS

In this chapter Daily, weekly and monthly cumulative Rainfall analysis has been studied for the stations Bapatla, Kakinada, Nandigama, Rentachintala, Tuni, Vijayawada, Visakhapatnam, Anantapur, Tirupathi,(AP) and Badrachalam, Medak, Nizamabad and Ramagundam (TS) for Monsoon season (June-September) Year 2014. Fig (4.1.1(a) To 4.3.13(b)).

4. 1 DAILY CUMULATIVE RAINFALL FOR THE ABOVE 13 STATIONS.

4.1.1 Daily Cumulative Rainfall for the station Bapatla.

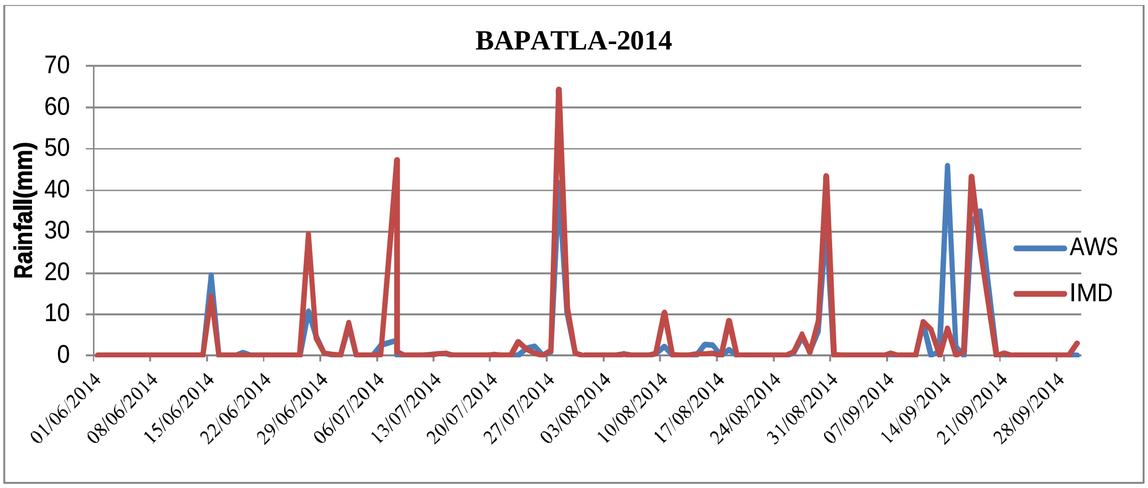


Fig 4.1.1(a) Daily cumulative rainfall over Bapatla Station (Jun-Sep) year 2014

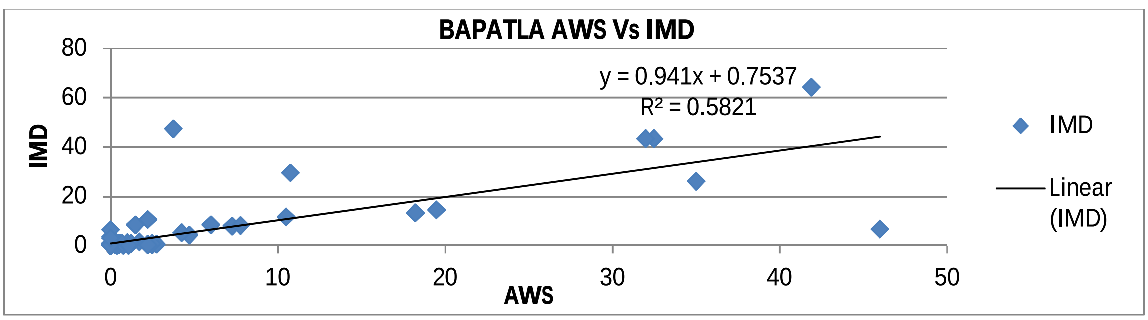


Fig 4.1.1(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Bapatla Station.

From Fig 4.1.1(a) Daily comparisons between AWS and IMD, cumulative Rainfall over Bapatla station in monsoon season (June-September) for the Year 2014has been observed. It is observed that AWS rainfall is underestimated over IMD. IMD Very high rainfall recorded in 28th July 2014 64.3mm recorded AWS 41.9mm Rainfall recorded.

From Fig 4.1.1(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Bapatla Station. is 0.582, The Correlation coefficient (r) AWS & IMD has calculated for Bapatla rainfall 0.76 for the period of (June-September) year 2014.

4.1.2 Daily Cumulative Rainfall for the station Kakinada.

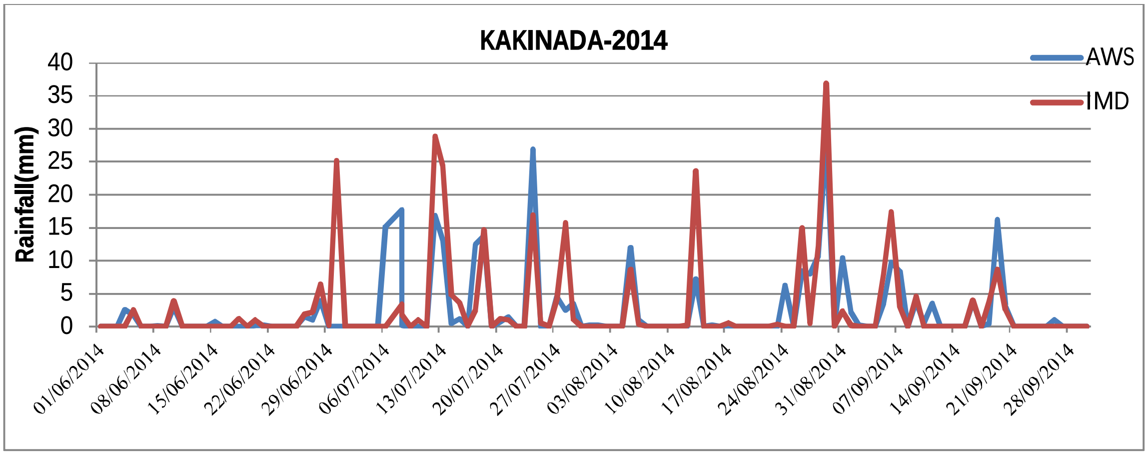


Fig 4.1.2(a) Daily cumulative rainfall over Kakinada Station (Jun-Sep) year 2014

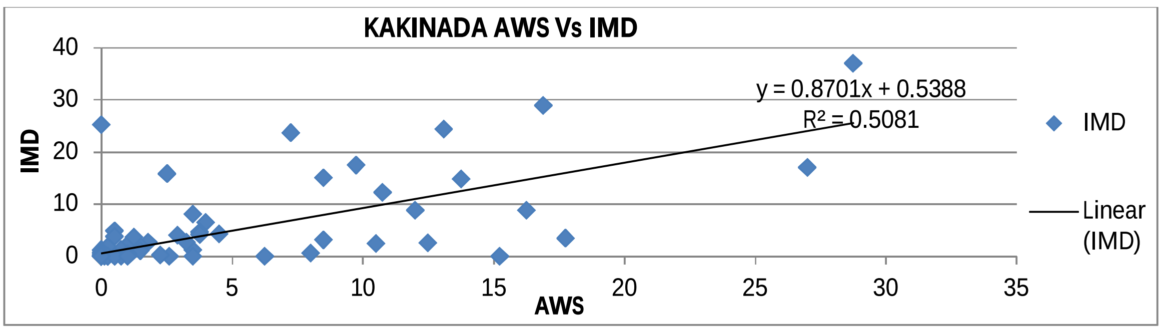


Fig 4.1.2(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Kakinada Station.

From Fig 4.1.2(a) Daily comparisons between AWS and IMD, cumulative Rainfall over Kakinada station in monsoon season (June-September) for the Year 2014has been observed. It is observed that AWS rainfall is underestimated over IMD. IMD Very high rainfall recorded in 29th August 2014 37mm recorded AWS 28.75mm Rainfall recorded.

From Fig 4.1.2(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Kakinada Station. is 0.508, The Correlation coefficient (r) AWS & IMD has calculated for Kakinada rainfall 0.71 for the period of (June-September) year 2014.

4.1.3 Daily Cumulative Rainfall for the station Nandigama.

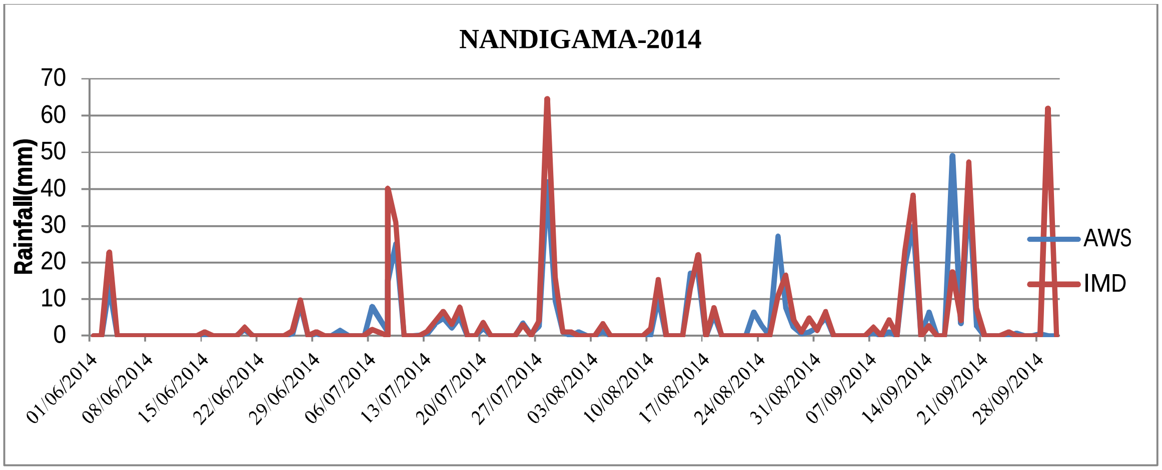


Fig 4.1.3(a) Daily cumulative rainfall over Nandigama Station (Jun-Sep) year 2014

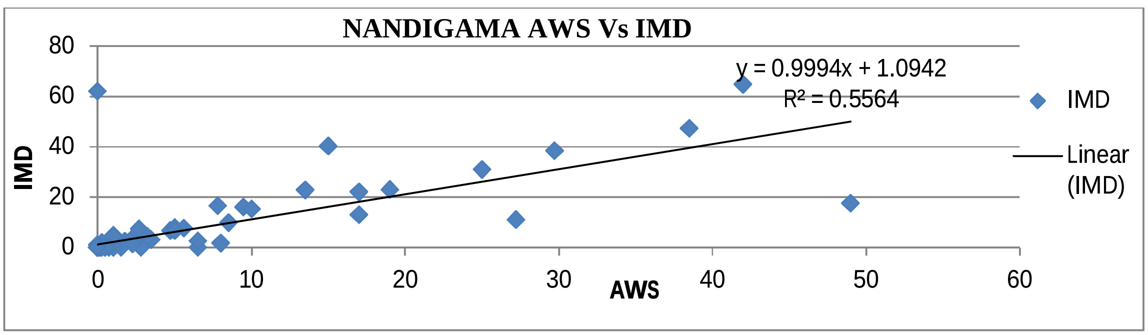


Fig 4.1.3(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Nandigama Station.

From Fig 4.1.2(a) Daily comparisons between AWS and IMD, cumulative Rainfall over Nandigama station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD. IMD Very high rainfall recorded in 27th July 2014 64.6 mm recorded AWS 42mm Rainfall recorded.

From Fig 4.1.3(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Nandigama Station. is 0.556, The Correlation coefficient (r) AWS & IMD has calculated for Nandigama rainfall 0.74 for the period of (June-September) year 2014.

4.1.4 Daily Cumulative Rainfall for the station Rentachintala.

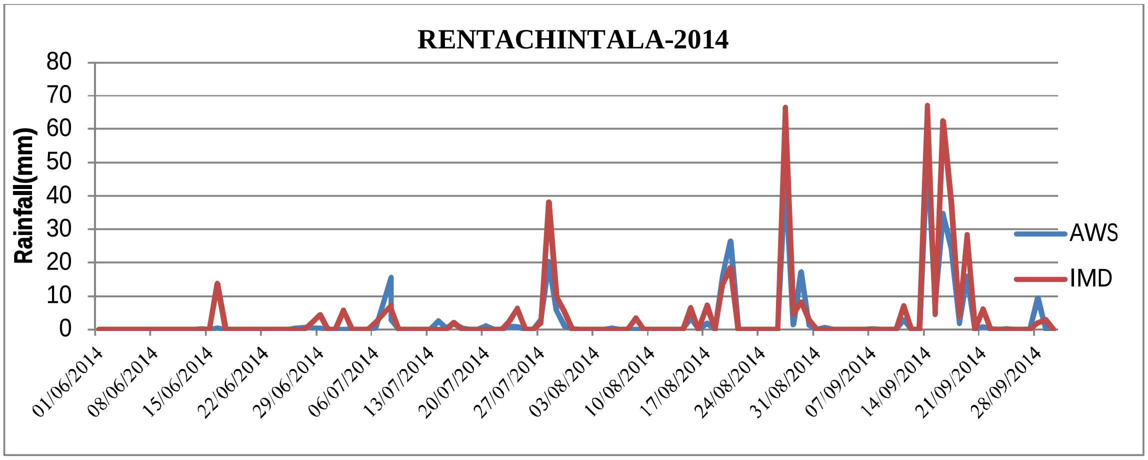


Fig 4.1.4(a) Daily cumulative rainfall over Rentachintala Station (Jun-Sep) year 2014

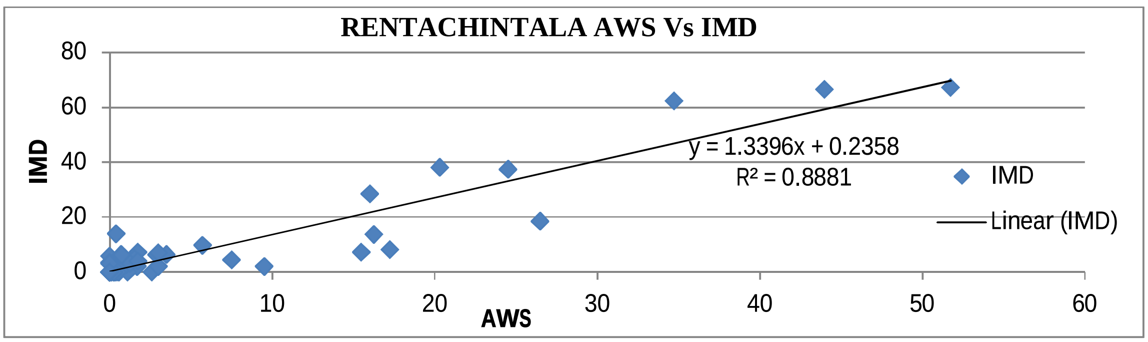


Fig 4.1.4(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Rentachintala Station.

From Fig 4.1.4(a) Daily comparisons between AWS and IMD, cumulative Rainfall over Rentachintala station in monsoon season (June-September) for the year 2014has been observed. It is observed that AWS rainfall is underestimated over IMD. IMD Very high rainfall recorded in 19th September 2014 67.1mm recorded AWS 51.75mm Rainfall recorded.

From Fig 4.1.4(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Rentachintala Station. is 0.888, The Correlation coefficient (r) AWS & IMD has calculated for Rentachintala rainfall 0.94 for the period of (June-September) year 2014.

4.1.5 Daily Cumulative Rainfall for the station Tuni.

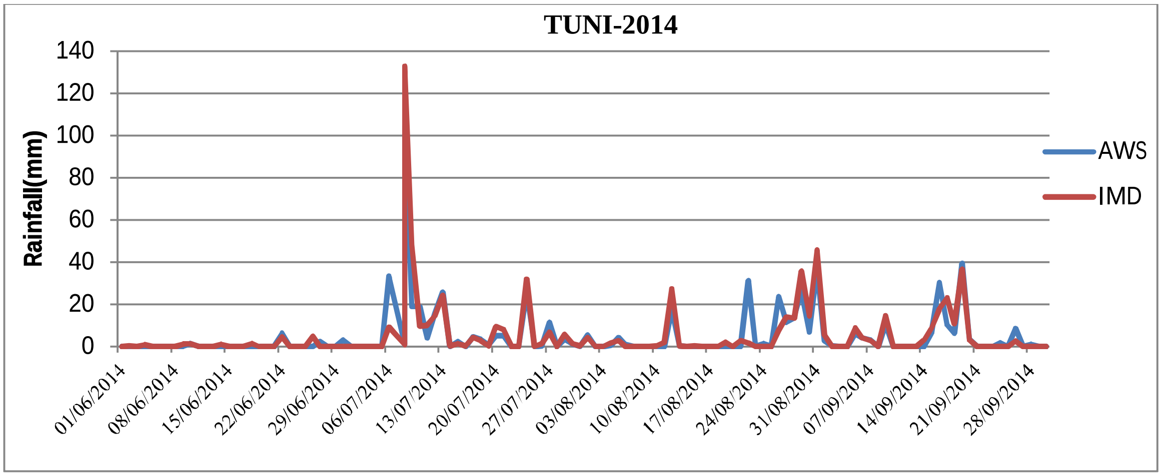


Fig 4.1.5(a) Daily cumulative rainfall over Tuni Station (Jun-Sep) year 2014

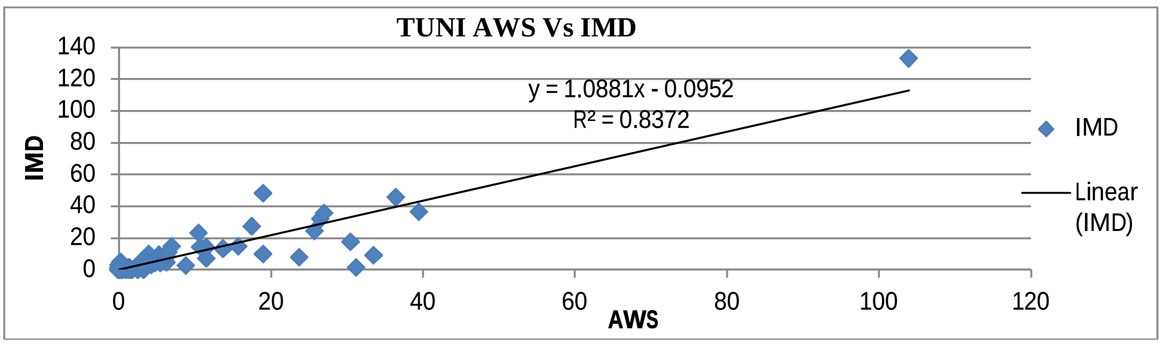


Fig 4.1.5(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Tuni Station.

From Fig 4.1.5(a) Daily comparisons between AWS and IMD, cumulative Rainfall over Tuni station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD. IMD Very high rainfall recorded in 8th July 2014 133 mm recorded AWS 104 mm Rainfall recorded.

From Fig 4.1.5(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Tuni Station. Is 0.837, The Correlation coefficient (r) AWS & IMD has calculated for Tuni rainfall 0.91 for the period of (June-September) year 2014.

4.1.6 Daily Cumulative Rainfall for the station Vijayawada.

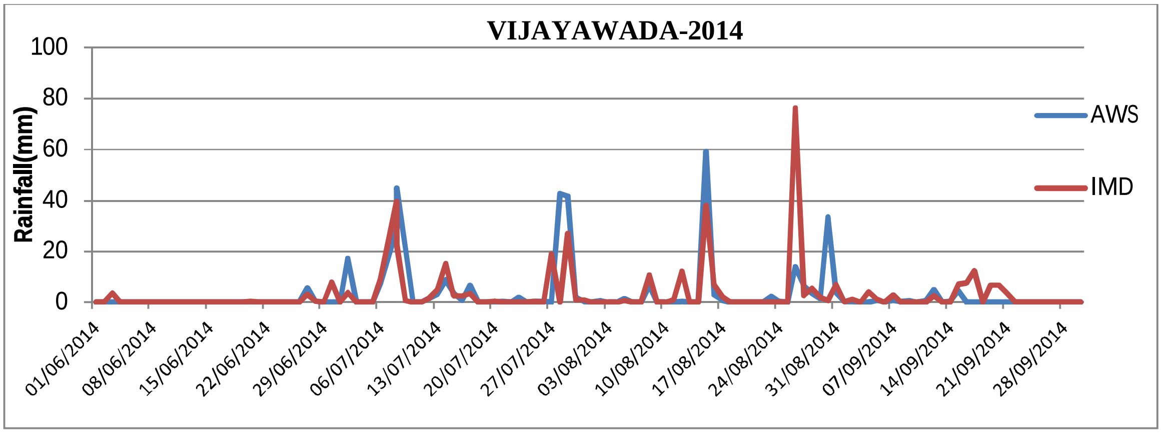


Fig 4.1.6(a) Daily cumulative rainfall over Vijayawada Station (Jun-Sep) year 2014

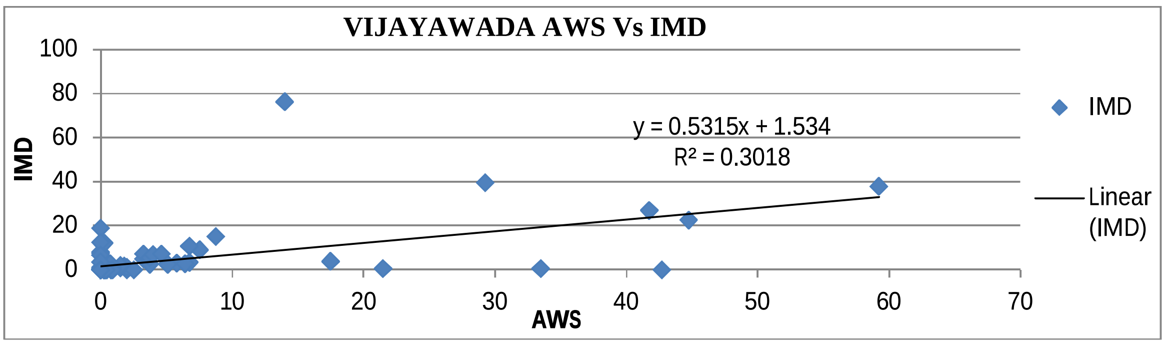


Fig 4.1.6(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Vijayawada Station.

From Fig 4.1.6(a) Daily comparisons between AWS and IMD, cumulative Rainfall over Vijayawada station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD. IMD Very high rainfall recorded in 26th August 2014 76.4 mm recorded AWS 14 mm Rainfall recorded.

From Fig 4.1.6(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Vijayawada Station. is 0.301, The Correlation coefficient (r) AWS & IMD has calculated for Vijayawada rainfall 0.54 for the period of (June-September) year 2014.

4.1.7 Daily Cumulative Rainfall for the station Visakhapatnam.

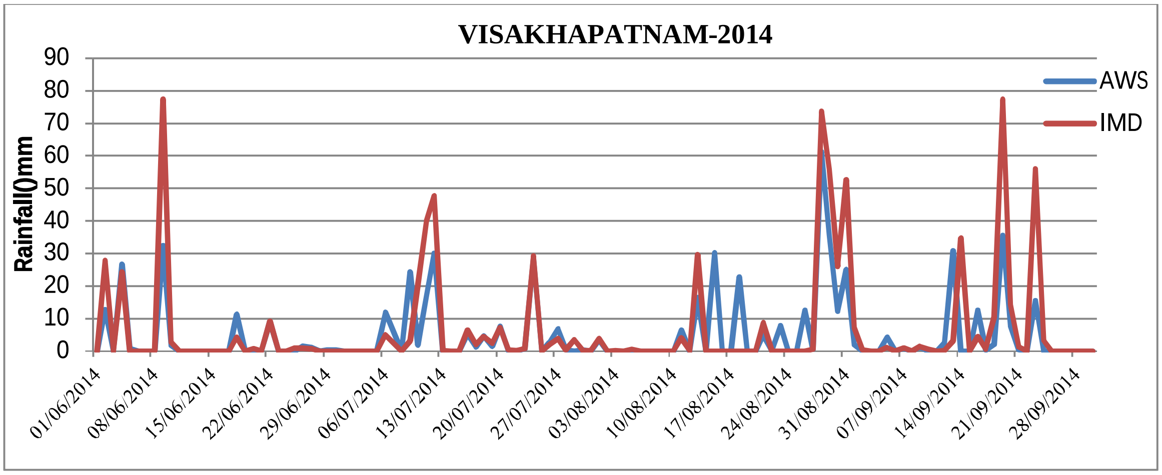


Fig 4.1.7(a) Daily cumulative rainfall over Visakhapatnam Station (Jun-Sep) year 2014

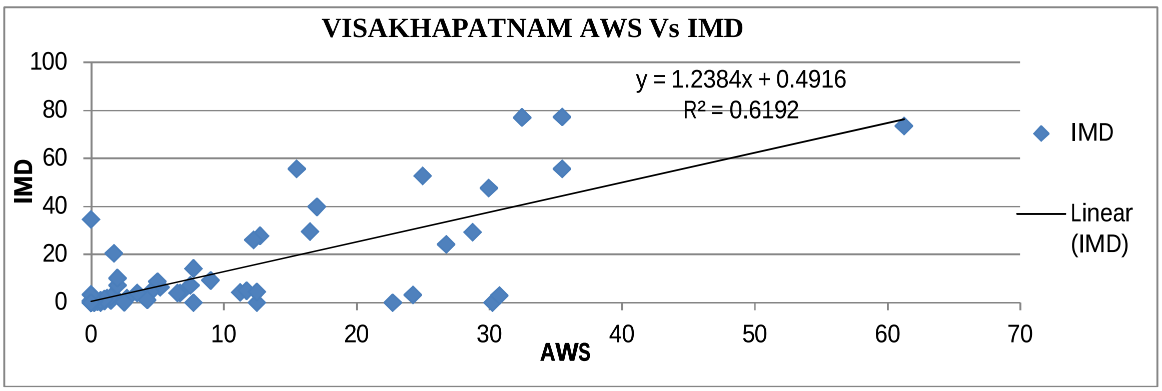


Fig 4.1.7(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Visakhapatnam station.

From Fig 4.1.7(a) Daily comparisons between AWS and IMD, cumulative Rainfall over Visakhapatnam station in monsoon season (June-September) for the year 2014has been observed. It is observed that AWS rainfall is underestimated over IMD. IMD Very high rainfall recorded in 19th September 2014 77.4mm recorded AWS 35.5 mm Rainfall recorded.

From Fig 4.1.7(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Visakhapatnam Station. is 0.619, The Correlation coefficient (r) AWS & IMD has calculated for Visakhapatnam rainfall 0.78 for the period of (June-September) year 2014.

4.1.8 Daily Wise Cumulative Rainfall for the station Anantapur.

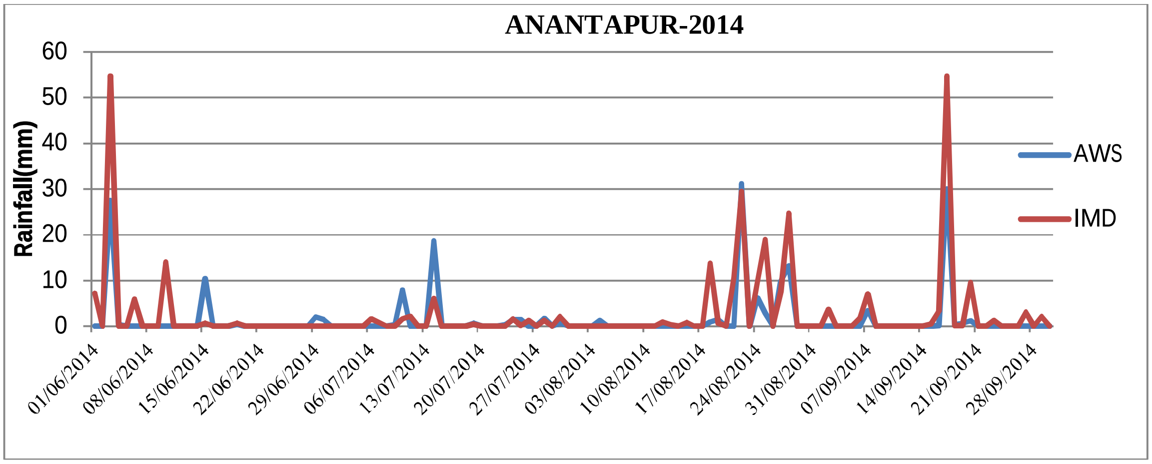


Fig 4.1.8(a) Daily cumulative rainfall over Anantapur Station (Jun-Sep) Year 2014

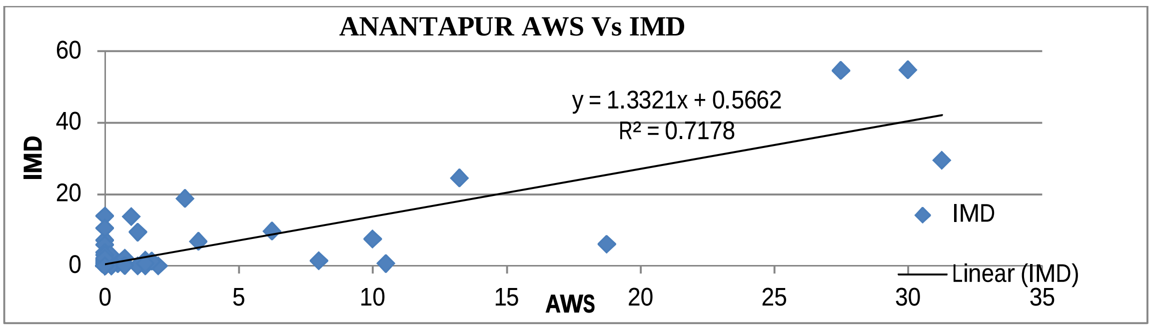


Fig 4.1.8 (b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Anantapur Station.

From Fig 4.1.8(a) Daily comparisons between AWS and IMD, cumulative Rainfall over Anantapur station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD. IMD Very high rainfall recorded in 17th September 2014 54.8 mm recorded AWS 30 mm Rainfall recorded.

From Fig 4.1.8(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Anantapur Station. is 0.717, The Correlation coefficient (r) AWS & IMD has calculated for Anantapur rainfall 0.84 for the period of (June-September) year 2014.

4.1.9 Daily Cumulative Rainfall for the station Tirupathi.

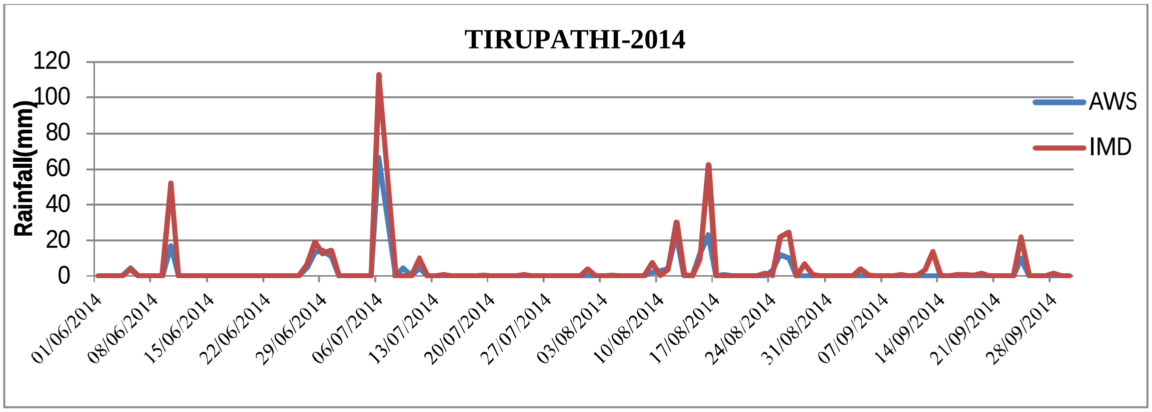


Fig 4.1.9(a) Daily cumulative rainfall over Tirupathi Station (Jun-Sep) year 2014

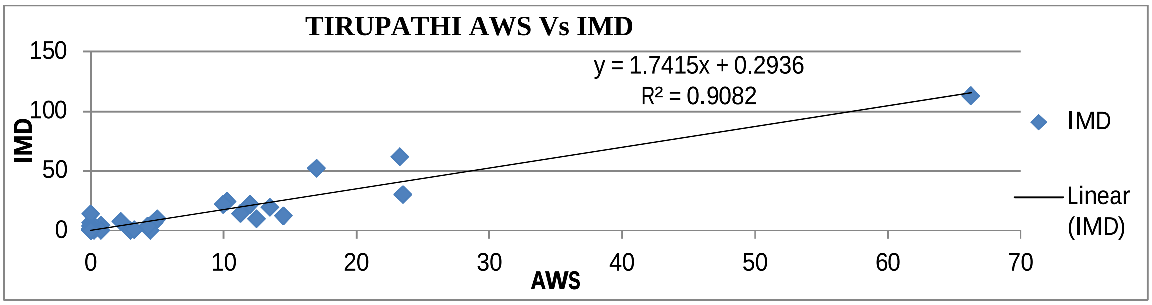


Fig 4.1.9(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Tirupathi Station.

From Fig 4.1.9(a) Daily comparisons between AWS and IMD, cumulative Rainfall over Tirupathi station in monsoon season (June-September) for the year 2014has been observed. It is observed that AWS rainfall is underestimated over IMD. IMD Very high rainfall recorded in 6th July 2014 113.1mm recorded AWS 66.25mm Rainfall recorded.

From Fig 4.1.9(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Tirupathi Station. is 0.908, The Correlation coefficient (r) AWS & IMD has calculated for Tirupathi rainfall 0.95 for the period of (June-September) year 2014.

4.1.10 Daily Cumulative Rainfall for the station Badrachalam.

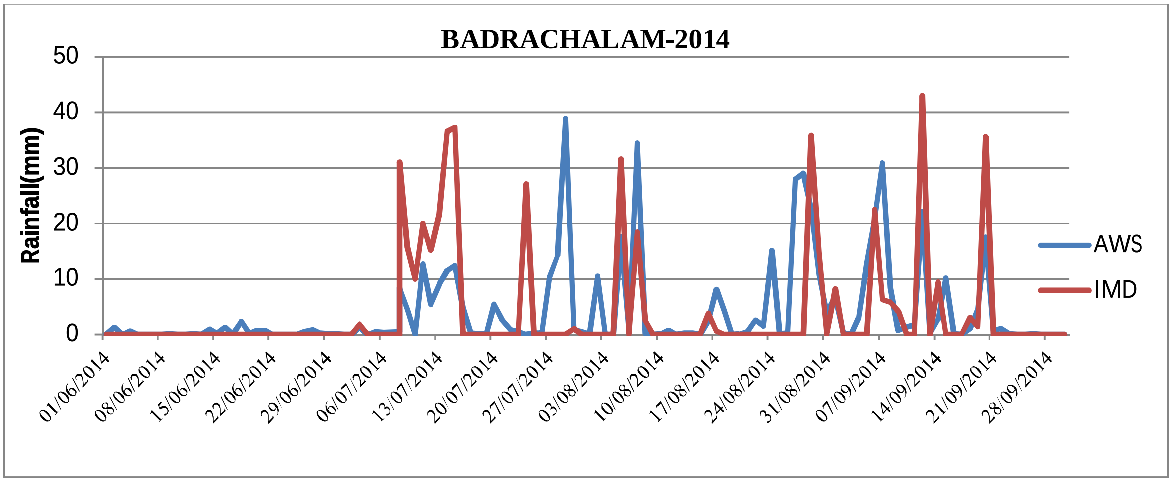


Fig 4.1.10(a) Daily cumulative rainfall over Badrachalam Station (Jun-Sep) year 2014

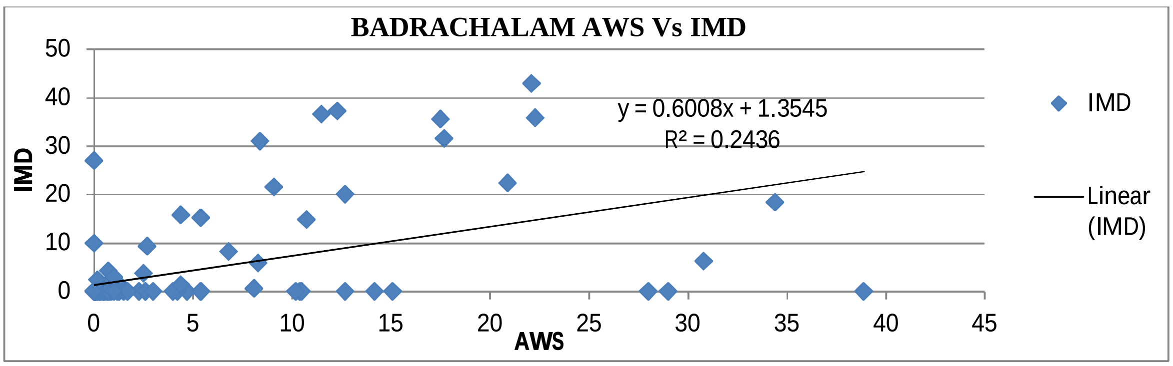


Fig 4.1.10(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Badrachalam Station.

From Fig 4.1.10(a) Daily comparisons between AWS and IMD, cumulative Rainfall over Badrachalam station in monsoon season (June-September) for the Year 2014has been observed. It is observed that AWS rainfall is underestimated over IMD. IMD Very high rainfall recorded in 12th September 2014 43mm recorded AWS 22.5mm Rainfall recorded.

From Fig 4.1.10(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Badrachalam Station. is 0.508, The Correlation coefficient (r) AWS & IMD has calculated for Badrachalam rainfall 0.49 for the period of (June-September) year 2014.

4.1.11 Daily Cumulative Rainfall for the station Medak.

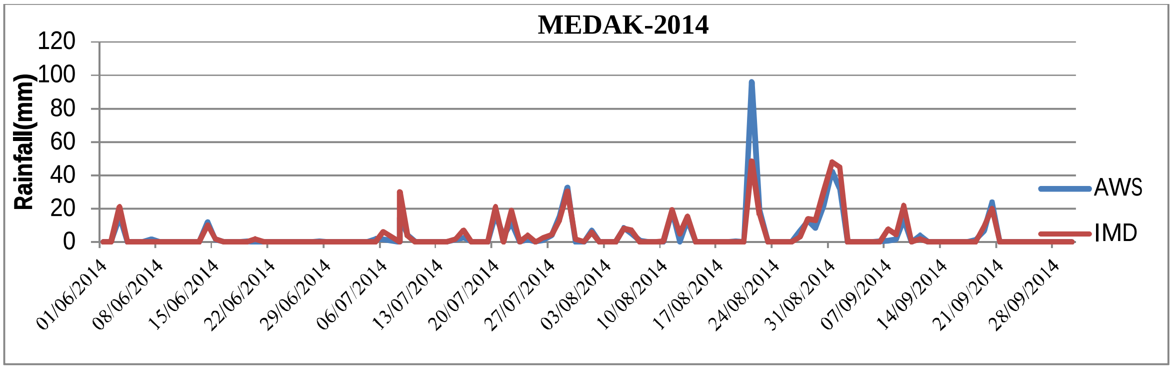


Fig 4.1.11(a) Daily cumulative rainfall over Medak Station (Jun-Sep) Year 2014

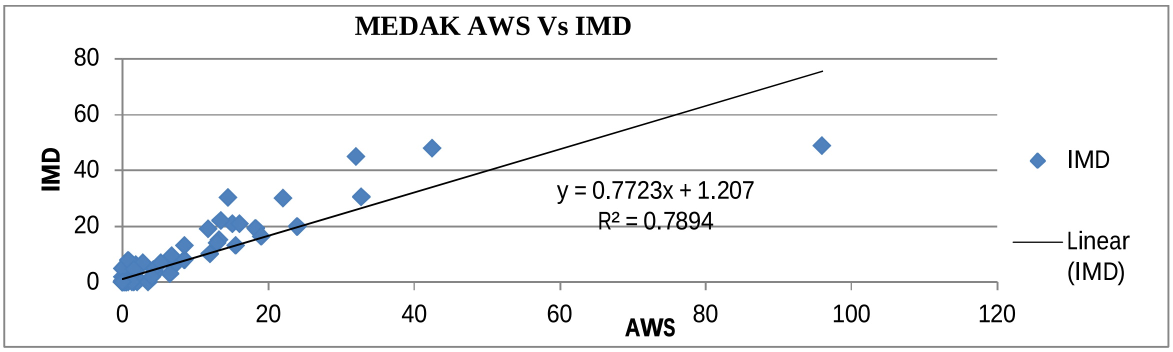


Fig 4.1.11(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Medak Station.

From Fig 4.1.11(a) Daily comparisons between AWS and IMD, cumulative Rainfall over Medak station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD. IMD Very high rainfall recorded in 21th August 2014 78.8 mm recorded AWS 96mm Rainfall recorded.

From Fig 4.1.11(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Medak Station. is 0.789, The Correlation coefficient (r) AWS & IMD has calculated for Medak rainfall 0.88 for the period of (June-September) year 2014.

4.1.12 Daily Cumulative Rainfall for the station Nizamabad.

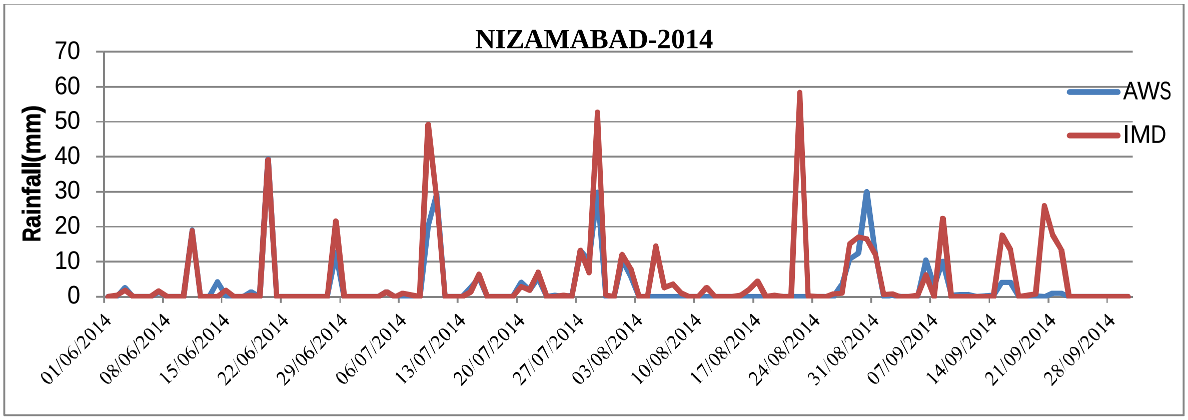


Fig 4.1.12(a) Daily cumulative rainfall over Nizamabad Station (Jun-Sep) year 2014

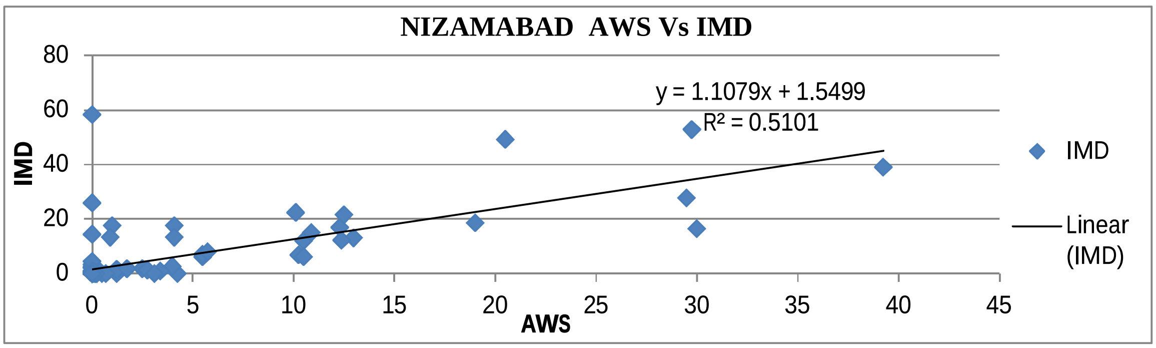


Fig 4.1.12(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Nizamabad Station.

From Fig 4.1.12(a) Daily comparisons between AWS and IMD, cumulative Rainfall over Nizamabad station in monsoon season (June-September) for the year 2014has been observed. It is observed that AWS rainfall is underestimated over IMD. IMD Very high rainfall recorded in 22th August 2014 58.4mm recorded AWS 0 mm Rainfall recorded.

From Fig 4.1.12(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Nizamabad Station. is 0.510, The Correlation coefficient (r) AWS & IMD has calculated for Nizamabad rainfall 0.71 for the period of (June-September) year 2014.

4.1.13 Daily Cumulative Rainfall for the station Ramagundam.

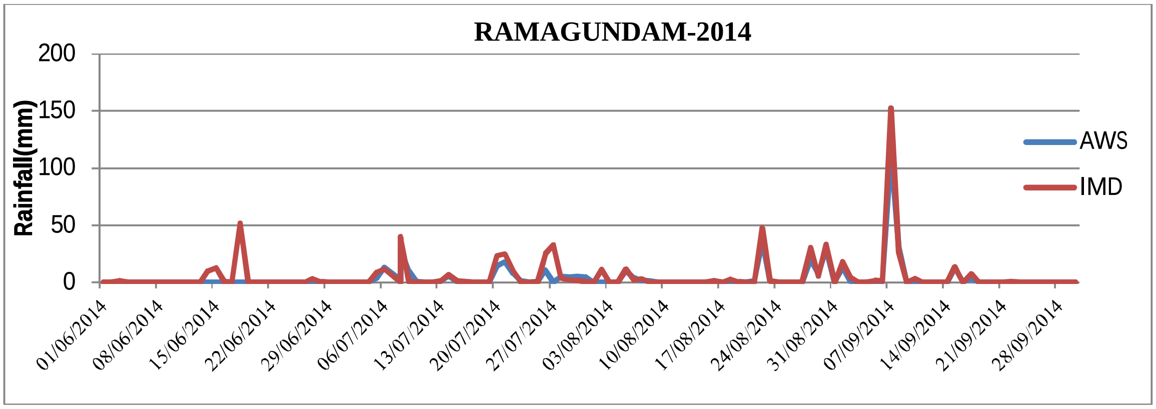
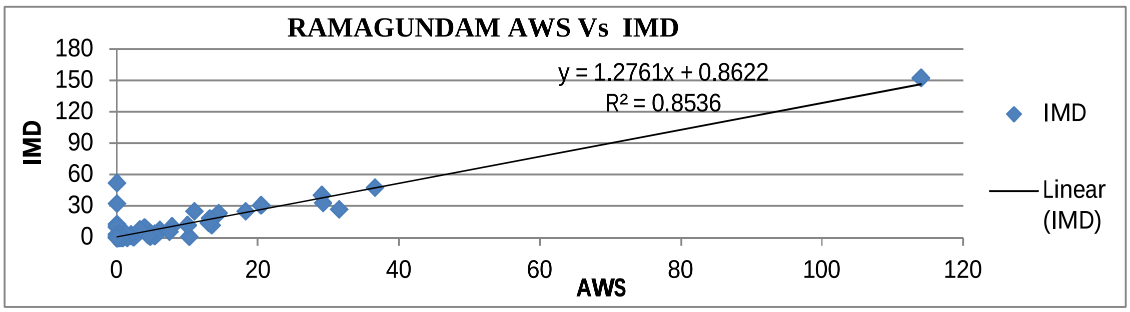


Fig 4.1.13(a) Daily cumulative rainfall over Medak Station (Jun-Sep) year 2014



4.1.13(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Ramagundam Station.

From Fig 4.1.13(a) Daily comparisons between AWS and IMD, cumulative Rainfall over Ramagundam Station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD. IMD Very high rainfall recorded in 7th September 2014 152.6 mm recorded AWS 114 mm Rainfall recorded.

From Fig 4.1.13(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Ramagundam Station. is 0.853, The Correlation coefficient (r) AWS & IMD has calculated for Ramagundam Station rainfall 0.92 for the period of (June-September) year 2014.

4. 2 WEEKLY CUMULATIVE RAINFALL FOR THE ABOVE 13 STSTIONS.

4.2.1 Weekly Cumulative Rainfall for the station Bapatla.

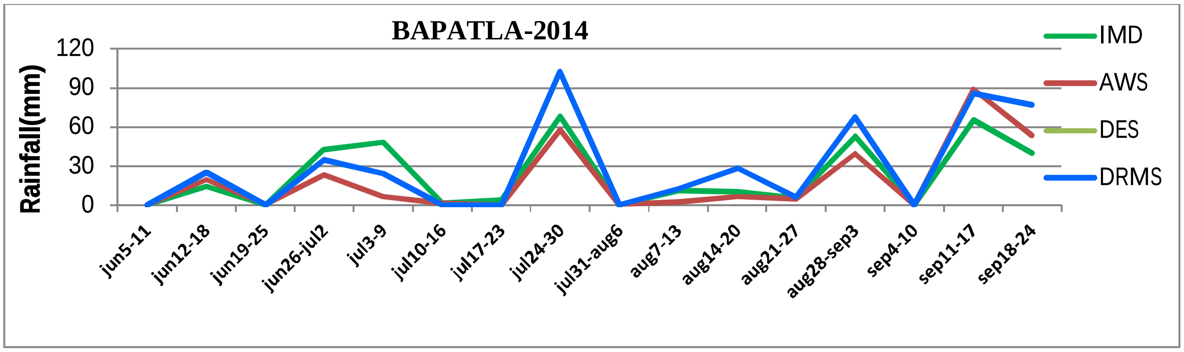
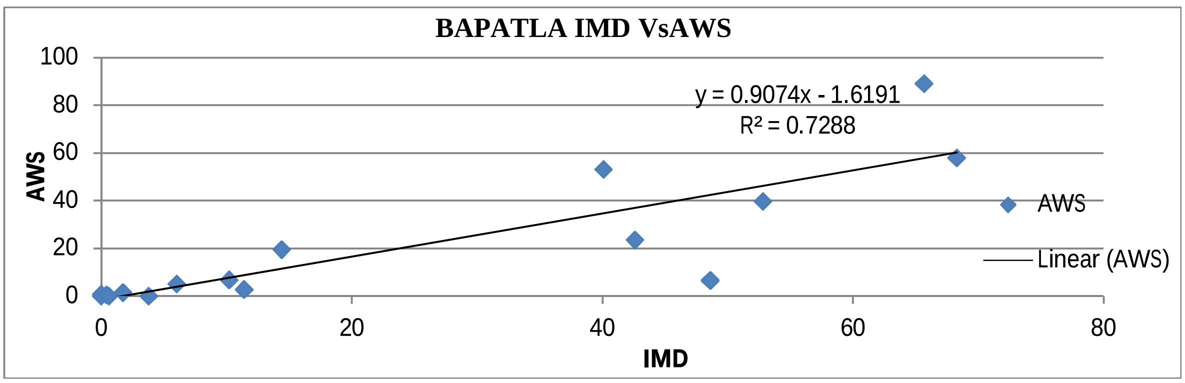


Fig 4.2.1(a) weekly cumulative rainfalls over Bapatla Station (Jun-Sep) Year 2014



4.2.1(b) Regression plot between AWS and IMD Rainfall data(Jun-Sep) year 2014over Bapatla Station.

From Fig 4.2.1(a) weekly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Bapatla station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD, DES and DRMS. AWS Very high rainfall recorded in 15^{th} week (Sep 11-17) 89.1mm, IMD 65.7mm, DES 85.8mm and DRMS 85.8mm.

From Fig 4.2.1(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Bapatla Station. is 0.728, The Correlation coefficient (r) AWS & IMD has calculated for Bapatla rainfall 0.85 for the period of (June-September) and AWS & DES 0.93.

4.2.2 Weekly Cumulative Rainfall for the station Kakinada.

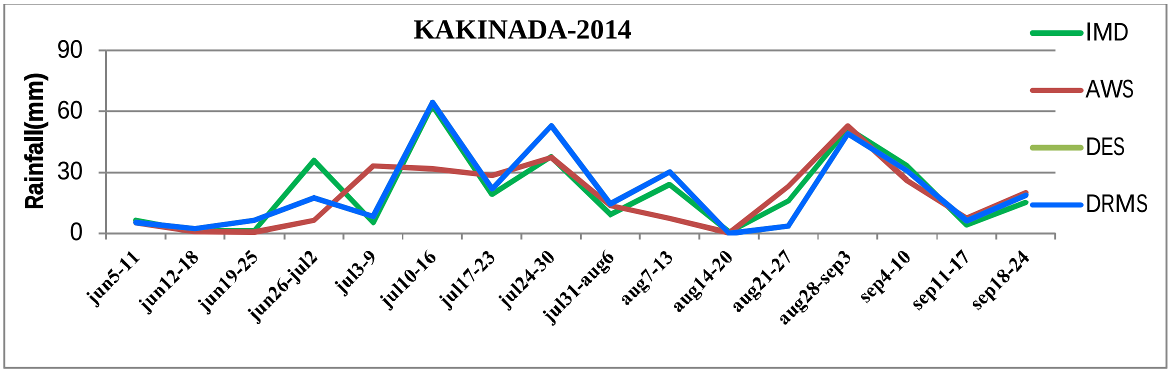
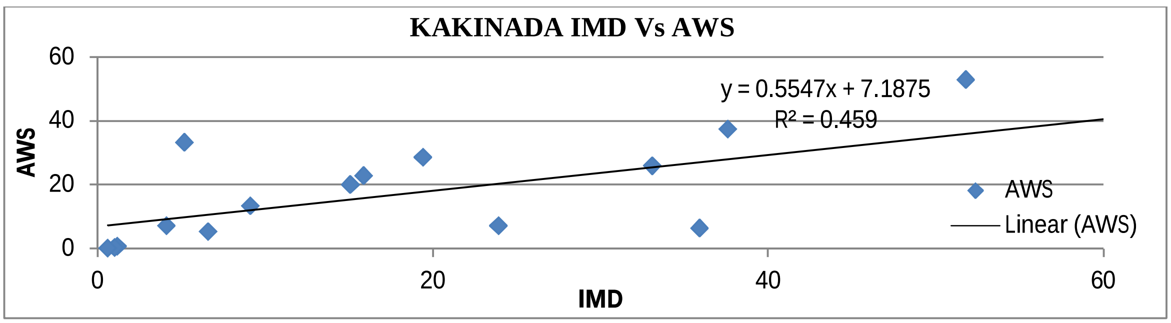


Fig 4.2.2(a) weekly cumulative rainfalls over Kakinada Station (Jun-Sep) Year 201



4.2.2 (b) Regression plot between AWS and IMD Rainfall data(Jun-Sep) year 2014over Kakinada Station.

From fig 4.2.2(a) Weekly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Kakinada station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD, DES and DRMS. AWS Very high rainfall recorded in 13^{th} week (Aug28-Sep03) 53mm, IMD 51.8mm, DES49mm and DRMS 49mm.

From Fig 4.2.2(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Kakinada Station is 0.459, The Correlation coefficient (r) IMD & AWS has calculated for Kakinada rainfall 0.67 for the period (June -September), AWS & DES 0.70.

4.2.3 Weekly Cumulative Rainfall for the station Nandigama.

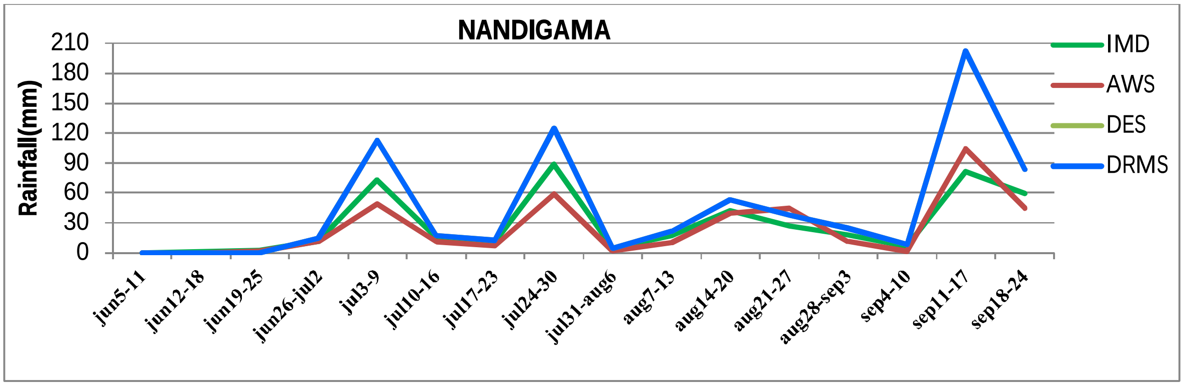


Fig 4.2.3(a) weekly cumulative rainfalls over Nandigama Station (Jun-Sep) year 2014

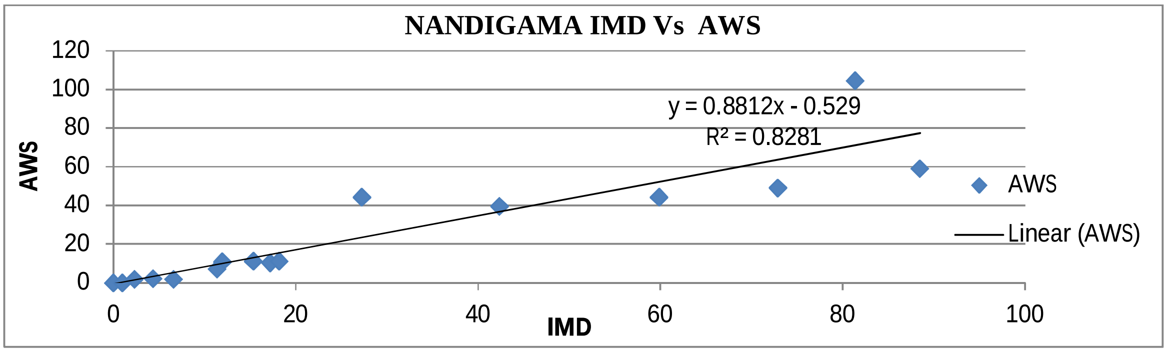


Fig 4.2.3(b) Regression plot between AWS and IMD Rainfall data(Jun-Sep) year 2014over Nandigama Station.

From Fig 4.2.3(a) weekly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Nandigama station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD, DES and DRMS. AWS Very high rainfall recorded in 15^{th} week (Sep11-17) 104.5mm, IMD 81.4mm, DES 202.6mm and DRMS 202.6mm.

From Fig 4.2.3(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Nandigama Station is 0.828, The Correlation coefficient (r) AWS & IMD has calculated for Nandigama rainfall 0.90 for the period of (June -September), AWS & DES 0.96.

4.2.4 Weekly Cumulative Rainfall for the station Rentachintala.

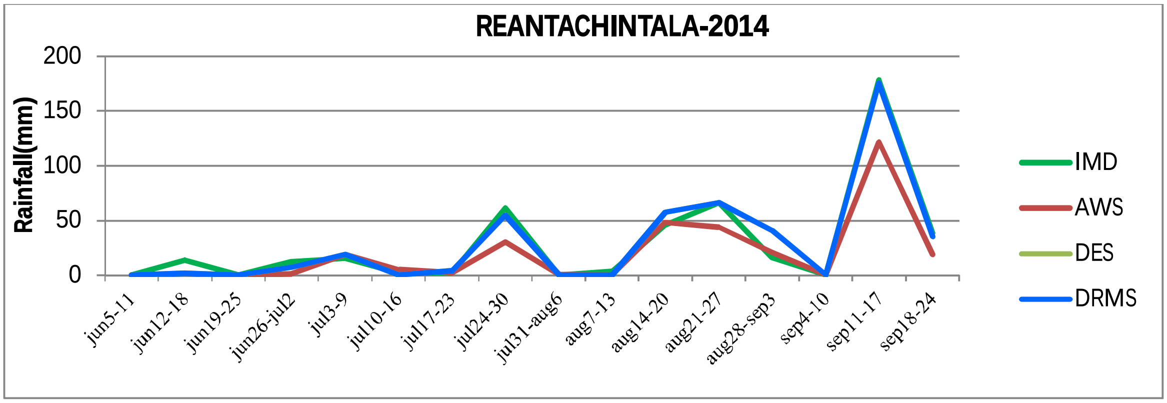
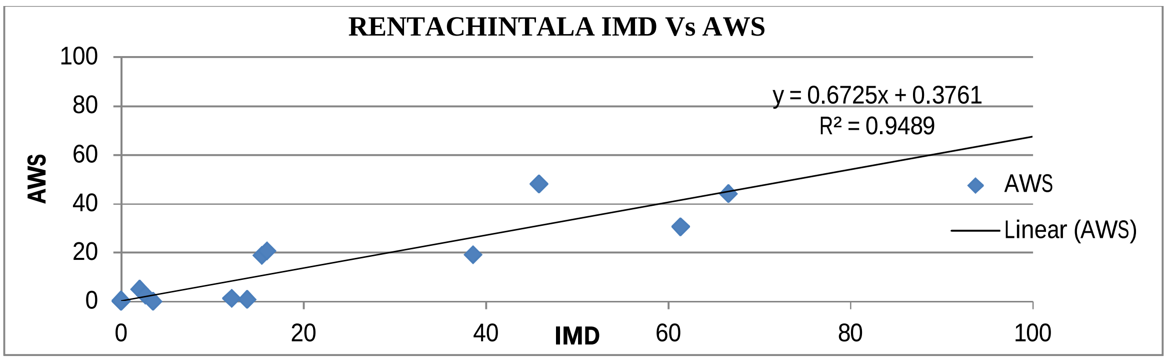


Fig 4.2.4(a) weekly cumulative rainfalls over Rentachintala Station (Jun-Sep) year 2014



4.2.4(b) Regression plot between AWS and IMD Rainfall data(Jun-Sep) year 2014over Rentachintala Station.

From Fig 4.2.4(a) weekly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Rentachintala station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD, DES and DRMS. AWS Very high rainfall recorded in 15thweek (Sep 11-17) 121.5mm, IMD 178.4mm, DES 175.4mm and DRMS 175.4mm.

Fig 4.2.4(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Rentachintala Station is 0.948,The Correlation coefficient (r) AWS & IMD has calculated for Rentachintala rainfall 0.97 for the period of (June -September), AWS & DES 0.99.

4.2.5 Weekly Cumulative Rainfall for the station Tuni.

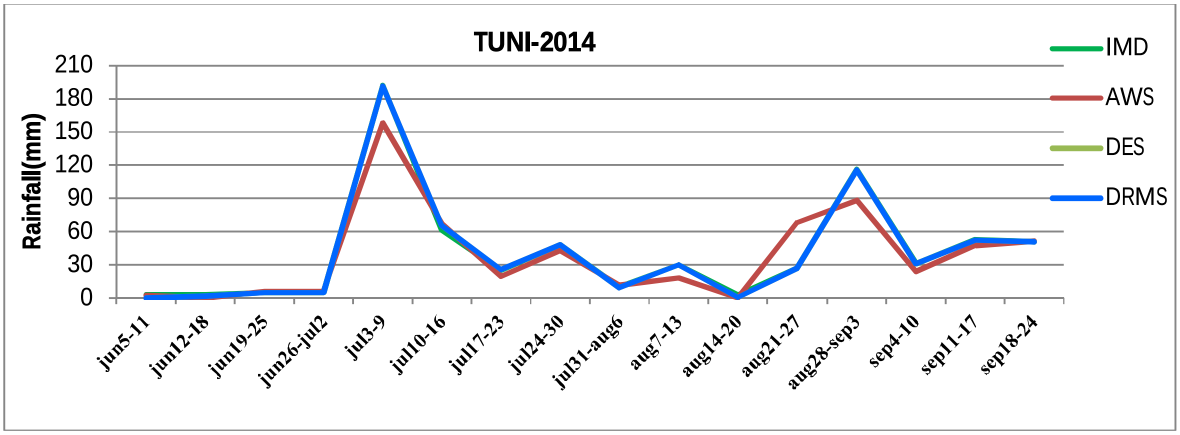
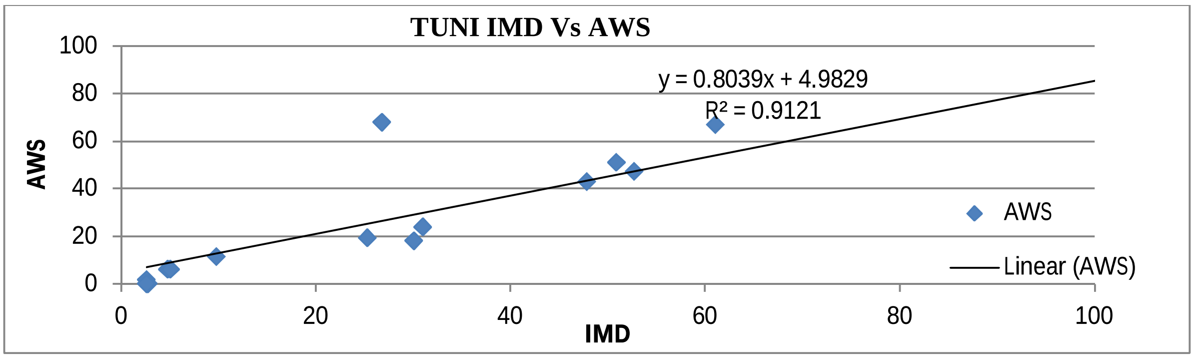


Fig 4.2.5(a) weekly cumulative rainfalls over Tuni Station (Jun-Sep) Year 2014



4.2.5(b) Regression plot between AWS and IMD Rainfall data(Jun-Sep)Year 2014over Tuni Station.

From Fig 4.2.5(a) weekly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Tuni station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD, DES and DRMS. AWS Very high rainfall recorded in 5th week (Jul03-09) 157.75mm, IMD 191.6mm, DES 191mm and DRMS 191mm**.**

From Fig 4.2.5(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Tuni Station is 0.912,The Correlation coefficient (r) AWS & IMD has calculated for Tuni rainfall 0.99 for the period of (June -September), AWS & DES 0.95.

4.2.6 Weekly Cumulative Rainfall for the station Vijayawada.

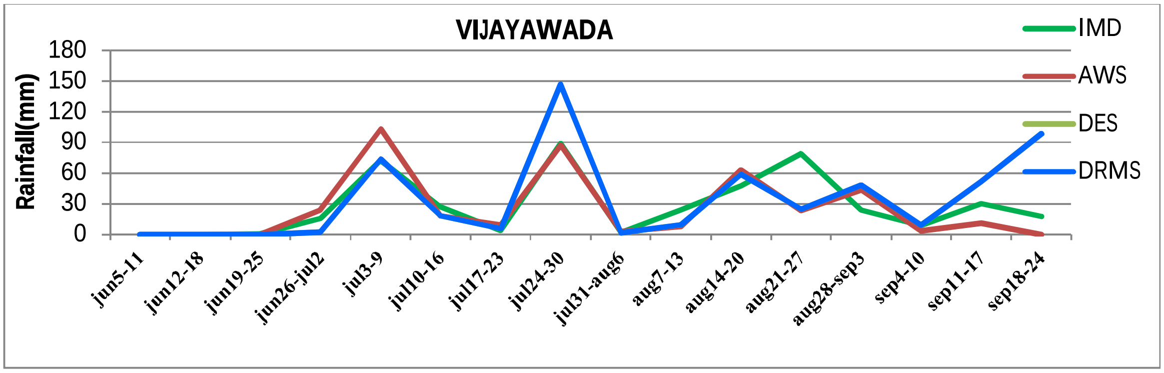
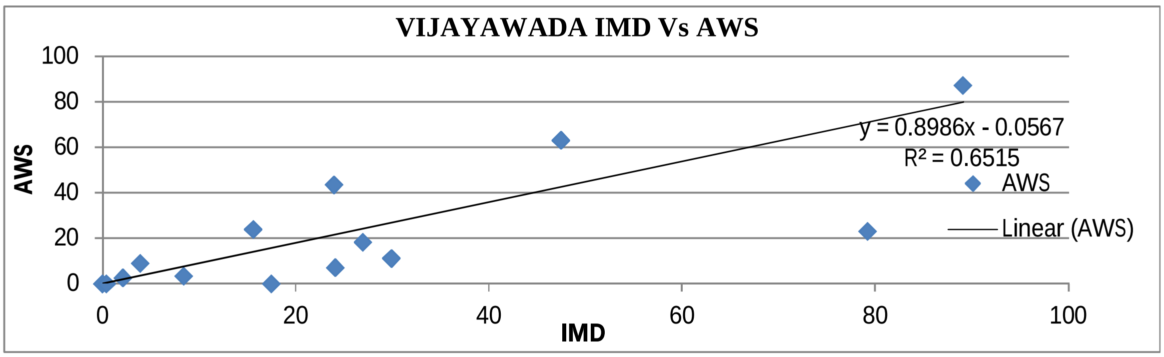


Fig 4.2.6(a) weekly cumulative rainfalls over Vijayawada Station (Jun-Sep) year 2014



4.2.6(b) Regression plot between AWS and IMD Rainfall data(Jun-Sep) year 2014over Vijayawada Station.

From Fig 4.2.6(a) weekly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Vijayawada station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD, DES and DRMS. AWS Very high rainfall recorded in 5^{th} week (Jul03-09) 103mm, IMD 72.2mm, DES 73.8mm and DRMS 73.8mm.

From Fig 4.2.6(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Vijayawada Station is 0.651,The Correlation coefficient (r) AWS & IMD has calculated for Vijayawada rainfall 0.80 for the period of (June -September), AWS & DES 0.68.

4.2.7 Weekly Cumulative Rainfall for the station Visakhapatnam.

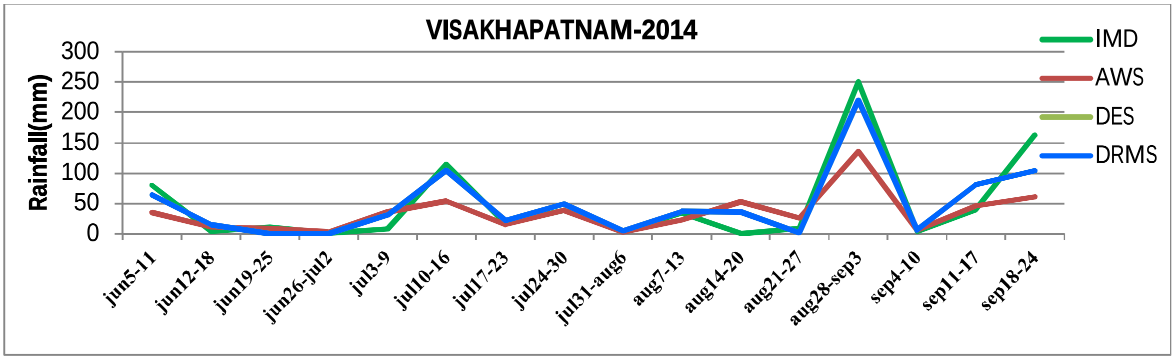


Fig 4.2.7(a) weekly cumulative rainfalls over Visakhapatnam Station (Jun-Sep) Year 2014

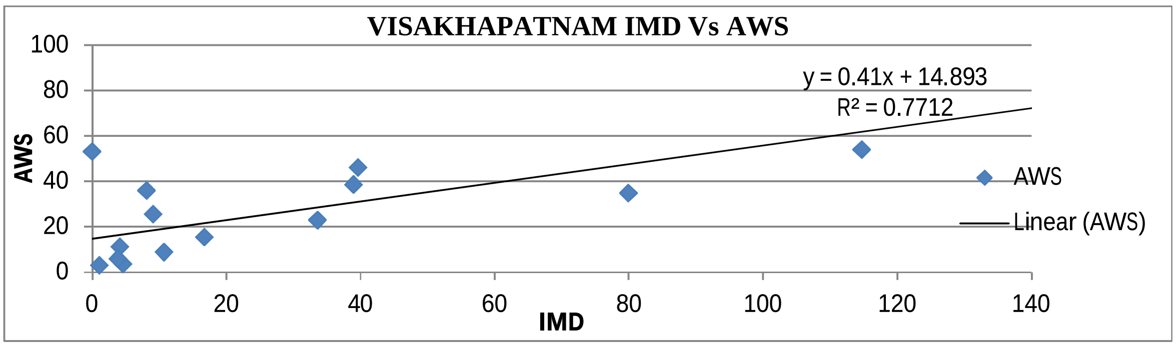
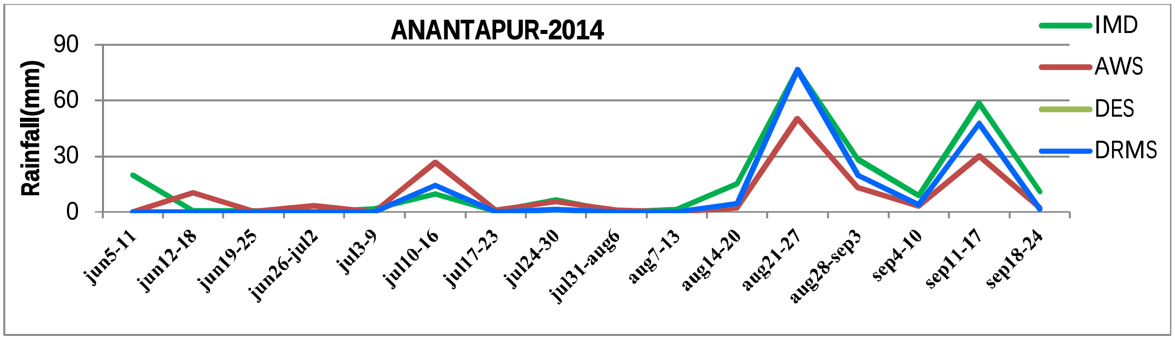


Fig 4.2.7(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Visakhapatnam Station.

From Fig 4.2.7(a) weekly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Visakhapatnam station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD, DES and DRMS. AWS Very high rainfall recorded in 15th week (Sep11-17) 46mm, IMD 39.6mm, DES 80.6mm and DRMS 80.6mm**.**

From Fig 4.2.7(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Visakhapatnam Station is 0.771,The Correlation coefficient (r) AWS & IMD has calculated for Visakhapatnam Rainfall 0.87 for the period of (June -September), AWS & DES 0.95.

4.2.8 Weekly Cumulative Rainfall for the station Anantapur.



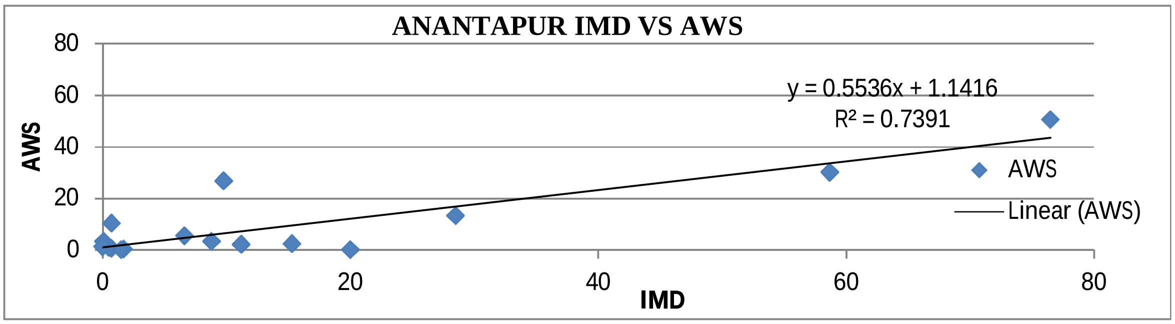


Fig 4.2.8(a) weekly cumulative rainfalls over Anantapur Station (Jun-Sep) Year 2014

Fig 4.2.8(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Anantapur Station.

From Fig 4.2.8(a) weekly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Anantapur station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD, DES and DRMS. AWS Very high rainfall recorded in 12^{th} week (Aug 21-27) 50.5mm, IMD 76.5mm, DES 76.8mm and DRMS 76.8mm.

From Fig 4.2.8(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Anantapur Station is 0.739,The Correlation coefficient (r) AWS & IMD has calculated for Anantapur rainfall 0.85 period of (June -September), AWS & DES 0.94.

4.2.9 Weekly Cumulative Rainfall for the station Tirupathi

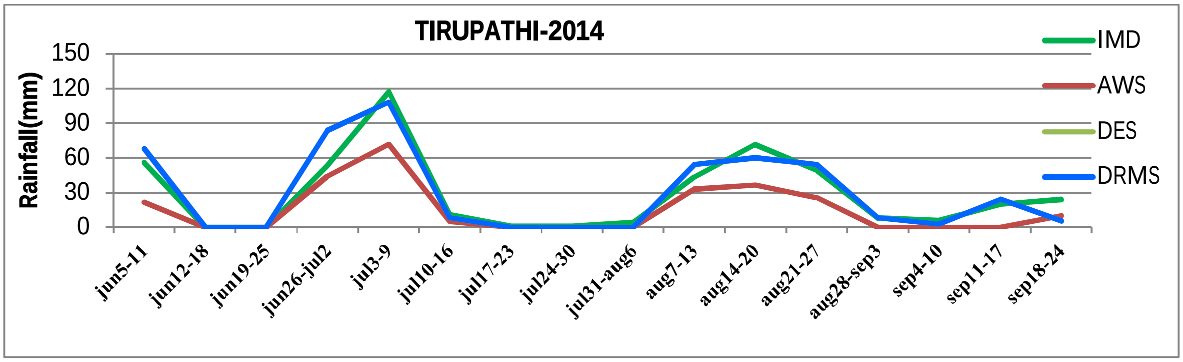


Fig 4.2.9(a) weekly cumulative rainfalls over Tirupathi Station (Jun-Sep) Year 2014

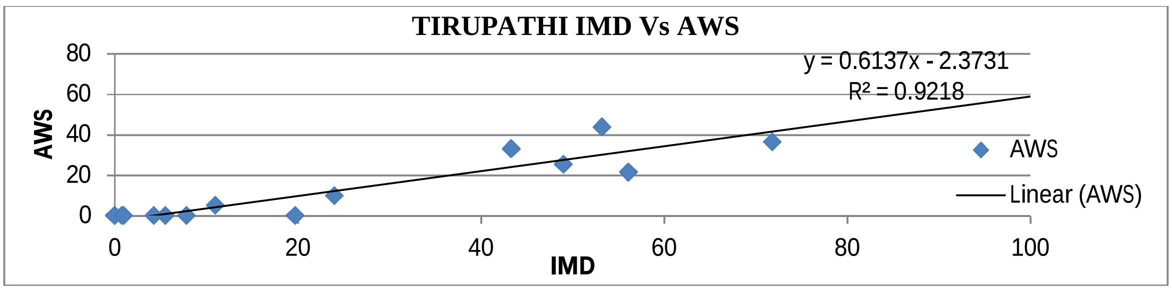


Fig 4.2.9(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Tirupathi Station.

From Fig 4.2.9(a) weekly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Tirupathi station in monsoon season (June-September) for the year 2014has been observed. It is observed that AWS rainfall is underestimated over IMD, DES and DRMS. AWS Very high rainfall recorded in 5^{th} week (Jul03-09) 71.5mm, IMD 117.3mm, DES 108.4mm and DRMS 108.4mm.

From Fig 4.2.9(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Tirupathi Station is 0.921,The Correlation coefficient (r) AWS & IMD has calculated for Tirupathi rainfall 0.96 period of (June -September), AWS & DES 0.95.

4.2.10 Weekly Cumulative Rainfall for the station Badrachalam.

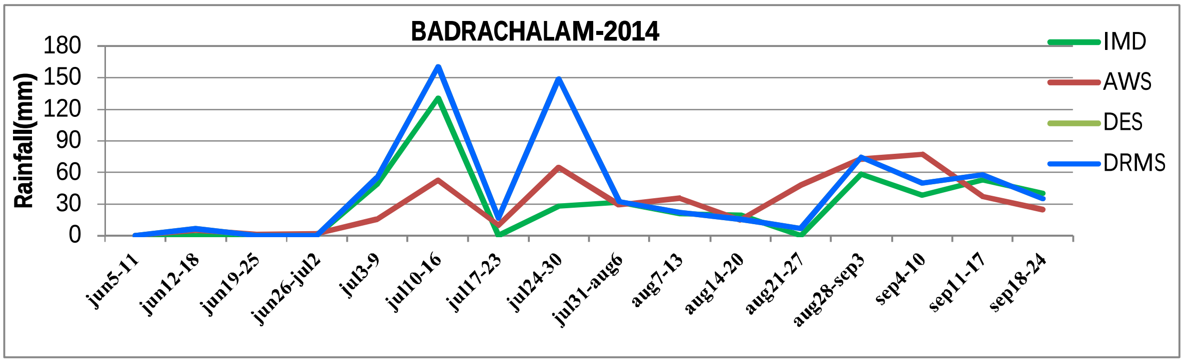


Fig 4.2.10(a) weekly cumulative rainfalls over Badrachalam Station (Jun-Sep) Year 2014.

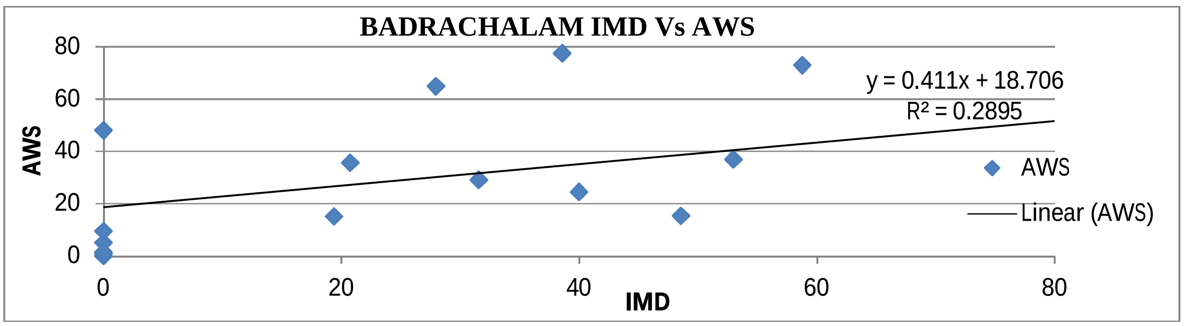


Fig 4.1.10(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Badrachalam Station.

From Fig 4.2.10 (a) weekly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Badrachalam station in monsoon season (June-September) for the Year 2014has been observed. It is observed that AWS rainfall is underestimated over IMD, DES and DRMS. AWS Very high rainfall recorded in 14th week (Sep 04-10) 77.65mm, IMD 38.6mm, DES 50.2mm and DRMS 50.2mm.

From Fig 4.2.10(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Badrachalam Station is 0.289,The Correlation coefficient (r) AWS & IMD has calculated for Badrachalam rainfall 0.53 for the period of (June -September), AWS & DES 0.66 .

4.2.11 Weekly Cumulative Rainfall for the station Medak.

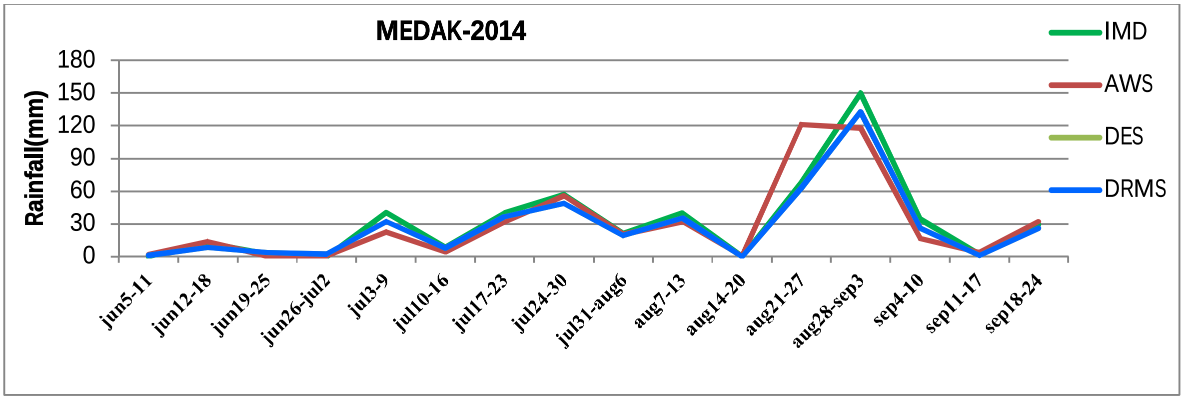
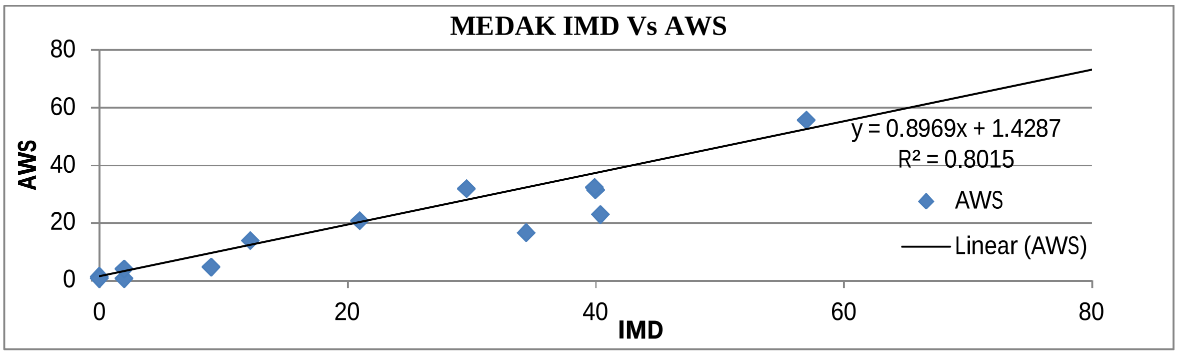


Fig 4.2.11(a) weekly cumulative rainfalls over Medak Station (Jun-Sep) Year 2014



4.2.11(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Medak Station.

From Fig 4.2.11(a) weekly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Medak station in monsoon season (June-September) for the Year 2014has been observed. It is observed that AWS rainfall is underestimated over IMD, DES and DRMS. AWS Very high rainfall recorded in 12^{th} week (Aug 21-27) 121.5mm, IMD 68.2mm, DES 63.2mm and DRMS 63.2mm.

From Fig 4.2.11(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Medak Station is 0.801,The Correlation coefficient (r) AWS & IMD has calculated for Medak rainfall 0.89 for the period of (June -September), AWS & DES 0.90.

4.2.12 Weekly Cumulative Rainfall for the station Nizamabad.

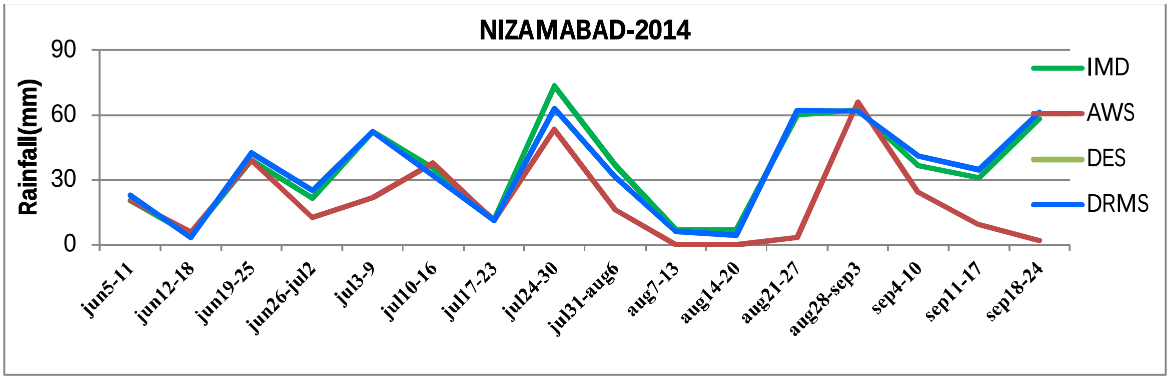


Fig 4.2.12(a) weekly cumulative rainfalls over Nizamabad Station (Jun-Sep) year 2014

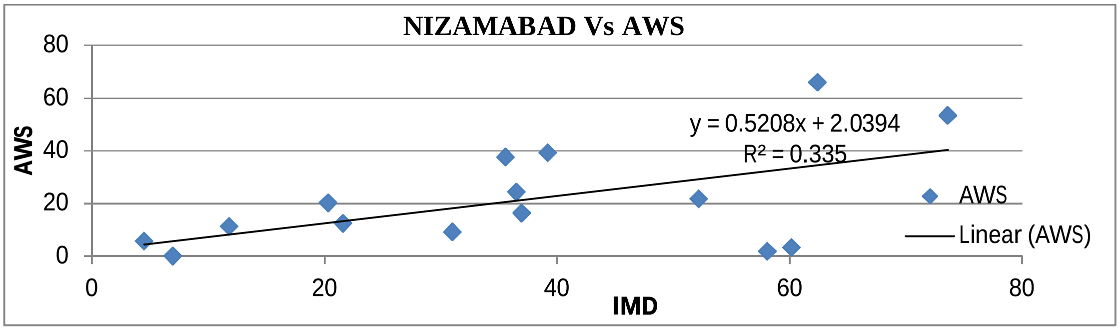


Fig 4.2.12(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Nizamabad Station.

From Fig 4.2.12(a) weekly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Nizamabad station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD, DES and DRMS. AWS Very high rainfall recorded in 13th week (Aug28-Sep03) 66mm, IMD 62.4mm, DES 61.8mm and DRMS 61.8mm.

From Fig 4.2.12(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Nizamabad Station is 0.335,The Correlation coefficient (r) AWS & IMD has calculated for Nizamabad rainfall 0.57.for the period of (June -September), AWS & DES 0.52.

4.2.13 Weekly Cumulative Rainfall for the station Ramagundam.

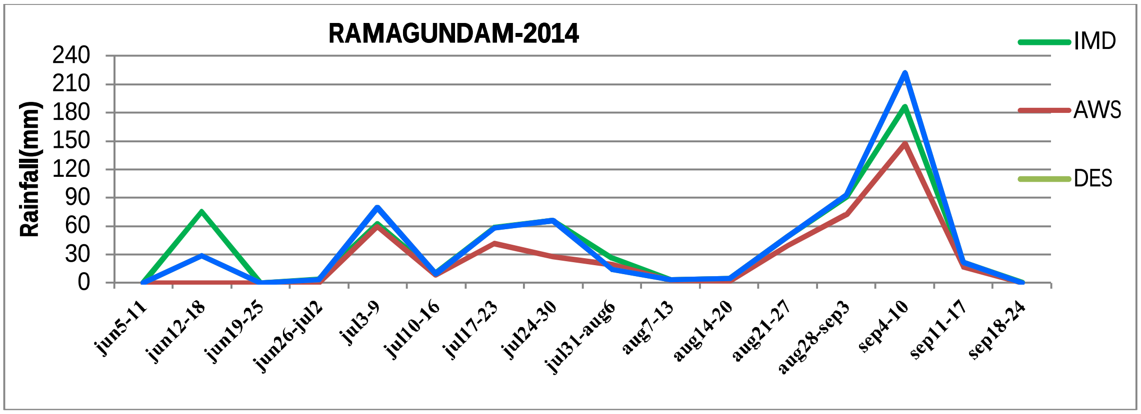
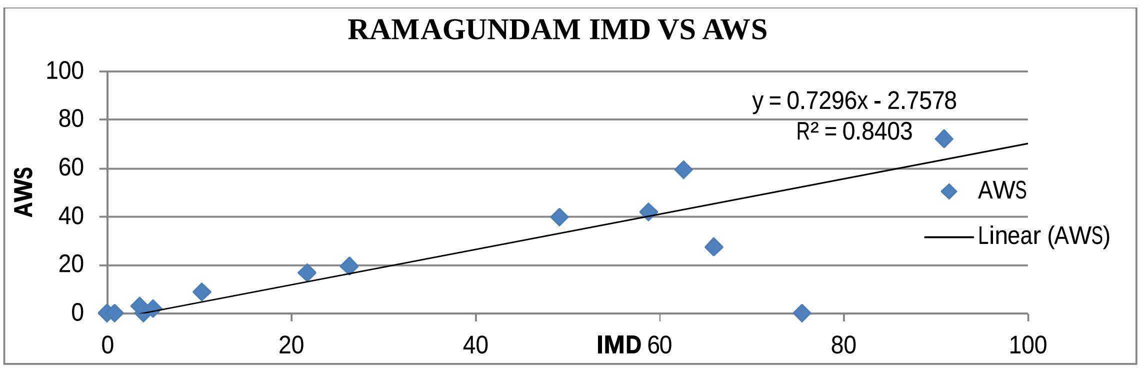


Fig 4.2.13(a) weekly cumulative rainfalls over Ramagundam Station (Jun-Sep) year 2014



4.2.13(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Ramagundam Station.

From Fig 4.2.13(a) weekly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Ramagundam station in monsoon season (June-September) for the year 2014 has been observed. It is observed that AWS rainfall is underestimated over IMD, DES and DRMS. AWS Very high rainfall recorded in 14th week (Sep04-10) 147.5mm, IMD 186.1mm, DES 221.6mm and DRMS 221.6mm.

From Fig 4.2.3(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Ramagundam Station is 0.840,The Correlation coefficient (r) AWS & IMD has calculated for Ramagundam rainfall 0.91 for the period of (June -September), AWS & DES 0.97.

4.3 Monthly Cumulative Rainfall for Andhra Pradesh and Telangana State:

4.3.1 Monthly Cumulative Rainfall for the Station Bapatla.

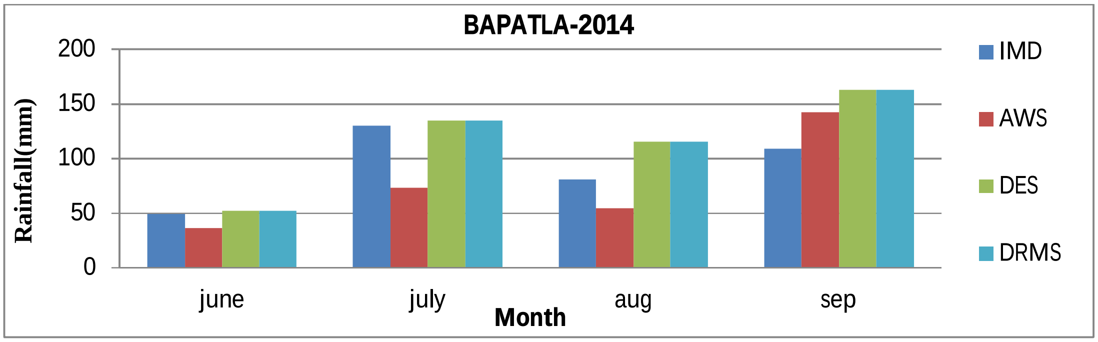


Fig 4.3.1(a) monthly cumulative rainfalls over Bapatla Station 2014 year

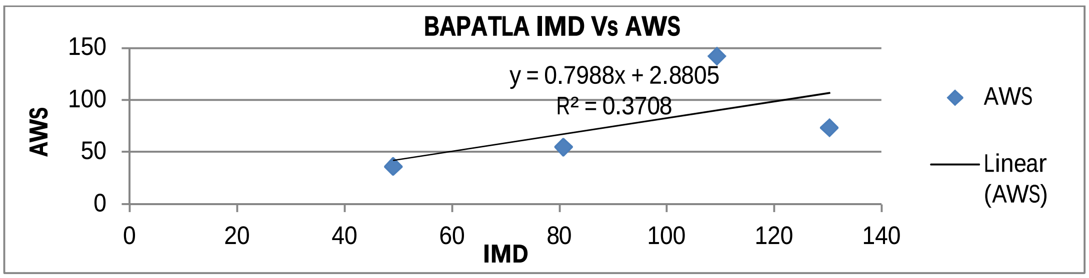


Fig 4.3.1(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Bapatla Station.

From Fig 4.3.1(a) monthly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Bapatla station in monsoon season (June-September) for the year 2014 has been observed. The AWS Stations recoded near to IMD manual Record all four months. September monthly cumulative rainfall is above 150 mm recorded DES but AWS is recorded as 142.35 mm and IMD 109.4mm recorded.

From Fig 4.3.1(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Bapatla Station is 0.370, Correlation coefficient (r) AWS & IMD has calculated for Bapatla rainfall 0.60 for the period of (June -September), AWS & DES 0.86.

4.3.2 Monthly Cumulative Rainfall for the station Kakinada.

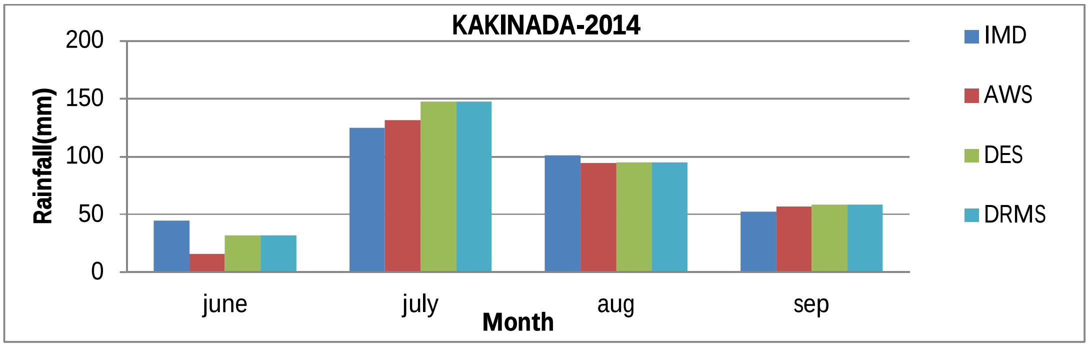


Fig 4.3.1(a) monthly cumulative rainfalls over Bapatla Station 2014 year

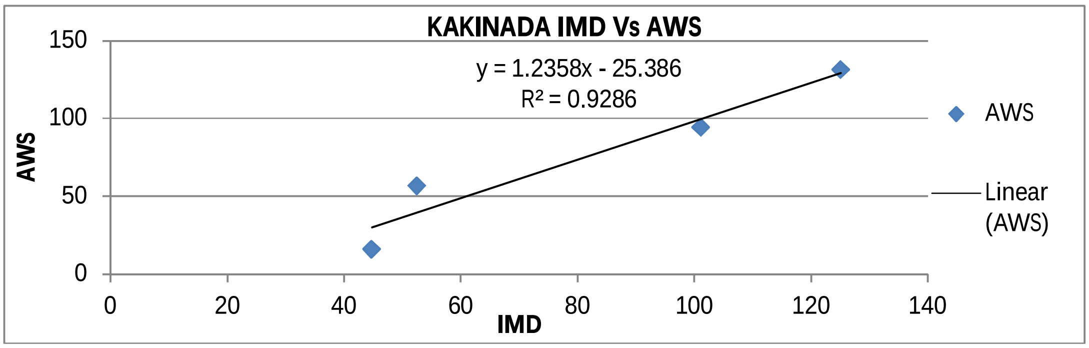


Fig 4.3.2(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Kakinada Station.

From Fig 4.3.2(a) monthly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Kakinada station in monsoon season (June-September) for the year 2014 has been observed. The AWS Stations recoded near to IMD manual Record all four months. July monthly cumulative rainfall is 147.40 mm recorded DES but AWS is recorded as 131.25 mm and IMD is recorded 125.10mm.

From Fig 4.3.2(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Kakinada Station is 0.928, Correlation coefficient (r) AWS & IMD has calculated for Kakinada rainfall 0.96 for the period of (June -September), AWS & DES 0.98.

4.3.3 Monthly Cumulative Rainfall for the station Nandigama.

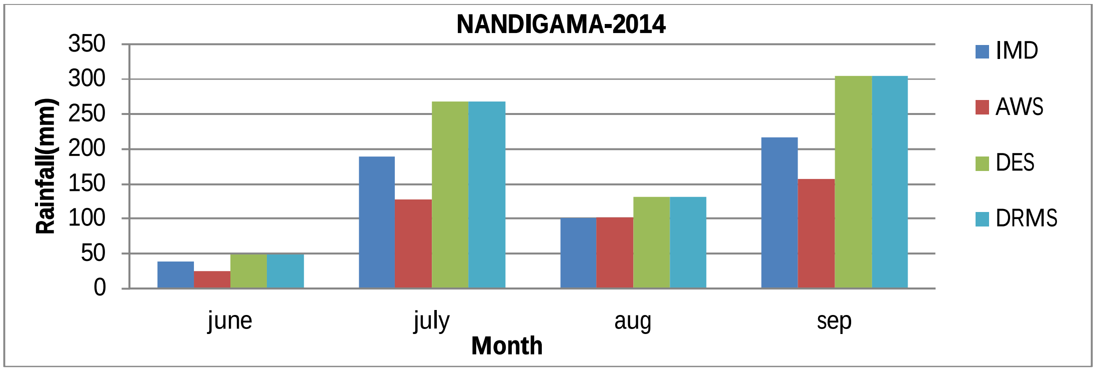


Fig 4.3.3(a) monthly cumulative rainfalls over Nandigama Station in the year 2014

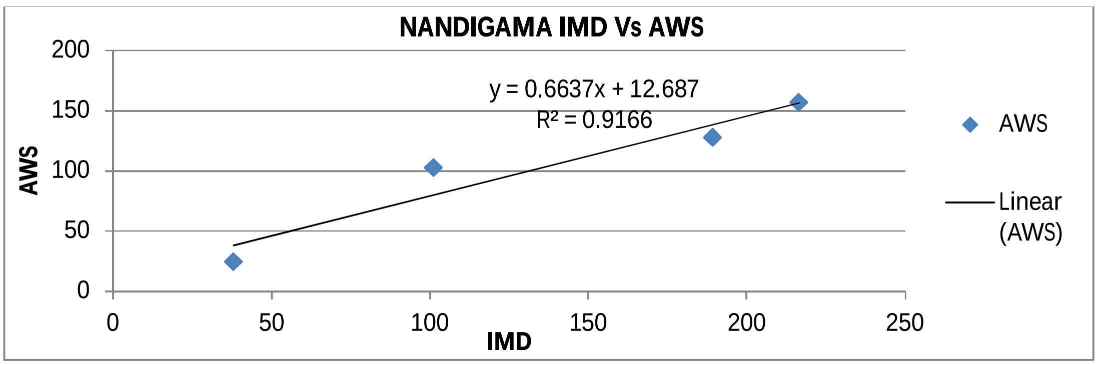


Fig 4.3.3(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Nandigama Station.

From Fig 4.3.3(a) monthly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Nandigama station in monsoon season (June-September) for the Year 2014has been observed. The AWS Stations recoded near to IMD manual Record all four months. September monthly cumulative rainfall is high 305.2 mm recorded DES but AWS is recorded as 157 mm and IMD 216.5mm recorded. August month IMD and DES both are equal.

From Fig 4.3.3(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Nandigama Station is 0.916, Correlation coefficient (r) AWS & IMD has calculated for Nandigama rainfall 0.95 for the period of (June -September), AWS & DES 0.94.

4.3.4 Monthly Cumulative Rainfall for the station Rentachintala.

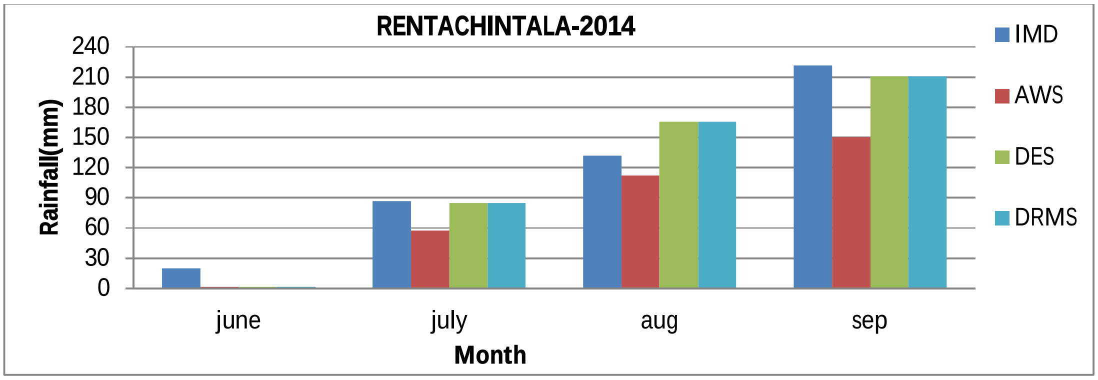


Fig 4.3.4(a) monthly cumulative rainfalls over Rentachintala Station in the year 2014

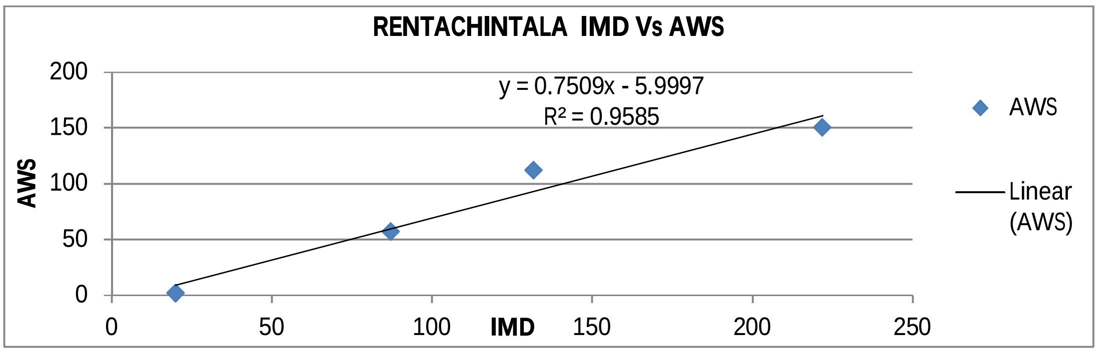


Fig 4.3.4(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Rentachintala Station.

From Fig 4.3.4(a) monthly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Rentachintala station in monsoon season (June-September) for the year 2014 has been observed. The AWS Stations recoded near to IMD manual Record all four months. June month is below 25 mm recorded over all manual station (IMD, DES & DRMS), September monthly cumulative rainfall is 222 mm recorded IMD but AWS is recorded as 150.75 mm and DES and DRMS 211mm recorded.

From Fig 4.3.4(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Rentachintala Station is 0.958, Correlation coefficient (r) AWS & IMD has calculated for Rentachintala rainfall 0.97 for the period of (June -September), AWS & DES 0.99.

4.3.5 Monthly Cumulative Rainfall for the station Tuni.

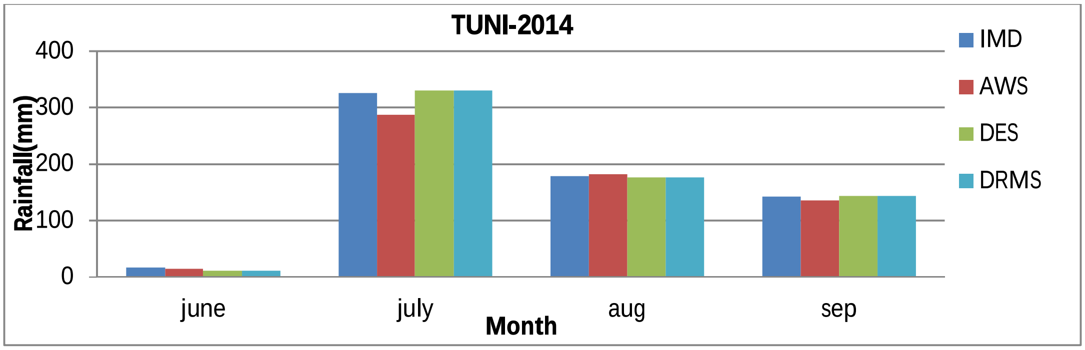


Fig 4.3.5(a) monthly cumulative rainfalls over Tuni Station in the year 2014

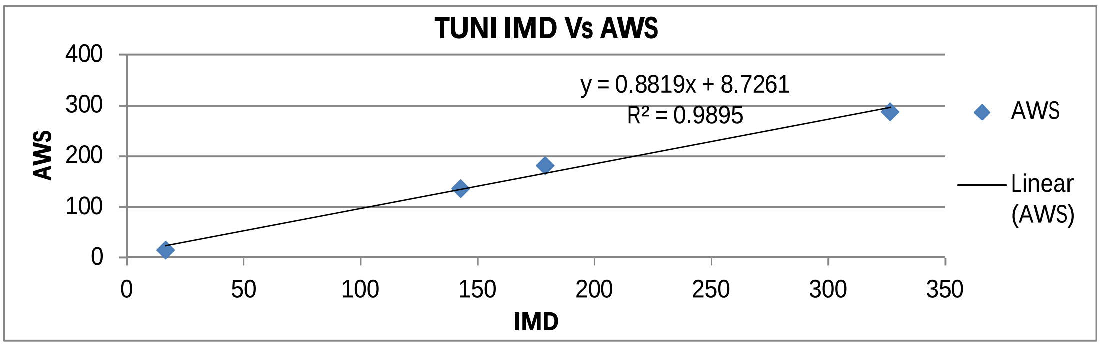


Fig 4.3.5(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Tuni Station.

From Fig 4.3.5(a) monthly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Tuni station in monsoon season (June-September) for the year 2014has been observed. The AWS Stations recoded near to IMD manual Record all four months. June month is low 20 mm recorded over all manual station (IMD, DES & DRMS), July monthly cumulative rainfall is 326.6 mm recorded IMD but AWS is recorded as 287.8 mm and DES 330.1mm. August month cumulative rainfall is 182.35mm record AWS but IMD is recorded 179.1mm andDES176.6mm recorded.

From Fig 4.3.5(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Tuni Station is 0.989, Correlation coefficient (r) AWS & IMD has calculated for Tuni rainfall 0.99 for the period of (June -September), AWS & DES 0.99.

4.3.6 Monthly Cumulative Rainfall for the station Vijayawada.

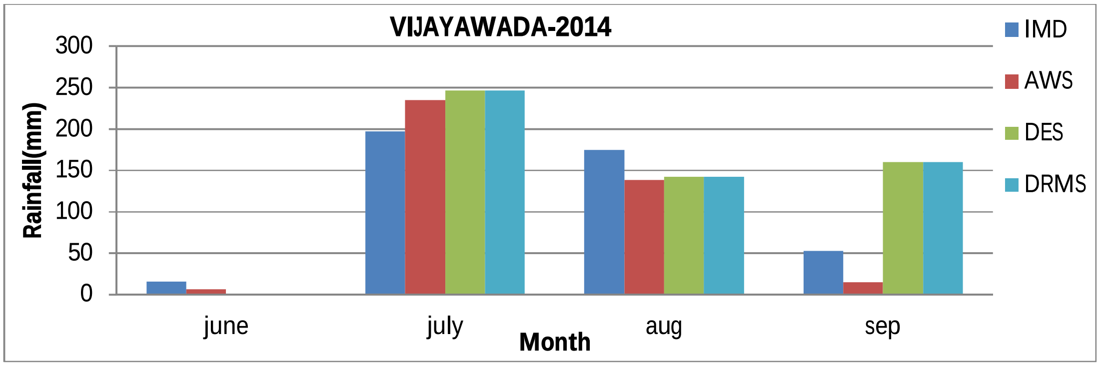


Fig 4.3.6(a) monthly cumulative rainfalls over Vijayawada Station in the year 2014

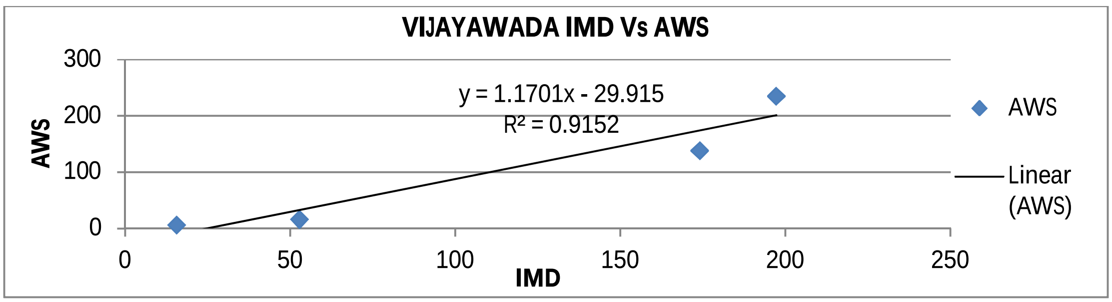


Fig 4.3.6(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Vijayawada Station.

From Fig 4.3.6(a) monthly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Vijayawada station in monsoon season (June-September) for the year 2014 has been observed. The AWS Stations recoded near to IMD manual Record all four months. June month is below 16 mm recorded over all manual station (IMD, DES & DRMS) and AWS, July monthly cumulative rainfall is 246.4 mm recorded DES but AWS is recorded as 235.25 mm and IMD 197.3mm recorded.

From Fig 4.3.6(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Vijayawada Station is 0.915, Correlation coefficient (r) AWS & IMD has calculated for Vijayawada rainfall 0.95 for the period of (June -September), AWS & DES 0.77.

4.3.7 Monthly Cumulative Rainfall for the station Visakhapatnam.

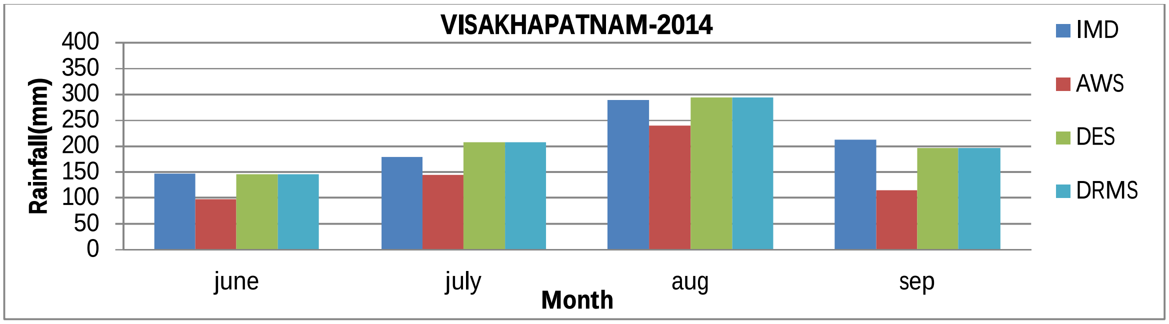


Fig 4.3.7(a) monthly cumulative rainfalls over Visakhapatnam Station in the year 2014

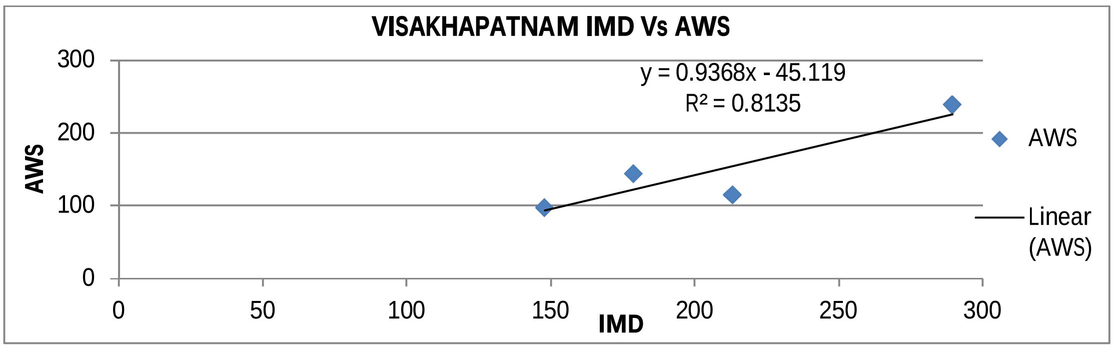


Fig 4.3.7(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Visakhapatnam Station.

From Fig 4.3.7(a) monthly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Visakhapatnam station in monsoon season (June-September) for the year 2014 has been observed. The AWS Stations recoded near to IMD manual Record all four months. June month is below 150 mm recorded over all manual station (IMD, DES & DRMS) and AWS, August month cumulative high rainfall is 289.5 mm recorded IMD but AWS is recorded as 142.35 mm and DES 294.2mm recorded.

From Fig 4.3.7(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Visakhapatnam Station is 0.813,Correlation coefficient (r) AWS & IMD has calculated for Visakhapatnam rainfall 0.90for the period of (June -September), AWS & DES 0.97.

4.3.8 Monthly Wise Cumulative Rainfall for the station Anantapur.

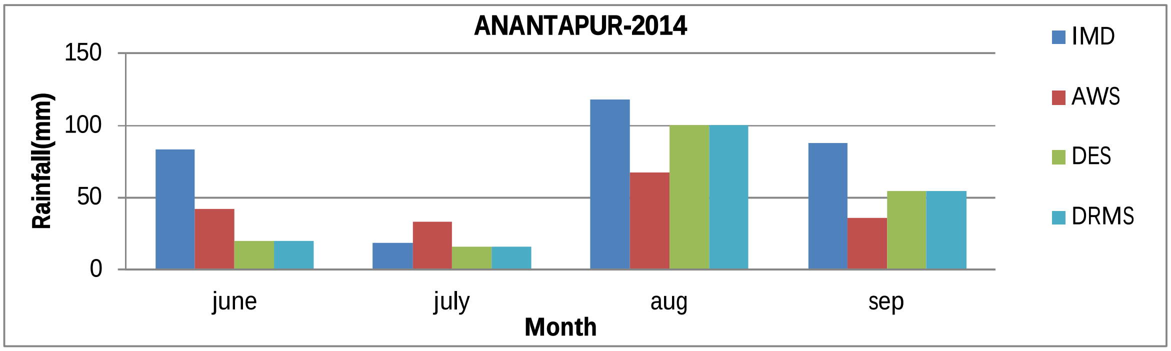


Fig 4.3.8(a) monthly cumulative rainfalls over Anantapur Station in the year 2014

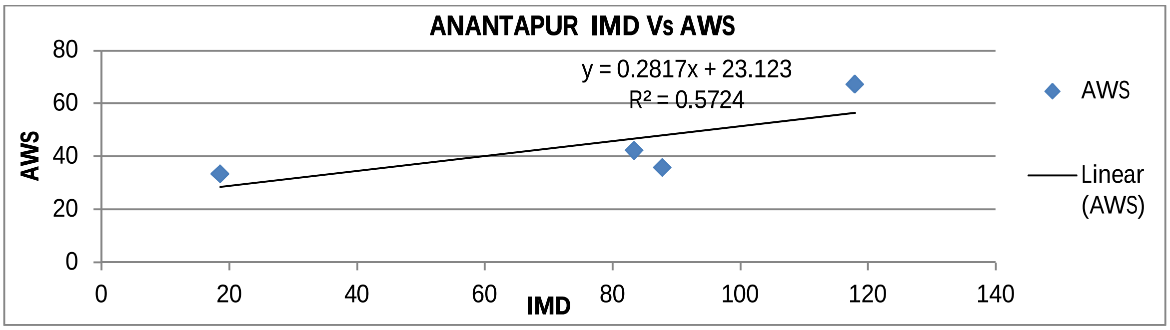


Fig 4.3.8(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Anantapur Station.

From Fig 4.3.8(a) monthly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Anantapur station in monsoon season (June-September) for the year 2014 has been observed. The AWS Stations recoded near to IMD manual Record all four months. July month AWS cumulative rainfall is high 33.5mm is high recorded DES but AWS is recorded as 142.35 mm. August month cumulative high rainfall is 118 mm recorded IMD but AWS is recorded as 67.5 mm and DES 100.6mm recorded.

From Fig 4.3.8(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Anantapur Station is 0.572 Correlation coefficient (r) AWS & IMD has calculated for Anantapur rainfall 0.75 for the period of (June -September), AWS & DES 0.85.

4.3.9 Monthly Cumulative Rainfall for the station Tirupathi.

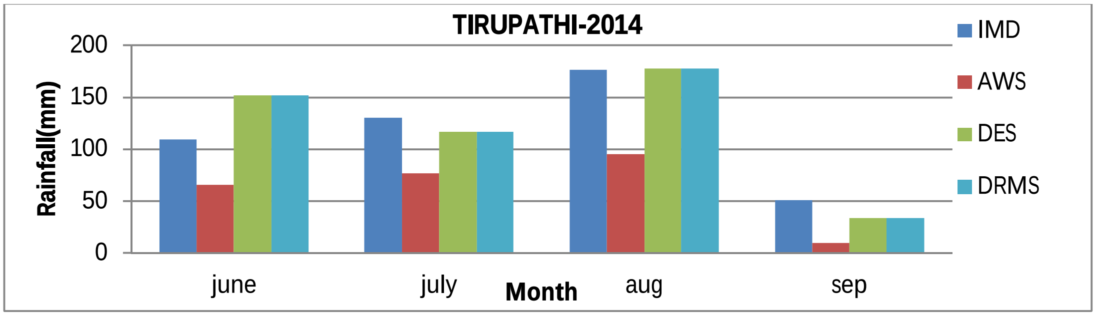


Fig 4.3.9(a) monthly cumulative rainfalls over Tirupathi Station in the year 2014

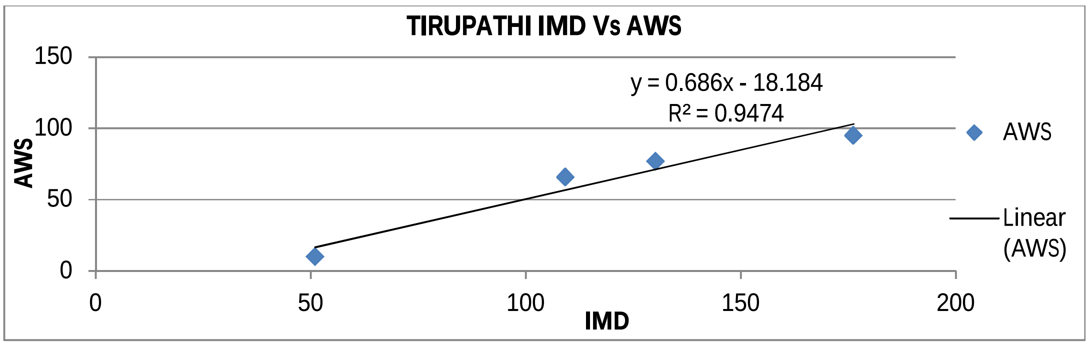


Fig 4.3.9(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Tirupathi Station.

From Fig 4.3.9(a) monthly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Tirupathi station in monsoon season (June-September) for the year 2014 has been observed. The AWS Stations recoded near to IMD manual Record all four months. August monthly cumulative rainfall is high 177.4 mm DES recorded but AWS is recorded as 95.5 mm and IMD 176.2 mm recorded.

From Fig 4.3.9(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Tirupathi Station is 0.947, Correlation coefficient (r) AWS & IMD has calculated for Tirupathi rainfall 0.97 for the period of (June -September), AWS & DES 0.93.

4.3.10 Monthly Cumulative Rainfall for the station Badrachalam.

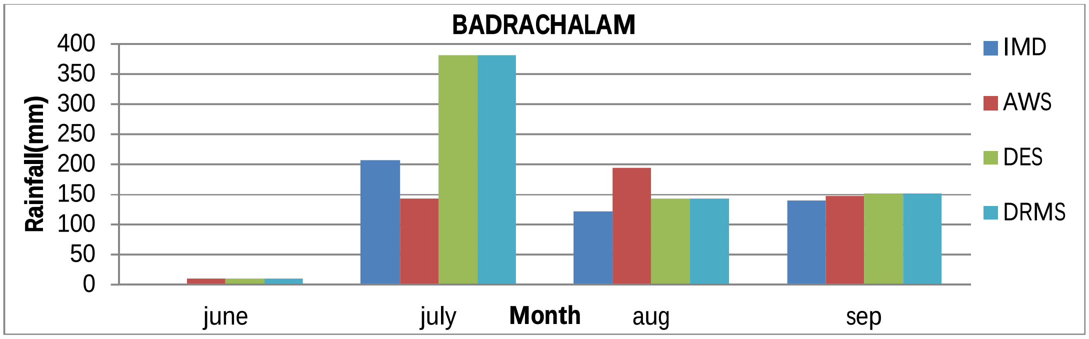


Fig 4.3.10(a) monthly cumulative rainfalls over Badrachalam Station in the year 2014

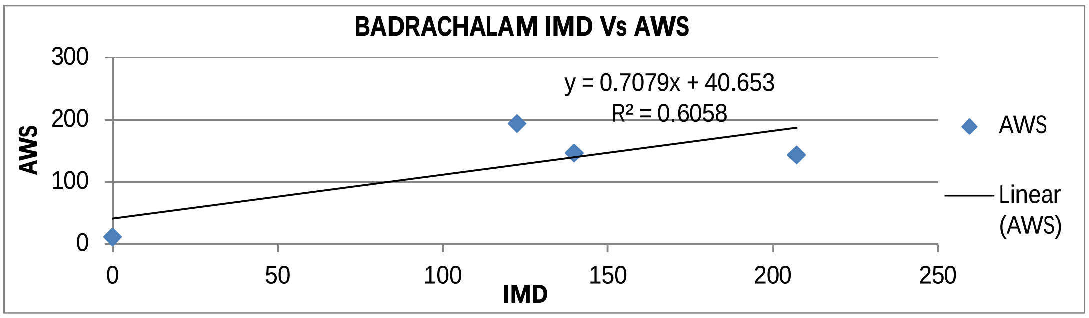


Fig 4.3.10(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Badrachalam Station.

From Fig 4.3.10(a) monthly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Badrachalam station in monsoon season (June-September) for the year 2014 has been observed. The AWS Stations recoded near to IMD manual Record all four months. June month is below 50 mm recorded over all manual station (IMD, DES & DRMS) and AWS, July monthly cumulative rainfall is high 381.4 mm recorded DES and DRMS but AWS is recorded as 143.25 mm. IMD 207.2 mm recorded. August month AWS rainfall is 193.8mm higher than the IMD 139.8mm and DES 151.8mm.

From Fig 4.3.10(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Badrachalam Station is 0.605, Correlation coefficient (r) AWS & IMD has calculated for Badrachalam rainfall 0.77 for the period of (June -September), AWS & DES 0.54.

4.3.11 Monthly Cumulative Rainfall for the station Medak.

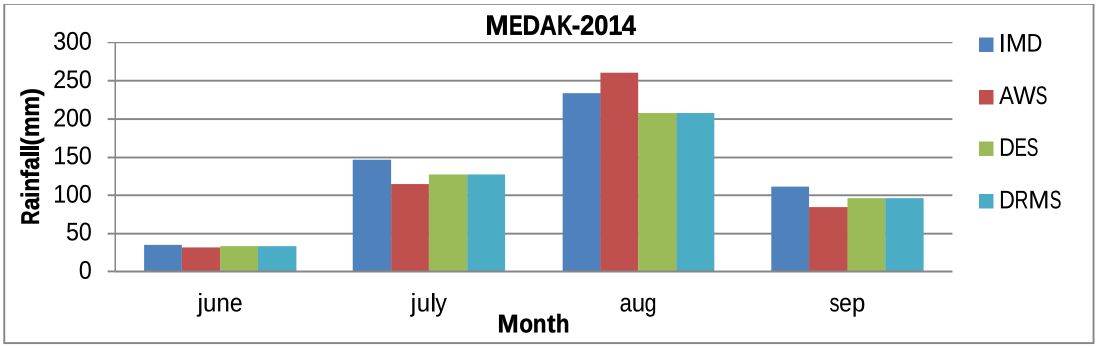


Fig 4.3.11(a) Monthly cumulative rainfalls over Medak Station in the year 2014

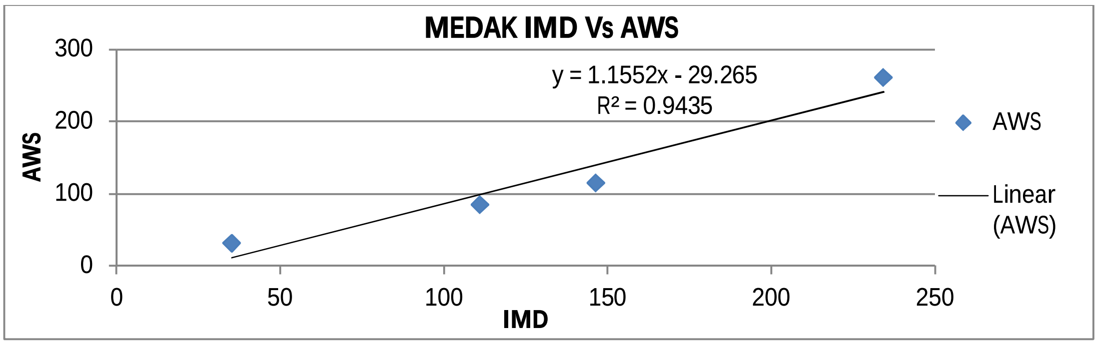


Fig 4.3.11(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Medak Station.

From Fig 4.3.11(a) monthly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Medak station in monsoon season (June-September) for the year 2014 has been observed. The AWS Stations recoded near to IMD manual Record all four months. June month is below 50 mm recorded over all manual station (IMD, DES & DRMS) and AWS, August monthly cumulative rainfall is high 261mm mm recorded AWS but IMD is recorded as 234.3mm and DES 208mm recorded.

From Fig 4.3.11(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Medak Station is 0.943, Correlation coefficient (r) AWS & IMD has calculated for Medak rainfall 0.97 for the period of (June -September), AWS & DES 0.97.

4.3.12 Monthly Cumulative Rainfall for the station Nizamabad.

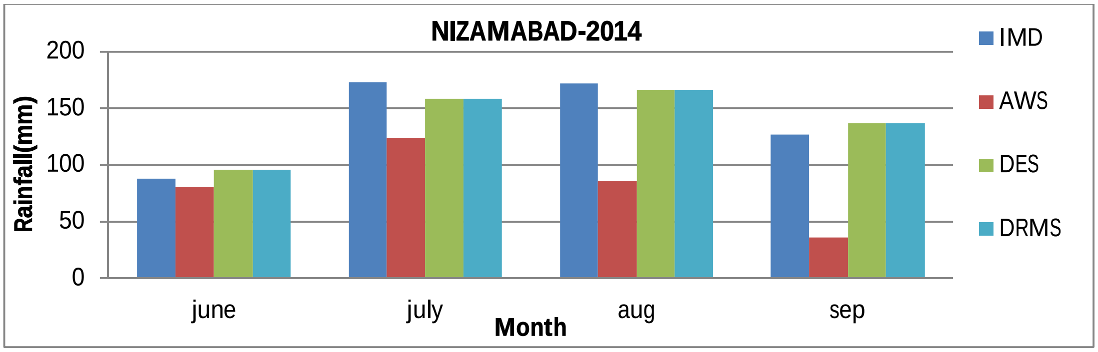


Fig 4.3.12(a) monthly cumulative rainfalls over Nizamabad Station in the year 2014

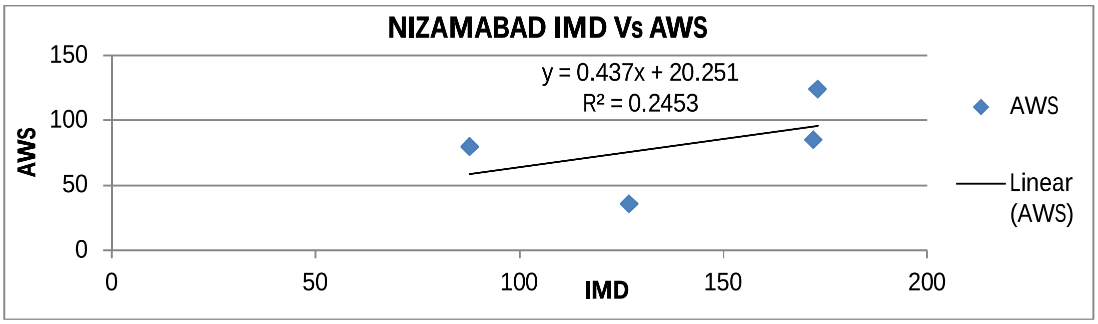


Fig 4.3.12(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014over Nizamabad Station.

From Fig 4.3.12(a) monthly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Nizamabad station in monsoon season (June-September) for the Year 2014has been observed. The AWS Stations recoded near to IMD manual Record all four months. July monthly cumulative rainfall is high 173.2 mm recorded IMD but AWS is recorded as 124.25 mm and DES 158.2mm recorded.

From Fig 4.3.12(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Nizamabad Station is 0.245, Correlation coefficient (r) AWS & IMD has calculated for Nizamabad rainfall 0.49 for the period of (June -September), AWS & DES 0.31.

4.3.13 Monthly Cumulative Rainfall for the station Ramagundam.

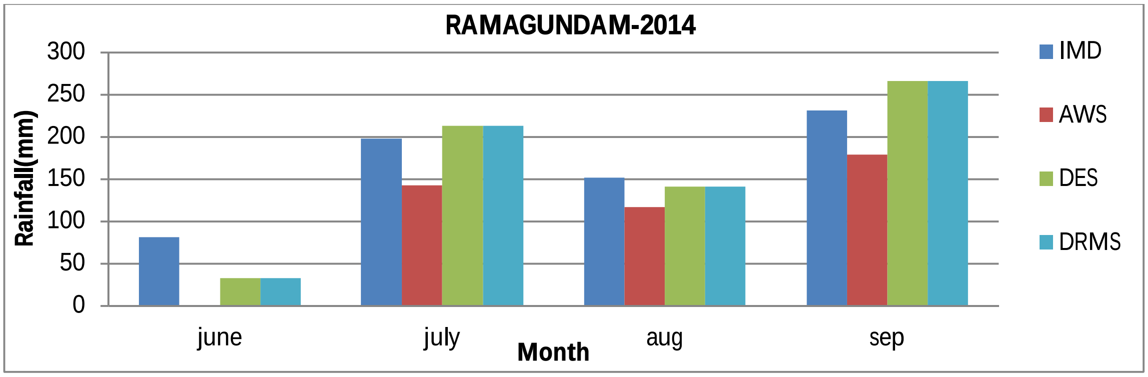


Fig 4.3.13(a) monthly cumulative rainfalls over Ramagundam Station in the year 2014

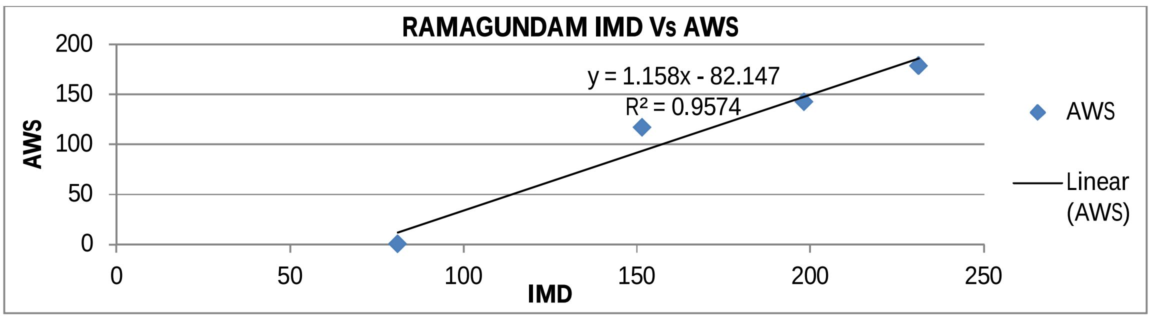


Fig 4.3.13(b) Regression plot between AWS and IMD Rainfall data (Jun-Sep) year 2014 over Ramagundam Station.

From Fig 4.3.13(a) monthly comparisons between AWS, IMD, DES and DRMS cumulative Rainfall over Ramagundam station in monsoon season (June-September) for the year 2014 has been observed. The AWS Stations recoded near to IMD manual Record all four months. The AWS Stations recoded near to IMD manual Record all four months. September monthly cumulative rainfall is high 266 mm recorded DES but AWS is recorded as 178.75 mm and IMD 231.3mm recorded.

From Fig 4.3.13(b) the R^2 value between AWS and IMD Rainfall data (Jun-Sep) Year 2014over Ramagundam Station is 0.957, Correlation coefficient (r) AWS & IMD has calculated for Ramagundam rainfall 0.97 period of (June -September), AWS & DES 0.97.

4.4 Andhra Pradesh State Weekly Averages using Grid Average Method (IDW):

Table 4.1 Andhra Pradesh State Weekly Averages using Grid Average Method (IDW):

DATE	IMD	IMD&DRMS	AWS	DES
Jun5-11	12.7	7.6	7.3	11.1
Jun12-18	4.3	2.0	2.1	2.5
Jun19-25	2.3	2.5	2.0	2.7
Jun26-Jul2	16.0	9.3	7.9	11.4
Jul3-9	48.2	22.7	18.8	33.4
Jul10-16	32.4	17.4	15.8	30.3
Jul17-23	7.4	7.7	5.9	12.5
Jul24-30	36.6	24.5	20.0	40.0
Jul31-Aug6	2.1	6.6	5.8	9.0
Aug7-13	17.0	10.5	10.7	17.5
Aug14-20	23.7	16.6	16.8	26.5
Aug21-27	46.4	28.5	27.8	48.1
Aug28-Sep3	42.4	24.4	21.5	41.9
Sep4-10	13.3	14.1	13.8	24.9
Sep11-17	50.7	19.1	20.6	40.9
Sep18-24	35.3	19.1	17.7	35.0

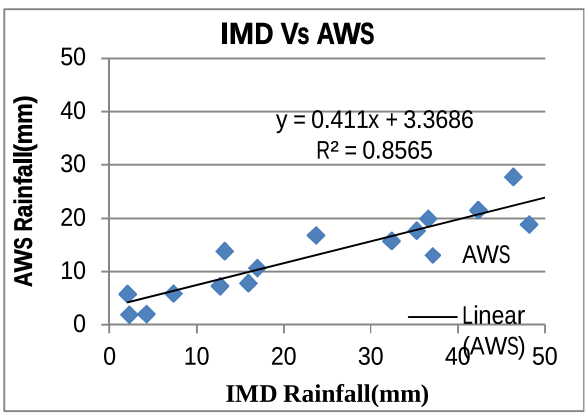


Fig 4.4.1 IMD and AWS Regression plot

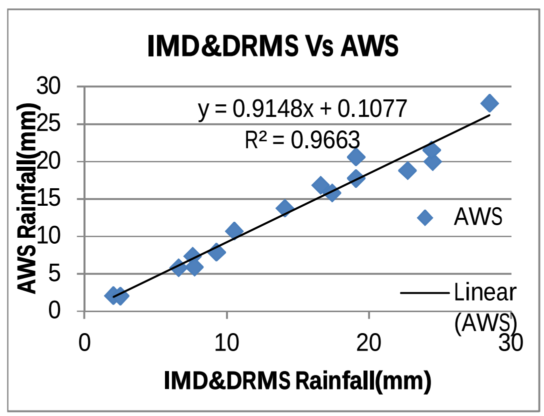


Fig 4.4.2 IMD&DRMS and AWS Regression plot

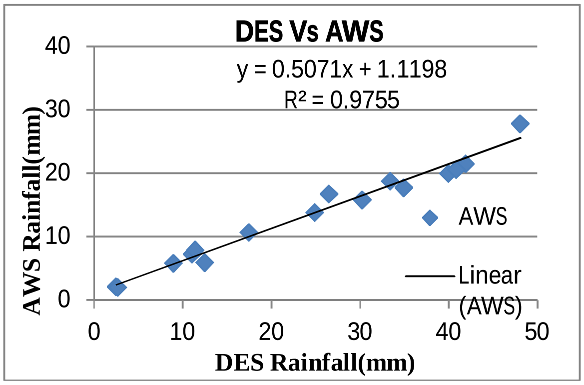


Fig 4.4.3 DES and AWS Regression plot

Table 4.2 Andhra Pradesh State Averages Weekly grid Data Correlations(r).

Correlation(r)		
IMD Vs AWS	IMD&DRMS Vs AWS	DES Vs AWS
0.92	0.98	0.98

From Table: 4.1 shows State wise cumulative rainfall converted to grid average Inverse Distance Weighting (IDW) based all 16 weeks average in manual & automatic. IMD compared with AWS is underestimated. IMD&DRMS is good signification total all weeks and IMD and DES is signification levels is accurate. The total state averages correlation is IMD and AWS 0.92, IMD&DRMS and AWS Correlation 0.98 and DES and AWS Correlation 0.98.

4.5 Andhra Pradesh State Averages using Grid Average Method (IDW):

Table 4.3 Andhra Pradesh State Averages using Grid Average Method (IDW)

	June01-June15	June01-June30	June01-July15	June01-July31	June01-Aug15	June01-Aug31	June01-Sep15	June01-Sep30
IMD	28.4	47.6	128.1	172.0	197.8	305.8	351.3	416.2
IMD & DRMS	33.2	49.8	114.4	75.5	208.8	314.8	366.1	432.9
AWS	17.5	27.7	61.7	89.4	107.9	168.0	196.0	229.8
DES	29.1	43.0	105.3	161.2	191.1	296.4	347.9	414.2

From Table: 4.3 State wise cumulative rainfall converted to grid average Inverse Distance Weighting (IDW) based every 15 days in manual & automatic. Every 15 days grid average cumulative rainfall IMD, IMD&DRMS and DES compared with AWS is underestimated. The total four months total AWS is recorded 229.8mm, IMD 416.2mm, IMD&DRMS 432.9mm and DES 414.2mm recorded. Over all AWS in understand to all manual recorded.

4.6 Telangana State Weekly Averages using Grid Average Method (IDW):

Table 4.4 Telangana State Weekly Averages using Grid Average Method (IDW):

DATE	IMD	IMD&DRMS	AWS	DES
Jun5-11	1.7	3.4	2.6	2.7
Jun12-18	20.7	16.4	12.2	20.4
Jun19-25	5.8	6.8	5.9	7.3
Jun26-Jul2	13.1	8.0	6.6	8.0
Jul3-9	48.9	27.3	22.2	35.7
Jul10-16	33.9	18.5	18.3	34.8
Jul17-23	21.0	10.1	10.3	20.1
Jul24-30	59.9	33.4	30.9	55.2
Jul31-Aug6	14.9	11.4	12.6	17.5
Aug7-13	18.5	6.5	8.1	11.3
Aug14-20	9.8	6.4	6.1	9.4
Aug21-27	65.4	31.1	32.6	51.5
Aug28-Sep3	78.8	65.3	63.8	112.3
Sep4-10	43.5	29.8	32.5	63.3
Sep11-17	45.9	17.7	18.2	33.7
Sep18-24	28.6	11.3	10.8	20.8

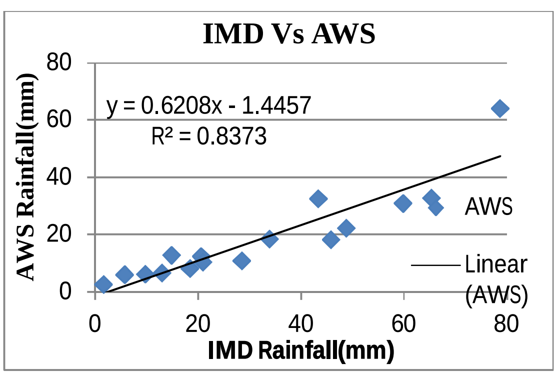


Fig 4.6.1 IMD and AWS Regression plot

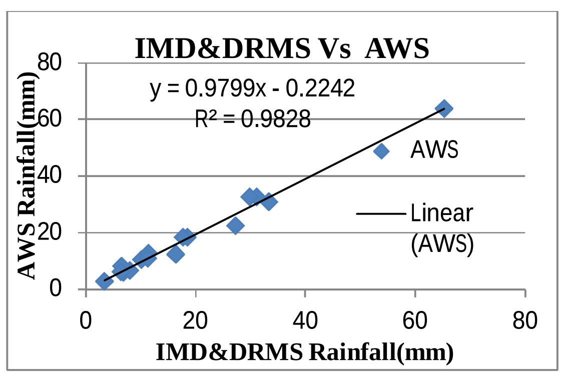


Fig 4.6.2 IMD&DRMS and AWS Regression Plot

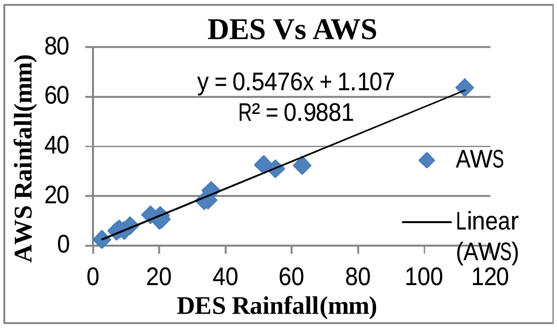


Fig 4.6.3 DES and AWS Regression plot

Table 4.5 Telangana State Averages Weekly grid Data Correlations(r).

Correlation(r)		
IMD Vs AWS	IMD&DRMS Vs AWS	DES Vs AWS
0.91	0.99	0.99

From Table: 4.4 State wise cumulative rainfall converted to grid average Inverse Distance Weighting (IDW) all 16 weeks average in manual & automatic. IMD compared with AWS is underestimated. IMD&DRMS is good signification total all weeks and IMD and DES is signification levels is good. The total state averages correlation is IMD and AWS 0.91, IMD&DRMS and AWS Correlation 0.99 and DES and AWS Correlation 0.99.

4.7 Telangana State Averages using Grid Average Method (IDW):

Table 4.6 Telangana State Averages using Grid Average Method (IDW):

	June01-June15	June01-June30	June01-July15	June01-July31	June01-Aug15	June01-Aug31	June01-Sep15	June01-Sep30
IMD	23.9	53.9	134.4	220	253.4	411.1	502.6	548.9
IMD & DRMS	28.8	59.6	132.6	221.8	251.1	416.2	519.7	558.6
AWS	16.7	36.0	74.8	119.8	139.9	232.8	285.2	304.9
DES	24.7	52.6	118.3	201.1	229.0	384.4	484.3	521.2

From Table: 4.6 State wise cumulative rainfall converted to grid average Inverse Distance Weighting (IDW) every 15 days in manual & automatic. Every 15 days grid average cumulative rainfall IMD, IMD&DRMS and DES compared with AWS is underestimated. The total four months total AWS is recorded 304.9mm, IMD 548.6mm, IMD&DRMS 558.6mm and DES 521.2mm recorded. Over all AWS in understand to all manual recorded.

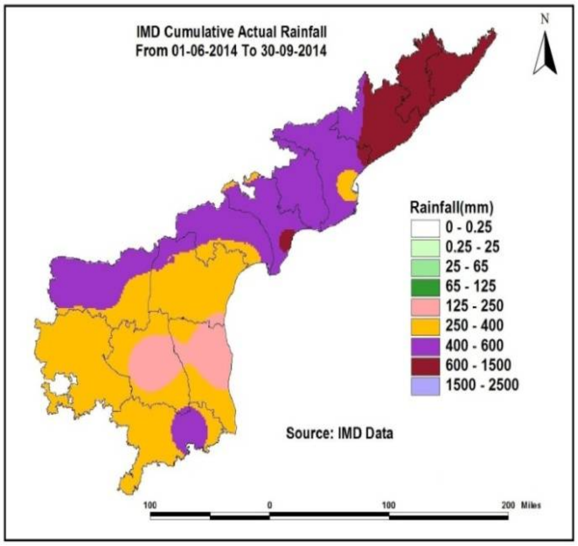
Table 4.7 Status of AWS and IMD Rainfall Different Methods of Averaging.

Status of Rainfall Using Different method of Averaging																			
		AWS With Thiessen Based DES Normals				Normals			Normals			DES With Thiessen Based DES Normals				IMD With IMD Normals			
S.No	District	AWS Cumulative Actual Rainfall	Cumulative normal Rainfall(Thiessen based)	% Deviation	Status W.r.t Theissian based normal	DES Normal Arithmetic Average based	% Deviation w.r.t DES Normal	Status w.r.t. DES Arithmetic (Average based Normal)	DES Cumulative Actual (Arithmetic Ave	% Deviation w.r.t DES Normal	Status w.r.t. DES Arithmetic (Average	DES Cumulative Actual	Cumulative Normal Rainfall (Theissen based)	% Deviation w.r.t DES Normal	w.r.t. DES Arithmetic Average based	Cumulative Actual Rainfall	Cumulative IMD Normal Rainfall	% Deviation w.r.t IMD Normal	Status
1	ADILABAD	355.5	1170.7	-70	Scanty	1165.9	-70	Scanty	699.4	-40	Deficient	699.4	1170.4	-40	Deficient	695.8	959.4	-27	Deficient
2	ANANTAPUR	141.3	286.1	-51	Deficient	286.6	-51	Deficient	193	-33	Deficient	193	286.1	-33	Deficient	307.8	310.3	-1	Normal
3	CHITTOOR	200.3	393	-49	Deficient	397.8	-50	Deficient	348.1	-13	Deficient	348.1	393	-11	Normal	378.6	377.6	0	Normal
4	EAST GODAVARI	284	820.8	-65	Scanty	789.5	-64	Scanty	488.6	-38	Deficient	488.6	820.8	-40	Deficient	494.3	709.5	-30	Deficient
5	GUNTUR	188	505.3	-63	Scanty	518.9	-64	Scanty	411.4	-21	Deficient	411.4	505.3	-19	Normal	415.4	567.4	-27	Deficient
6	KADAPA	170.6	372.7	-54	Deficient	374.8	-54	Deficient	251.7	-33	Deficient	251.7	372.7	-32	Deficient	135.2	383.9	-65	Scanty
7	KARIMNAGAR	370.8	986.6	-62	Scanty	956.4	-61	Scanty	557.1	-42	Deficient	557.1	986.6	-44	Deficient	662	819	-19	Deficient
8	KHAMMAM	284.2	1074	-74	Scanty	1034.8	-73	Scanty	637.6	-38	Deficient	637.6	1074	-41	Deficient	234.7	866.5	-73	Scanty
9	KRISHNA	281	730.5	-62	Scanty	726.6	-61	Scanty	558.8	-23	Deficient	558.8	730.5	-24	Deficient	547	700.5	-22	Deficient
10	KURNOOL	204.7	435.9	-53	Deficient	444.7	-54	Deficient	451.7	2	Normal	451.7	435.9	-4	Normal	474.3	457.4	4	Normal
11	MAHABUBNAGAR	253.1	483.5	-48	Deficient	482.9	-47	Deficient	408.6	-15	Normal	408.6	483.5	-15	Normal	722.4	587.7	-23	Deficient
12	MEDAK	375.2	771.5	-51	Deficient	772.4	-51	Deficient	394.9	-49	Deficient	394.9	771.5	-49	Deficient	593.55	789.7	-25	Deficient
13	NALGONDA	179.8	566.3	-68	Scanty	583.2	-69	Scanty	320.6	-45	Deficient	320.6	566.3	-43	Deficient	414.8	545.9	-24	Deficient
14	NELLORE	174.8	317	-45	Deficient	314	-44	Deficient	232.3	-26	Deficient	232.3	317	-27	Deficient	192.6	317.2	-39	Deficient
15	NIZAMABAD	353.7	981.4	-64	Scanty	988.9	-64	Deficient	456.2	-54	Deficient	456.2	981.4	-54	Deficient	560.2	928.8	-40	Deficient
16	PRAKASAM	154.9	347.3	-55	Deficient	342.9	-55	Deficient	256.6	-25	Deficient	256.6	347.3	-26	Deficient	284.1	393.5	-28	Deficient
17	RANGA REDDY	302.9	626.9	-52	Deficient	639.4	-53	Deficient	439.8	-31	Deficient	439.8	626.9	-30	Deficient	554.6	657.8	-16	Normal
18	SRIKAKULAM	410.6	694.9	-41	Deficient	693.4	-41	Deficient	847.4	-22	Deficient	847.4	694.9	-22	Deficient	619.7	725.8	-15	Normal
19	VISAKHAPATNAM	340.7	795.2	-57	Deficient	715.7	-52	Deficient	723.6	1	Normal	723.6	795.2	-9	Normal	726.8	657	11	Normal
20	VIZIANAGARAM	432.8	688.6	-37	Deficient	677.7	-36	Deficient	648.1	-4	Normal	648.1	688.6	-6	Normal	654.7	719	-9	Normal
21	WARANGAL	334.6	991.3	-66	Scanty	944.6	-65	Scanty	582.7	-38	Deficient	582.7	991.3	-41	Deficient	505.1	805.5	-37	Deficient
22	WEST GODAVARI	340.1	854.8	-60	Scanty	847	-60	Scanty	594.8	-30	Deficient	594.8	854.8	-30	Deficient	584.8	757.2	-23	Deficient

Table 4.8 Status of AWS and IMD&DRMS Rainfall using Different Methods of Averaging.

		AWS With Thessian Based DRMS Normals				AWS With Aritmetic Based DRMS Normals			DRMS With Aritmetic Based DRMS Normals			DRMS With Thessian Based DRMS Normals			
S.No	District	AWS Cumulative Actual Rainfall	DRMS Cumulative normal Rainfall(Thessian based)	% Deviation	Status W.r.t Theissian based normal	DRMS Normal Arithmetic Average based	% Deviation w.r.t DRMS Normal	Status w.r.t. DRMS Arithmetic (Average based Normal)	DRMS Cumulative Actual (Arithmetic Ave based)	% Deviation w.r.t DRMS Normal	Status w.r.t. DRMS Arithmetic (Average based Normal)	DRMS Cumulative Actual	Cumulative Normal Rainfall (Theissen based)	% Deviation w.r.t DRMS Normal	Status w.r.t. DRMS Arithmetic Average based Normal
1	ADILABAD	355.5	1179.6	-70	Scanty	1185	-70	Scanty	693.7	-41	Deficient	693.7	1179.6	-41	Deficient
2	ANANTAPUR	141.3	306.3	-54	Deficient	292.3	-52	Deficient	214.3	-27	Deficient	214.3	306.3	-30	Deficient
3	CHITTOOR	200.3	407.7	-51	Deficient	410.2	-51	Deficient	326.7	-20	Deficient	326.7	407.7	-20	Deficient
4	EAST GODAVARI	284	792.5	-64	Scanty	765.6	-63	Scanty	492.9	-36	Deficient	492.9	792.5	-38	Deficient
5	GUNTUR	188	535.8	-65	Scanty	543.2	-65	Scanty	455.2	-16	Normal	455.2	535.8	-15	Normal
6	KADAPA	170.6	386.1	-56	Deficient	384.3	-56	Deficient	272.7	-29	Deficient	272.7	386.1	-29	Deficient
7	KARIMNAGAR	370.8	1056.4	-65	Scanty	1052.9	-65	Scanty	595.7	-43	Deficient	595.7	1056.4	-44	Deficient
8	KHAMMAM	284.2	1028.1	-72	Scanty	1076	-74	Scanty	725.6	-33	Deficient	725.6	1028.1	-29	Deficient
9	KRISHNA	281	728.4	-61	Scanty	726.4	-61	Scanty	563.9	-22	Deficient	563.9	728.4	-23	Deficient
10	KURNOOL	204.7	434.3	-53	Deficient	438.9	-53	Deficient	445.8	2	Normal	445.8	434.3	3	Normal
11	MAHABUBNAGAR	253.1	516.5	-51	Deficient	515.9	-51	Deficient	506	-2	Normal	506	516.5	-2	Normal
12	MEDAK	375.2	801.9	-53	Deficient	817.8	-54	Deficient	474.5	-42	Deficient	474.5	801.9	-41	Deficient
13	NALGONDA	179.8	562.8	-68	Scanty	526.7	-66	Scanty	349.6	-34	Deficient	349.6	562.8	-38	Deficient
14	NELLORE	174.8	338.0	-48	Deficient	343.4	-49	Deficient	301.9	-12	Normal	301.9	338.0	-11	Normal
15	NIZAMABAD	353.7	1001.3	-65	Scanty	1014.7	-65	Scanty	475.2	-53	Deficient	475.2	1001.3	-53	Deficient
16	PRAKASAM	154.9	378.2	-59	Deficient	335.2	-54	Deficient	279.7	-17	Normal	279.7	378.2	-26	Deficient
17	RANGA REDDY	302.9	652.2	-54	Deficient	649.6	-53	Deficient	490	-25	Deficient	490	652.2	-25	Deficient
18	SRIKAKULAM	410.6	701.4	-41	Deficient	703.2	-42	Deficient	837.1	19	Normal	837.1	701.4	-19	Deficient
19	VISAKHAPATNAM	340.7	729.8	-53	Deficient	703.4	-52	Deficient	689	-2	Normal	689	729.8	-6	Normal
20	VIZIANAGARAM	432.8	696.5	-38	Deficient	700.8	-38	Deficient	777.5	11	Normal	777.5	696.5	-12	Normal
21	WARANGAL	334.6	1036.0	-68	Scanty	1036.3	-68	Scanty	628.3	-39	Deficient	628.3	1036.0	-39	Deficient
22	WEST GODAVARI	340.1	853.1	-60	Scanty	854.2	-60	Scanty	613.4	-28	Deficient	613.4	853.1	-28	Deficient

4.8 Andhra Pradesh Actual Rainfall Spatial Maps (Jun-Sep) year 2014:



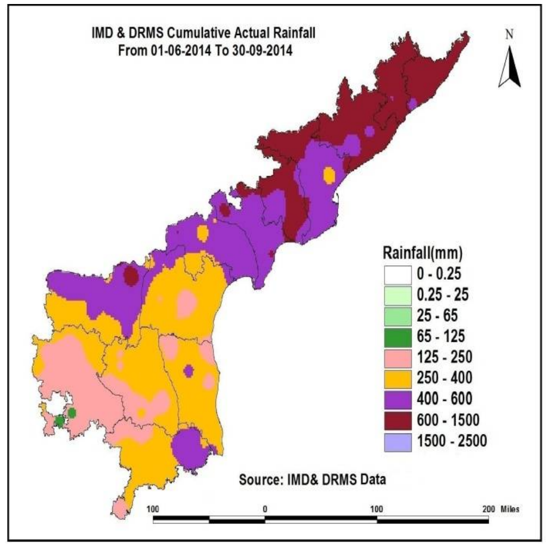
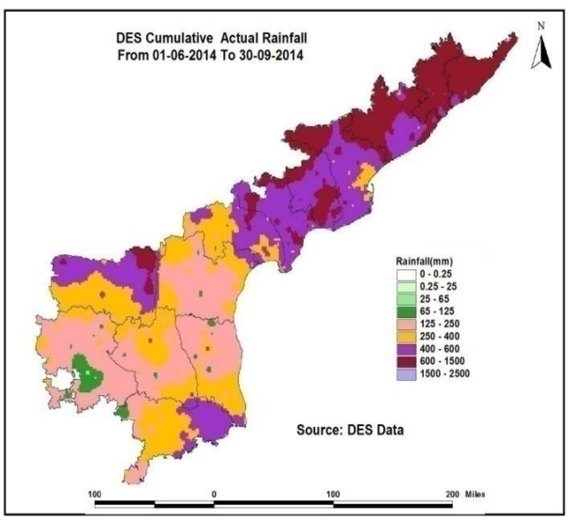


Fig 4 8.1 IMD Cumulative actual rainfall (Jun-Sep) year2014

Fig 4.8.2 IMD&DRMS Cumulative actual rainfall (Jun-Sep) year2014



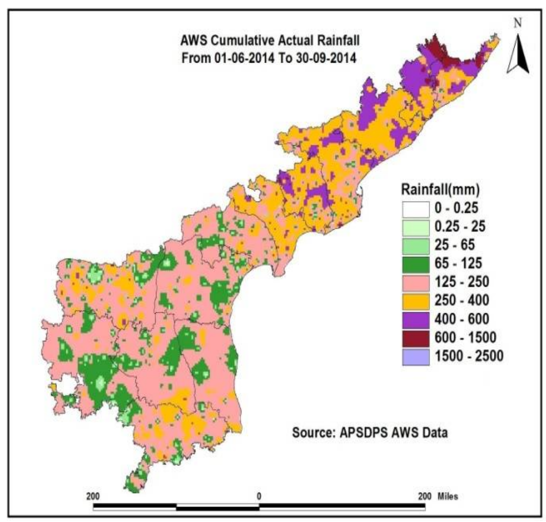


Fig 4.8.3 DES Cumulative actual rainfall (Jun-Sep) year 2014

Fig 4.8.4 AWS Cumulative actual rainfall (Jun-Sep) year 2014

Fig 4.8.1 shows IMD cumulative actual Rainfall From (June –Sep) for the year 2014, Srikakulam, Vizianagaram and Visakhapatnam very heavy rainfall recorded (600mm-1500mm), and central Andhra Pradesh and except east Godavari dist in Kakinada recorded (400mm-600mm), southern Andhra Pradesh except Nellore, Chittoor and Kadapa some areas Rainfall recorded (250mm-400mm).

Fig 4.8.2 shows IMD&DRMS cumulative actual Rainfall from (June-Sep) for the year 2014. North Andhra Pradesh Srikakulam, Vizianagaram and Visakhapatnam except Visakhapatnam small area rainfall recorded (600mm-1500).and central Andhra Pradesh except west Godavari some areas rainfall recorded (400mm-600mm). South Andhra Pradesh except Anantapur district Somany parts rainfall recorded (250mm-400mm).

Fig 4.8.3 shows DES cumulative actual rainfall from (June-Sep) for the year 2014. North Andhra Pradesh except east coast Visakhapatnam Ares rainfall recorded (600mm-1500mm), Central Andhra Pradesh except east of east Godavari area rainfall recorded (400mm-600mm) and south Andhra Pradesh Chittoor and Kurnool districts rainfall recorded (125mm-250mm).

Fig 4.8.4 shows AWS cumulative actual rainfall from (June-September) for the year 2014. North Andhra Pradesh except west side of Srikakulam, Vizianagaram and Visakhapatnam parts rainfall recorded (250mm-400mm).central Andhra Pradesh except Guntur district rainfall recorded (250mm-400mm).and south Andhra Pradesh except Chittoor, Kadapa, Anantapur and Kurnool districts small areas rainfall recorded (125mm -520mm).

4.8.1 Andhra Pradesh %Deviation Actual from Normal Rainfall Spatial Maps (Jun-Sep) year 2014:

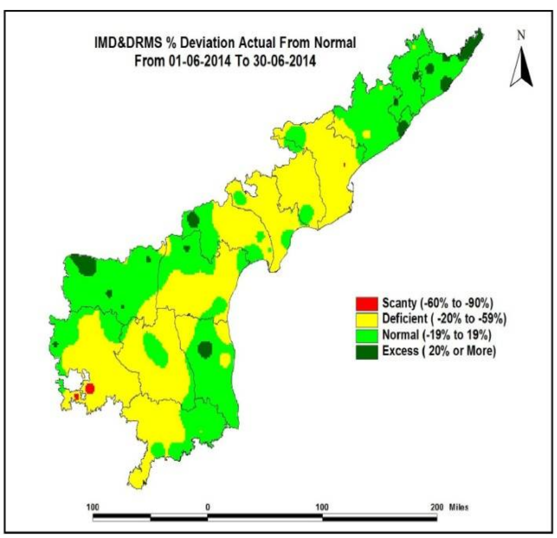


Fig 4.8.1(a) IMD&DRMS % Deviation actual from normal (Jun-Sep) year 2014

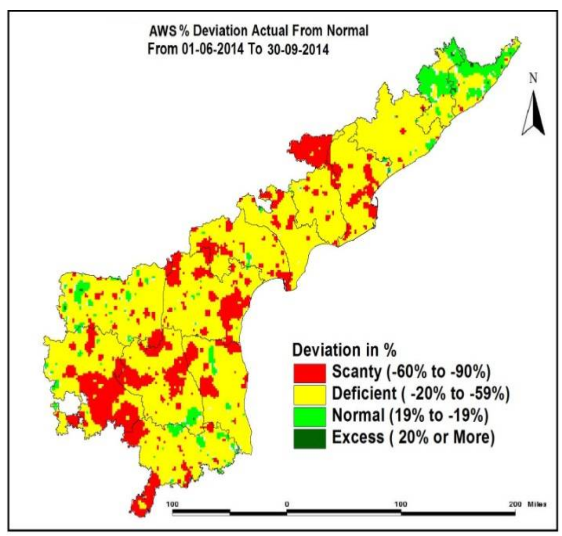


Fig4.8.1 (b) AWS % Deviation actual From normal (Jun-Sep) year 2014

Fig 4.8.1(a) shows IMD&DRMS % Deviation actual from normal from 01-06-2014 to 30-09-2014. North Andhra Pradesh districts except North part of Srikakulam and some areas total

Normal (19% to -19%) rainfall Recorded, East Godavari, West Godavari, Krishna, Guntur and except Prakasham district some areas Deficient rain fall recorded. South Andhra Pradesh except Nellore and Kurnool districts Deficient (-20% to -59%) Rainfall recorded.

Fig 4.8.1(b) shows AWS % Deviation actual from normal from 01-06-2014 to 30-09-2014.North Andhra Pradesh except Srikakulam district north part of mandals and Vizianagaram some mandals except Deficient(-20% to -59) rain fall recorded. Central Andhra Pradesh except east Godavari, west Godavari some mandals and Krishna some mandals deficient (-20% to -59%) Rainfall recorded. And south Andhra Pradesh Anantapur, Chittoor and Kadapa some mandals scanty Rainfall (-60% to -90%) rainfall recorded.

4.9 Telangana State Actual Rainfall Spatial Maps (Jun-Sep) year 2014:

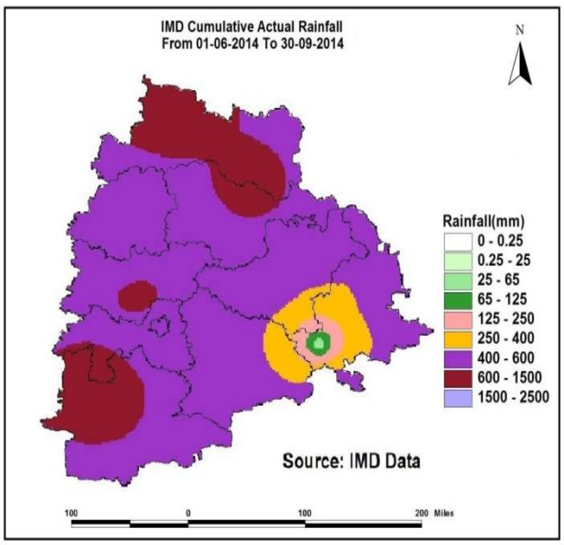


Fig 4.9.1 IMD Cumulative actual rainfall (Jun-Sep) year 2014

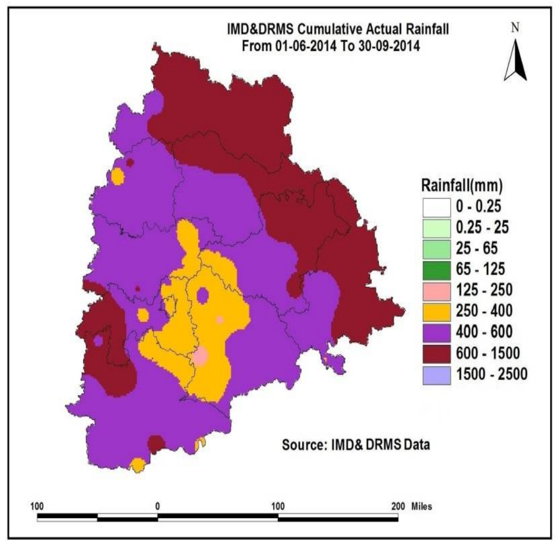
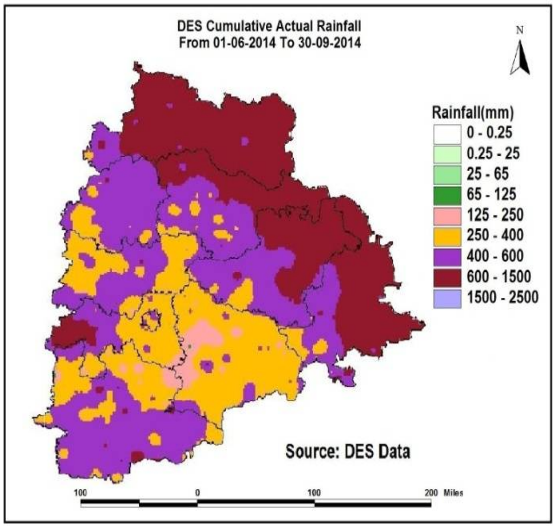


Fig 4.9.2 IMD&DRMS Cumulative actual rainfall (Jun- Sep) year 2014



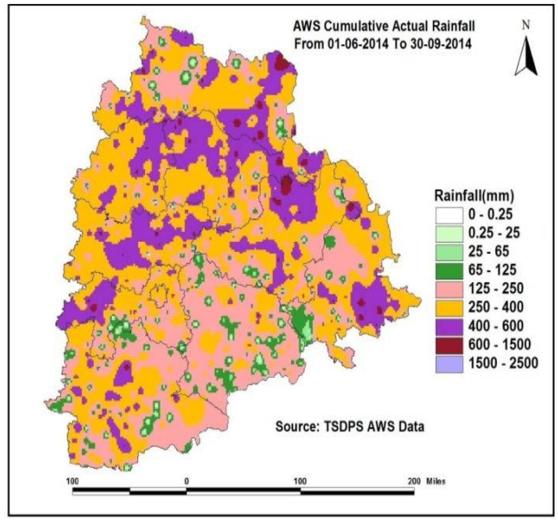


Fig 4.9.3 DES Cumulative actual rainfall (Jun-Sep) year 2014

Fig 4.9.4 AWS Cumulative actual rainfall (Jun-Sep) year 2014

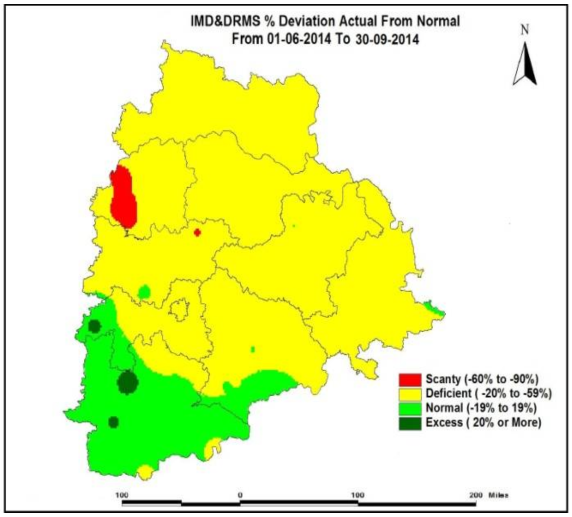
From Fig 4.9.1 shows IMD cumulative actual rainfalls from (June-September) for the year 2014. North part Telangana except Adilabad rainfall recorded (400mm-600mm). Badrachalam surround areas rainfall recorded (250mm-400mm) and southern part of Telangana except Mahabubnagar district west side rainfall recorded (400mm-600mm).

From Fig 4.9.2 shows IMD&DRMS cumulative actual rainfall from (June-September) for the year 2014. North Telangana rainfall recorded (600mm-1500mm), central Telangana Nalgonda, Hyderabad, Medak dew areas rainfall recorded (250mm-400mm).

From Fig 4.9.3 shows DES cumulative actual rainfalls from (June-September) for the year 2014. North Telangana rainfall recorded (600mm-1500mm), south of Telangana Mahabubnagar 400mm-600mm rainfall recorded. Central Telangana Hyderabad, Nalgonda districts and rainfall recorded 250mm-400mm.

From Fig 4.9.4 shows AWS cumulative actual rainfall from (June-September) for the year 2014. South Telangana Rainfall recorded except Mahabubnagar some mandals and Nalgonda rainfall recorded 125mm-250mm. west of Telangana except some mandals of Medak and Nizamabad rainfall recorded 250mm-400mm.

4.9.1 Telangana State %Deviation Actual from Normal Rainfall Spatial Maps (Jun-Sep) year 2014:



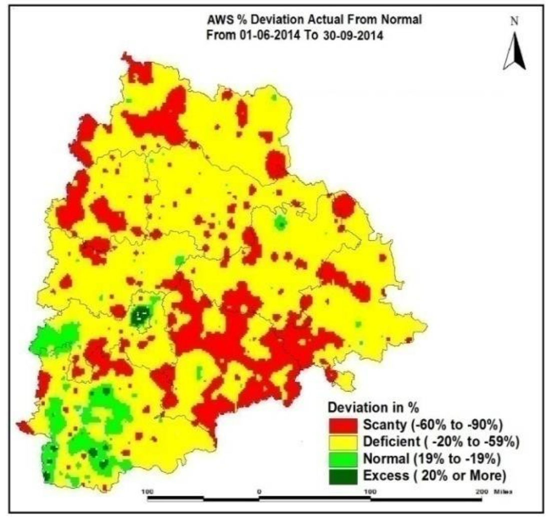


Fig 4.9.1(a) IMD&DRMS %Deviation actual from Normal (Jun-Sep) year 2014

Fig 4.9.1(b) AWS %Deviation actual from Normal (Jun-Sep) year 2014

From Fig 4.9.1(a) shows IMD&DRMS % Deviation actual from normal from 01-06-2014 to 30-09-2014. Telangana state Total Deficient Rainfall (-20%To-59%) recorded. Except Mahabubnagar district normal rainfall (19% to -19%) recorded. And Medak some mandals Scanty Rainfall (-60% to -90%) recorded.

From Fig 4.9.2(a) shows AWS % Deviation actual from normal from 01-06-2014 to 30-09-2014. Total Telangana Mostly Recorded Deficient (-20% to -59) Rainfall recorded. Except Nalgonda, Mahabubnagar, Khammam, Adilabad, Warangal and Medak some mandals scanty Rainfall (-60% to -90%) recorded.

For understanding the spatial distribution of rainfall over Andhra Pradesh and Telangana state surrounding during the period of (June-September) year (2014), the composite has plotted for entire season (Jun-Sep) cumulative rainfall IMD, DES, IMD&DRMS and AWS actual and Deviation. AWS stations identify scanty, deficient, normal and excess.

CHAPTER-5

CONCLUSIONS:

- As per the Graphs the rainfall trends were similar, though AWS recorded less rainfall than the conventional observations (IMD & DES & DRMS). This minor deviation may be mainly due to the fact that these stations are not Co-terrain.
- Daily IMD and AWS correlation coefficients Rentachintala (0.94), Ramagundam (0.92) and Tuni (0.91), Weekly IMD and AWS correlation coefficients Tuni (0.99), Rentachintala (0.97) and Tirupathi (0.96) are significant.

  Monthly IMD and AWS Correlation coefficients Tuni (0.99), Tirupathi (0.97), Ramagundam, Medak (0.97) and Kakinada (0.96) are significant. This shows AWS data is very relevant.
- Poor correlation exhibited near Badrachalam need to be studied further, as the correlation between AWS & manual gauges is good at other places.
- Inverse Distance Weighting (IDW) areal rainfall averages using grid average Andhra Pradesh Correlation Coefficients IMD and AWS 0.92, IMD&DRMS and AWS Correlation 0.98 and DES and AWS Correlation 0.98 significant.
- Inverse Distance Weighting (IDW) areal rainfall averages using grid average Telangana State Correlation Coefficients IMD and AWS 0.91, IMD&DRMS and AWS Correlation 0.99 and DES and AWS Correlation 0.99 significant.
- Dense AWS network is use full in understanding the rainfall phenomena better comparative IMD&DRMS network with less number of stations.
- Grid based averaging to convert point Rainfall to areal Rainfall is best suited. The arithmetic averaging being used by IMD & DES may not provide better picture due to the fact that the spatial rainfall variation is more across the state.
- AWS data shall also be included along with IMD data to provide better estimation of areal rainfall for districts as well as to the states.
- To accurately represent Drought conditions in all Mandals which is most important for agricultural and planning purposes AWS data is appearing more promising than other data sets..
- That results into systematic errors subject to wind field distortions along the gauge orifice. Such types of comparisons are very important for data quality control and standardization of. Since the Automatic gauge uses the tipping bucket mechanism, and

the rainfall in the tropics is mostly of showery type, there is also the possibility of overflow of the water collected due to the delay of the tipping hence a lower recording than actual.

- AWS data rainfall data more reliable for the agriculture purpose. Since coverage area is more total numbers of rain gauges more all so it is useful to small areas.
- Several studies showed that Tipping Bucket Rainguage data are corrupted by errors, both random and systematic. The systematic error is the most significant source of error and includes losses due to wind, wetting, evaporation, and splashing. Transforming the time-recorded number of tips into rainfall intensities can be made on different time scales to provide rainfall data products for numerous applications.
- A Tipping bucket rain gauge is used for measurement of rainfall in automatic weather station (AWS). The collector diameter is 2 inches and the resolution of the gauge is 0.25 mm, this may be one of the reason to get AWS trends are smaller than IMD.

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