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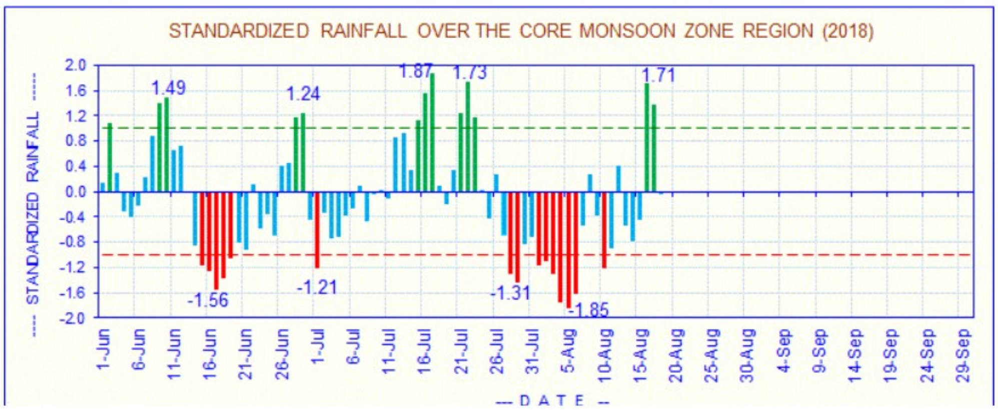

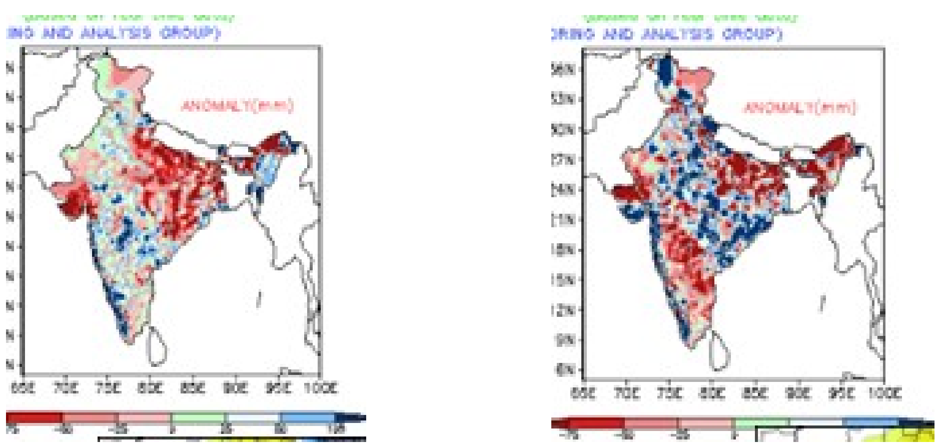

Spatial distribution of rainfall anomaly in the month of June (left) and July (right). Red color indicates rainfall lower than normal (Figure taken from IMD website www.imd.gov.in).

 Water spout at Nazare dam on 8 June 2018

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Bulletin of IMSP

August 2018

Contents

Mid season summary of Monsoon 2018

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Abstract

Mid season summary of monsoon 2018 is presented in this paper. In the month of May, two cyclonic storms developed over Arabian Sea (AS) on 19 and 22 May. These storms moved westward towards Yemen coast. A deep depression developed on 29 May off the coast of Myanmar. Onset of monsoon over Kerala occurred on 29 May, three days early from its normal date 1 June. A low pressure system (LPS) prevailed during 9-10 June over NE Bay of Bengal (BoB) and intensified in to depression on 11 June. The depression moved to Bangladesh on 13 June. The activity of monsoon remained subdued during 14-25 June. This period is considered as first break period, though theoretically break is called when the monsoon is established over the country. Monsoon covered the country by 29 June earlier than normal date. Country as a whole June rainfall was -5.1% of long period average (LPA). During first week of July, the monsoon trough shifted to foot of Himalayas. The monsoon activity remained subdued. Monsoon activity revived due to formation of LPS. There were six LPS and one depression in this month. In spite of these LPS and depression, the July rainfall was -5.8% of LPA. Every monsoon is unique and poses some problems for future studies. These have been enumerated in the summary section.

1. Introduction

The 90% economy of India is dependent on the southwest monsoon season June to September. The characteristics of the southwest monsoon viz. its arrival, onset at the southern tip of India, its day to day northward progress and its activity are not unique. They do not behave systematically following any mathematical/statistical/stochastic model. So every year it is a topic of interest to all meteorologists.

The farmers are eagerly waiting for the monsoon forecast as their farming activities very much depend on the onset and arrival of monsoon on their areas. In this paper, summary of monsoon behavior for the first two months is given.

2. Long range Monsoon forecast

This year the first forecast was given in the last week of April based on numerical and statistical models. The first stage forecast indicated for the country as a whole the monsoon seasonal rainfall will be 97% of the Long Period Average (LPA) with model error ±5 %. The LPA of the seasonal rainfall is 89 cm. The LPA is based on 50 years data 1951-2000. The region wise quantitative rainfall model forecast was as follows:

Northwest India 100; Northeast India 93; Central India 99; and Southwest Peninsula 95%.

From the point of view of the global warming effect, Wang et al. (2015) have predicted all India rainfall during 2018 to be 81.6 cm.

The second stage monsoon forecast was given on 31 May. As per second stage forecast monsoon season rainfall country as whole is likely to be 97% with model error of ± 4%. Region wise, monsoon rainfall is likely to be 100% over NW India, 99% over Central India, 95% over south peninsular India, and 93% over NE India with a model error of ± 8%. Rainfalls of July and August 2018 for the country as a whole will be 101 % and 94 % with model error ± 9% respectively.

3. May synoptic features

Monsoon circulation starts building up from the month of May. As the Arabian Sea (AS) surface temperatures are high (above threshold of 27^0C), and low wind shear in this month, the conditions are favorable for formation of cyclonic storms over the AS. Two cyclones formed over AS in the month of May. These are: Sagar and Mekunu. Sagar cyclone formed on 19 May in the northwest AS. It moved southwestward. Normally cyclone moves in the northward direction, but this seems to be exception.

Another cyclonic storm Mekunu formed on 22 May, it moved northward and intensified into very severe cyclonic storm at 1430 IST on 23 May. It further moved nearly northward with its center at 13.3 N, 55.5 E about 180 km, eastnorthwest of Socotra and 440 km southsoutheast of Salah (Oman) on 24 May. It weakened into deep depression on 27 May and further weakened into depression on 28 May.

Another system formed as deep depression over Bay of Bengal off the Myanmar coast in this month. It intensified into deep depression on 29 May.

4. Onset

The onset of monsoon over Kerala (MoK) was predicted by the forecast models as on 25 May 2018. Based on the study by Pai and Rajeevan (2007), the second forecast on 18 May 2018, stated that the MoK would be on 29 May, (with model error ± 4 days) three days early from its normal date 1 June. The onset of MoK occurred on 29 May, as predicted. Onset forecast over central India was given on May 7, 2018, to be on 15th June (with model error ± 4 days) using tipping element method (Veronika et al. 2016) by the scientist from Potsdam Institute for Climate Impact Research, Potsdam, Germany. As per their study the forecast made 40 days in advance was correct. Using the same technique, Elena Survytakina (email communication by secretary IMS) forecasted withdrawal date from central India as between 13-23 October.

5. June synoptic features

A low pressure system (LPS) formed over Bay of Bengal (BoB) on 9 June. Monsoon advanced to Odisha and Chattisgarh under the influence of the LPS. On 10 June LPS persisted over NE BoB and Bangladesh. On 11 June, low intensified in to depression. This was the first depression of the season. The depression moved north eastward and crossed the Bangladesh.

Monsoon circulation weakened on 13 June. The activity of monsoon remained subdued from 13 to 25 June due to weak monsoon flow in associations with (i) weak cross equatorial flow,

(ii) Unfavorable location of active phase of Madden Julian Oscillation (MJO) and
(iii) an equatorial eastwards propagating oscillation,which lay over central & east Pacific Oce an, Western Hemisphere and Africa.

Monsoon intraseasonal variability is governed by active and break conditions (Pai et al 2015). Figure 1 shows time series of daily all India rainfall anomaly (from IMD website www.imd.gov.in). Daily all Indian rainfall in the period 13 – June is below the climatological normal, hence may be called as first break period although strictly speaking, the break condition is called after the monsoon covers entire country.

Low level inversion and dryness prevailed in the lower levels 750-700 hPa during this period over many parts of country. A new term called mini-cloud burst is introduced to categorize rainfall in two hours (Deshpande et al 2018). If the rainfall in two hours is more than 5 cm, then that event is termed as mini-cloud burst. Pune received 55 mm of rain in less than 2 hours and hence attributed to mini-cloud burst on 10 June. On 29 June, monsoon covered entire country. The spatial distribution of anomaly rainfall is shown in Figure 2 (from IMD website, www.imd.gov.in). It is seen that north and east India received lesser rainfall than normal in this month. The rainfall distribution in four homogeneous regions is as follows.

Northwest India + 15%, East and Northeast India -26.9%, Central India -2.7% and South Peninsula +15.7%.

A new feature of monsoon circulation is detected viz. “water spout” over the Nazre dam area near Jejuri in the Madhya Maharashtra subdivision on 8 June 2018. Studies are required to understand the mechanism of this phenomenon.

6. July Synoptic features

In the first week of July (1-7 July), monsoon trough moved north of its normal position, towards the foothills of Himalaya. The monsoon activity remained subdued. There were six LPS and one depression in this month. On 13 July first LPS formed over BoB. The monsoon became active under the influence of LPS. On 11 July Mumbai recorded heavy rainfall of 114.4 mm. Mumbai experience flood situation. Second LPS formed over BoB, Odisha region and persisted during 13-15 July. Third LPS formed over Madhya Pradesh (MP) and adjoining Uttar Pradesh (UP) on 17 July. It moved to East MP on 18 July. On 19 July, fourth LPS formed over West Bengal and Odisha region. Thus on 18, 21 July, two LPS were present simultaneously over India. On 22 July, LPS intensified into depression. This is the second depression in this season. The depression was short lived and weakened on 23 July. On 24 July fifth LPS formed over Northwest MP and adjoining UP. LPS persisted till 28 July and dissipated on 29 July. Sixth LPS was formed over central UP on 30 July. The monsoon activity remained below normal during 24 – 31 July. The second break started from 25 July and continued beyond first week of August (Figure 1). The Country as a whole monsoon rainfall was -5.8% of the normal. July rainfall was 94.2% which was slightly lesser than the forecasted range of 101±9 i.e. 92-110 %. The monsoon rainfalls over four regions are as follows.

Northwest India – 7%, East and Northeast India -24.9%, Central India 8.5% and South Peninsula -9.5%. Figure 3 (from IMD web site, www.imd.gov.in) shows spatial distribution rainfall anomaly in the month of July.

The region wise performance of monsoon activity during June and July as expressed in % departure of rainfall from normal is as follows:

Region	June (%)	July (%)
All India	-5.1	-5.8
Northwest India	15.9	-7.0
East and Northeast India	-26.9	-24.9
Central India	-2.7	8.5
South Peninsula	15.7	-9.5

7. Discussion

In many earlier years it was observed, when cyclonic storms occurred in the month of May, it had impacted the monsoon onset. However, such impact was not seen in this year. Interesting thing noticed that the cyclone Sagar moved southwestwards which is some thing unusual. The studies are required for these unusual features.

In the month of June, northward movement of monsoon was halted for the long period during 14-24 June and then it rapidly covered the country by 29 June. The reasons for rapid covering on the country need to be studied. In the month of June one LPS and one depression formed, in the month of July six LPS and one depression formed. In spite of these systems, rainfalls in the months of June and July were below normal. The probable reason is that these systems did not move westward for the long distance. It is known from the earlier studies that the monsoon is highly correlated with the westward movement of LPS rather than number of LPS. More studies are required for not moving the systems westwards in this season.

8. Summary

As it is said that every monsoon is unique, is also this monsoon. This monsoon has posed some problems for study. These can be listed as below.

1) Fast coverage of entire country.
2) June and July rainfalls on the negative side of the normal.
3) Short life span of depressions and restricted westward movements of LPS.
4) Below normal daily rainfall in the presence of LPS.
5) Mechanism of formation of waterspout in June and The probability of formation of such system in other parts of India and during remaining months of the season.

Acknowledgments

The material for the paper is taken from IDWR and other products from the IMD site. Author acknowledges the same.

References

Veronika S.,E. Surovyatkina, B. Bookhagen and J. Kurths: 2016: Tipping elements of the Indian monsoon prediction of onset and withdrawal, GRL, 10.1002/2016GL068392, 3982-3990.

Deshpande N.R. D. R. Kothawale, Vinay Kumar, J. R. Kulkarni: 2018: Statistical characteristics of cloud burst and mini-cloud burst events during monsoon season in India, IJOC,17, 1-18.

Pai, D.S., Latha Sridhar and M. R. Ramesh Kumar: 2015: Active and break events of Indian summer monsoon during 1901-2014, Clim.Dyn. Doi 10.1007/S00382-015-2813-9.

Pai, D. S. and M. N. Rajeevan: 2007: Indian summer monsoon onset : Variability and Prediction, National Climate Centre Research Report 4/2007, 27 pp.

Wang, B**.**, B. Q. Xiang, J. Li, P. J. Webster, M. N. Rajeevan, J. Liu, and K. J. Ha: 2015: Rethinking Indian monsoon rainfall prediction in the context of recent global warming. *Nature Communications*, 6:7154 | doi: 10.1038/ncomms8154.

Figures

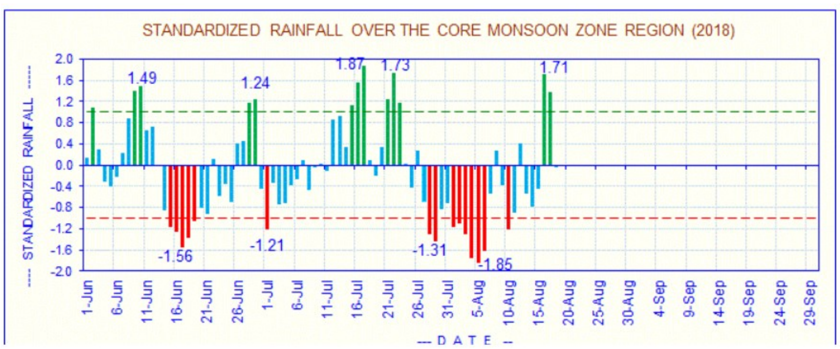

Figure 1: Standardized rainfall anomaly over the core monsoon zone (2018). The red bars show below normal rainfalls. The first break period is during 13-25 June and second break period is during 25 July to 16 August. (Figure taken from IMD website www.imd.gov.in)

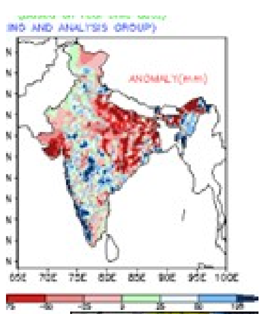

Figure 2

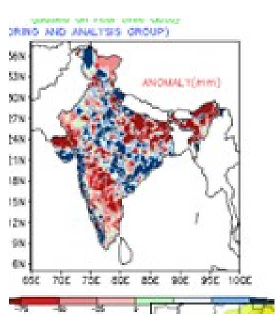

Figure 3

Figure 2, 3 Distribution of rainfall anomaly in the month of June. Red colour indicates rainfall lower than normal (Figure taken from IMD website www.imd.gov.in).

Onset of monsoon over Mumbai and Pune in climate change period

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Abstract

Onset dates for stations Thiruvananthapuram (TRV), Mumbai (MMB) and Pune (PNE) have extracted from the yearly IMD onset charts for 39 years for the recent warming period 1980-2018. The study showed that the new onset dates over PNE and MMBare 11 and 12 June respectively. These are later than IMD climatology onset dates over these stations by 2 and 3 days respectively. The mean time required for arrival of monsoon at these stations after striking at TRV are 11 and 12 days. There is no change of onset date over TRV in warming period. A feature "Hiatus" associated with the northward progression of monsoon is defined if the period taken for arrival of monsoon over these stations is more than mean +1 standard deviation of their normal travel time. Such hiatus have been observed in the years 1981,82,99, 2004, 07, 09. Information of new onset dates will be useful to farming community to plan the agriculture activities in a better way. The studies are required to forecast occurrence of hiatus at the time of onset forecast over Kerala.

1.Introduction

Onset of monsoon over Kerala is indicative of beginning of summer monsoon (June - September) season over India. Once the onset of monsoon is declared over Kerala, people in other parts of the county start expecting cool rainy season within few days over their regions. The farming community starts gearing up with agricultural activities as most of the agriculture in India depends on monsoon rainfall. Climatological normal onset dates used by India Meteorological Department (IMD) are based on the study by Ananthakrishnan et al., (1967). Ananthakrishnan and Soman (1988) identified onset dates over Kerala based on rainfall over a number of stations exceeding a threshold that is sustained for minimum period of time. There was not much difference between the onset dates in the two studies referred above. Pai and Nair (2009) developeda new method for the objective identification of onset date over Kerala, based on large scale circulation features and rainfall over Kerala. They compared onset dates over Kerala with old and new method.

InGoswami et al (2010), it has been shown that the northward progression of the monsoon has slowed down in recent periods. The reasons for slowing down were attributed to weakening of vertical easterly wind shear and weakening of north–south gradient of the mean low-level humidity around the equator. The recent period is an accelerated warming period (Kothawale et al. 2010). The climate shift in weather parameters has been dated from 1980s (Terray and Dominiak2005). Kothawale et al (2018) documented significant changes in monsoon rainfalls over different parts of the country after 1980.

In light of these recent findings, the question arises what is the relevance of onset dates based on data prior to 1967. With this background, we revisited the onset dates using recent period data. In this paper, we have given the onset dates for three stations for the period 1980-2018 viz. Thiruvananthapuram (TRV), Mumbai (MMB) and Pune (PNE). This is first in the series of papers, where we have identified onset dates over entire country in the recent period. The onset dates have been collected manually for the period 1980-2018 for 39 years from onset charts published by IMD.

2. Results and discussion

2.1 New onset dates over Mumbai and Pune

Table 1 shows onset dates over the three stations for the period 1980-2018. The dates in May are marked by symbol"*". The mean onset dates over TRV, MMB and PNE are 31 May, 12 June and 11 June respectively. There is no change in onset date over TRV, the result is consistent with the findings of Goswami et al (2010). The onset dates over PNE and BMB as mentioned by Goswami et al (2010)are 9 June. Thus new onset dates are 2 and 3 days later than earlier onset dates over these two stations. The standard deviations (SD) in onset dates over these three stations are 6,6 and 5 days respectively. The earliest and late onset over TRV occurred on 18 May 2004 and 13 June 1983. Similar dates for MMB are 31 May 2005 and 23 June 1981, and for PNE are 31 May 2005 and 21 June 2009. Mean period required for monsoon to arrive at Pune and Mumbai after onset over Thiruvananthapuram is 11 and 12 days respectively.

It is seen that in the recent years, monsoon onset over Pune and Mumbai occurred as follows. In 2012 it occurred on 17 June, in 2014on 15 June, in 2015 on 12 June, in 2016 on 20 June and in 2017 on 12 June. If these dates are compared with IMD onset date of 9 June over Mumbai and Pune, these are classified as considerable delay in arrival of monsoon over Mumbai and Pune. However, if new onset dates of 11 and 12 June are considered, then delay in onset is not more. Agricultural practices in Maharashtra are tuned with the onset over Kerala and assumed arrival of monsoon over the region as per IMD onset dates.As per existing onset dates, it is considered that the monsoon will arrive over the region in 9 days after striking at Kerala. Any delay after 9 days, is consider as the point of concern from agriculture point of view. However new onset dates will provide real information regarding climatology of arrival of monsoon over the region.

2.2 Hiatus in northward progression of monsoon

In some years monsoon takes longer time for arrival at Pune and Mumbai after striking at Thiruvananthapuram. A specific feature associated with delay in northward progression of monsoon is referred as "hiatus". i.e. after 16 for Pune (Mean onset date 11 June plus sd 5 days) and 18 June for Mumbai (mean onset date 12 June plus sd 6 days). Such hiatus are observed in the years 1981, 82, 99, 2004, 2007 and 2009. These are real concerns to the farming sectors. The studies are required to forecast such events along with the forecast of onset of monsoon over Kerala to help farming community.

3) Conclusions

As per present study the revised mean onset dates for SW monsoon over Pune and Mumbai are 11 and 12 June respectively based on the recent warming 39 year period. The impact of climate change is seen to shift the onset dates by 2, 3 days over these stations. As per earlier studies, this shifting is due to weakening of wind shear and weakening of north–south gradient of the mean low-level humidity around the equator due to warming. The new dates will be found more useful to the society and specially farming community for planning agriculture activities after onset of monsoon over Kerala.

References

Ananthakrishnan R, Acharya UR, Krishnan ARR. 1967. Forecasting manual. FMU Rep. No.IV-18.1, India Meteorological Department: Pune, India; 52.

Ananthakrishnan R, Soman MK. 1988. Onset of southwest monsoon over Kerala 1901–1980. Journal of Climatalogy 8: 283–296.

Goswami, B. N J. R. Kulkarni, V. R. Mujumdar and R. Chattopadhyay 2010. On factors responsible for recent secular trend in the onset phase of monsoon intraseasonal oscillations, Int. J. Climatol. 30: 2240–2246

Kothawale et al 2018: Monthly, Seasonal and Annual Rainfall Series for All-India, Homogeneous Regions and Meteorological Subdivisions : 1871-2016

Terray, P., and S. Dominiak (2005), Indian Ocean sea surface temperature and El Niño–Southern Oscillation: A new perspective, J. Clim., 18, 1351–1368.

Table 1: Onset dates over Trivandrum (TRV), Mumbai (BMB), Pune (PNE). Onset dates in May are marked by *. Column "TRV-MMB" represents number of days required for monsoon to progress from TRV to Mumbai. "TRV-PNE": number of days required for monsoon to progress from TRV to PNE and "PNE-MMB": number of days required for monsoon to progress from PNE to MMB

Year	TRV	MMB	PNE	TRV-MMB	TRV-PNE	MMB-PNE
1980	1	7	7	6	6	0
1981	30*	23	20	24#	21#	3
1982	30*	17	17	18#	18#	0
1983	13	20	20	7	7	0
1984	31*	12	8	12	8	4
1985	28*	8	8	11	11	0
1986	4	15	15	11	11	0
1987	2	9	9	7	7	0
1988	27*	13	9	17	13	4
1989	3	9	9	6	6	0
1980	1	7	7	6	6	0
1990	19*	31*	31*	12	12	0
1991	2	7	7	5	5	0
1992	5	19	16	14	11	3
1993	28*	13	12	16	15	1
1994	28*	6	5	9	8	1
1995	8	17	17	9	9	0
1996	3	12	11	9	8	1
1997	9	16	14	7	5	2
1998	2	16	15	14	13	1
1999	25*	13	12	19#	18#	1
2000	1	6	6	5	5	0
2001	23*	9	9	17	17	0
2002	29*	12	11	14	13	1
2003	8	16	16	8	8	0
2004	18*	10	10	23#	23#	0
2005	5	19	19	14	14	0
2006	26*	31*	31*	5	5	0
2007	28*	18	18	21#	21#	0
2008	31*	7	7	7	7	0
2009	23*	24	21	32#	29#	3
2010	31*	11	11	11	11	0
2011	29*	4	4	6	6	0
2012	5	17	17	12	12	0
2013	1	8	8	7	7	0
2014	6	15	15	9	9	0
2015	5	12	12	7	7	0
2016	8	20	20	12	12	0
2017	30*	12	12	13	13	0
2018	29*	9	9	11	11	0
Mean	31 May	12 June	11 June	12	11	1
SD	6	6	5	6	6	2

Rainfall Characteristics of Pune City

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Abstract

Characteristic features of Pune monsoon (June-September) rainfall are discussed in the present study. Daily rainfall data for the period 1901-2016 have been used to analyze the rainfall characteristics viz. monthly rainfall, seasonal rainfall, number of rainy days, heavy raindays, frequency distribution of daily rainfall, length of wet spells, annual cycle of daily rainfall. Diurnal cycle and monthly contributions of light/intense rain-hours are presented using hourly rainfall data of the period 1969-2010. Temporal changes in some of the rainfall characteristics are also presented in the study.

Seasonal rainfall of Pune is 55 cm which shows significant increase during the period 1901-2016. On an average, there are 41 rainy days in the season and one day records heavy rainfall of 6.5cm or more. Extreme rainfall of 18.1 cm was recorded in one day. Diurnal variation is low during the months of July and August.

1. Introduction

Pune is the 2nd largest city in the Maharashtra state after Mumbai. It is located at 18.5°N, latitude, 73.85°E longitude. The city's total area is 729 sq.km. Its population is nearly 3.13 million. It lies on the western side of the Deccan Plateau, at an altitude of 560 m. above mean sea level (MSL). It is on the leeward side of the Western Ghats, which forms a barrier to the moisture inflow from the Arabian Sea. It has a semi-arid climate with average temperatures ranging between 19 and 33°C. Maximum temperature sometimes reaches up to 42 °C in the month of May. While minimum temperature drops down below 8°C during late December to January. In addition to monsoon, rainfall occurs in the month of October. Summer monsoon (June-September) rainfall of the city is 554 mm. July is the wettest month of the season (monthly rainfall is 181 mm or 30% of the seasonal rainfall).

Weather-wise Pune is regarded as the comfortable city for the settlement as percentage days of extreme temperature and rainfall are very low. Not just as the cultural capital, Pune has also been an educational hub and one of the fastest growing cities in India. Many Industries including IT sector are situated here. Population of Pune is increasing exponentially. It has increased from 2.5 million to nearly 3.8 million in last 10 years. City is expanding in all directions none linearly putting pressure on the supply of water. As a result demand of water from different sectors such as, industry, irrigation, hydropower and domestic use is increasing tremendously. Water availability is one of the major issues facing in the development of this SMART city. Rainfall, being the prime source of fresh water, needs to be considered with top priority at a place. As a fresh water source, rainfall analysis is essential for this region. With this view, study of Pune monsoon rainfall has been carried out. Many studies on rainfall analysis are available on state/district level in India or for entire India (Sikka 1980, Mooley and Parthasarathy 1984, Gadgil 2003 etc). Guhathakurta and Rajeevan (2008) used station data to study the temporal changes in the seasonal rainfall of different places. Recently, Kothawale and Rajeevan (2017) published a research report on monthly, seasonal and annual rainfall time series of homogeneous regions and subdivisions in India during 1871-2016.

2. Data Used:

Daily rainfall data of Pune for the period 1901-2016 and hourly rainfall data for the period 1969-2010 have been collected from the National Data Centre (NDC), India Meteorological Department, Pune. After carrying out quality control checks, outliers were removed and the data set with at least 75% availability during monsoon season for each year has been used in the present study.

3. Analysis and discussion:

3.1. *Monthly and Seasonal distribution of rainfall*

Table 1: Rainfall statistics viz. mean monthly and seasonal rainfall (mm), Average number of rainy days (rainfall in 24 hour >2.5mm) and total number of heavy rainfall days (rainfall in 24 hour> 65mm.) during the observational period

Rainfall Feature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Monthly rainfall (mm)	0.9	0.9	2.9	13.5	37.8	110.5	181.0	132.6	130.4	81.9	24.	6.1
Coefficient of variation (%)	388	446	275	134	88	68	49	56	68	88	142	265
Average rainy days (>2.5mm)	0.0	0.1	0.6	1.1	2.8	9.5	12.8	10.6	8.4	4.6	2.0	0.4
Total heavy rain days (>6.5cm) during 1901-2016	-	-	-	-	2	19	24	7	20	9	-	-

Highest recorded 1day rainfall (cm)	-	-	-	-	10.3	13.2	13.0	10.1	13.0	18.1	-	-

Table 1 gives the rainfall information based on daily rainfall data. Fig.1 shows the seasonal rainfall time series with fitted linear trend. Excess (rainfall> mean+sd) and deficit (rainfall<mean-sd) rainfall years are also shown in the figure. Fig.2 shows the time series plots for 1-day extreme rainfall, number of rainy days (>2.5mm) and heavy rainfall days (>65mm). These are fitted with linear trends.

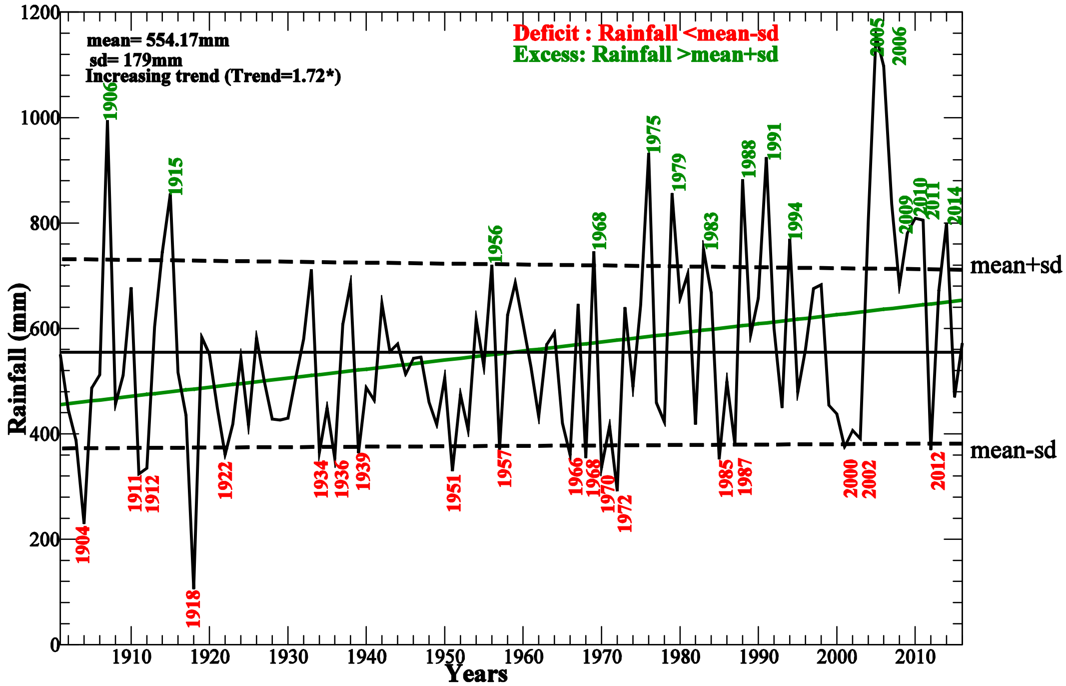

Fig.1: Monsoon Rainfall (June-Sept.), fitted linear trend and excess (Green) / deficit (Red) monsoon years during the period 1901-2016

It is clearly seen from the table 1 and figures 1 and 2 that annual rainfall of Pune is 716 mm out of which 554 mm (77%) occurs during monsoon season. July is the month of maximum rainfall (30% of seasonal). October rainfall is also substantial in Pune, while January and February are totally dry months. Seasonal rainfall ranges between 108 mm in 1918 to 1150 mm in 2005 with average 554 mm and standard deviation(SD) 179 mm. Number of rainy days during monsoon season ranges between 25 in 1904 to 68 in 1959 with average of 41 days during the monsoon season. Number of heavy rain days ranges from 0 to 4 with average number is approximately 1 day per year. 1-day extreme rainfall of 13.1cm has been recorded on 26th June 1961 which was the excess monsoon year for India. On 13th May 2015, Pune recorded 10.3cm of rainfall which is a record rainfall amount for the month of May, while on 4th October 2010 Pune recorded 18.1cm of rainfall in 24 hours which is all time record for 24 hr rainfall at Pune.

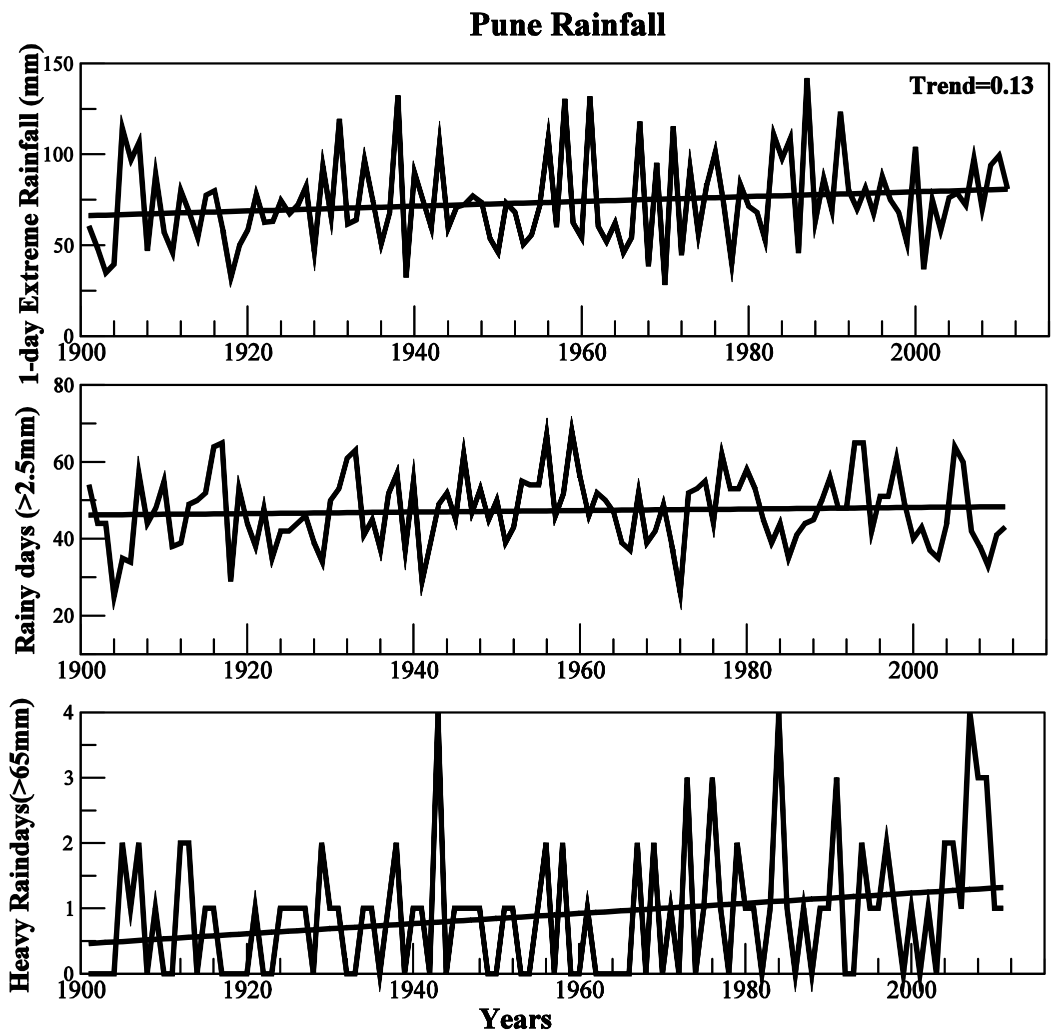

Fig.2: Time series plots and fitted linear trends for (a) 1-day extreme rainfall, (b) number of rainy days and (c) heavy rainfall days at Pune.

Significant increasing trend is observed in seasonal rainfall during the period of observation as seen from Fig.1. Guhathakurta and Rajeevan (2008) also detected such increasing trends in the seasonal rainfall of stations in central parts of Deccan plateau. Extreme rainfall amounts in one day shows increasing trend but not statistically significant (Fig 2). No change is noticed in the number of rainy days. Compared to the period 1901-1960, period 1961-2016 shows frequent occurrence of heavy rainfall events (>65mm/day). 3-4 events/year have been observed commonly during this period.

3.2 Annual cycle of daily rainfall

Annual cycle of daily rainfall, worked out using the daily rainfall data for the period 1901-2016, exhibits three distinct phases; the onset of monsoon, consistent high rainfall period and the withdrawal of the monsoon season. It helps to better identify the rainfall minima and peaks during the year. Figure 3 of annual cycle of daily rainfall of Pune, indicates that seasonal rainfall starts around 1st or 2nd week of June. During this onset phase rainfall activity is intense. Then this activity reduces to some extent and again it increases during the month of July. Whole month experiences good rainfall activity. Further it decreases upto mid September. Second maximum in the rainfall over Pune is generally observed during September end or October beginning which is clearly seen from the Figure 3.

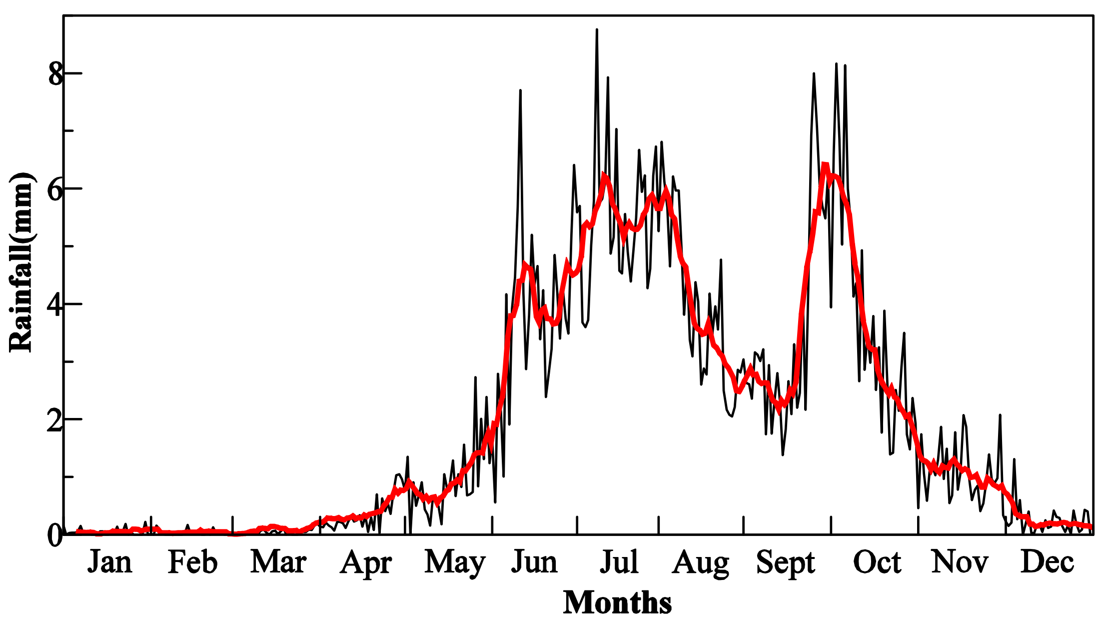

Fig 3: Annual cycle of daily rainfall at Pune

3.3 Frequency Distribution of Daily rainfall during monsoon season

Table 2: Frequency distribution of daily rainfall

Daily Rainfall (mm)	Proportion of days (%)
No rain	28
0-10	52
10-20	10
20-30	6
>30mm	4

It has been observed that out of 122 days of monsoon season, on an average, 28% days are of no rain (zero rain). From remaining 72% days, only 4% days are very intense (rainfall>30mm/day). It is clearly seen from the table 2 that on maximum number of days (52%) during the monsoon season rainfall ranges from 0 to 10 mm/day.

3.4 Wet Periods Contributing Different Percentages to Annual Rainfall

It has been noticed that Pune receives rainfall during the month of May and October also. Such rainfall activity is very important for agricultural sector. Nearly 23% rainfall occurs in non-monsoon months. Considering this aspect, wet periods contributing different percentages (10% to 90%) to annual rainfall have been identified. Present study discusses start, duration and intensity of rainfall during these wet periods. 10% wet period is defined here as the optimum duration during the year, contributing 10% to the annual rainfall total of that year. This wet period can be thought as intense rain spell. Similarly 50% and 75% wet periods are calculated here and can be considered as assured rainfall periods (Deshpande and Singh, 2011). Table 3 shows the average values of start, duration and intensity of these wet periods.

Table 3: Starting date, Duration (in days) and Intensity (mm/day) of wet periods contributing different percentages to annual rainfall

Wet period	Start	Duration(days)	Intensity (mm/day)
10%	Generally occurs during July month or September last week or October first week	2	33
25%	10 Jul	11	14.6
50%	6Jul	49	6.5
75%	20 Jun	99	5
90%	9 Jun	141	4.3

It is seen from the table that intense period of 2 days can contribute 10% of the annual rainfall and generally it occurs in the 2nd week of July or last week of September or first week of October. 50% of the annual rainfall requires 49 days with intensity of 6.5mm/day and generally it starts around 6th July. 90 % of annual rainfall is contributed by 141 days and it starts from 9th June and continues till 27th October.

3.5 Frequency distribution of length of Wet spells during monsoon seasonal

Table 2 shows the distribution of rainfall in terms of daily rainfall amount. It is seen from the table that on an average, only 4% days are very intense receiving rainfall amount of 30 mm or more, while 52 % days during monsoon season receive very light rain (<10mm/day). However, rainfall distribution in terms of length of wet and dry spells is not clear from this table. This section discusses about the distribution of length of wet spell (defined here as continuous raindays without any break of no rain day).

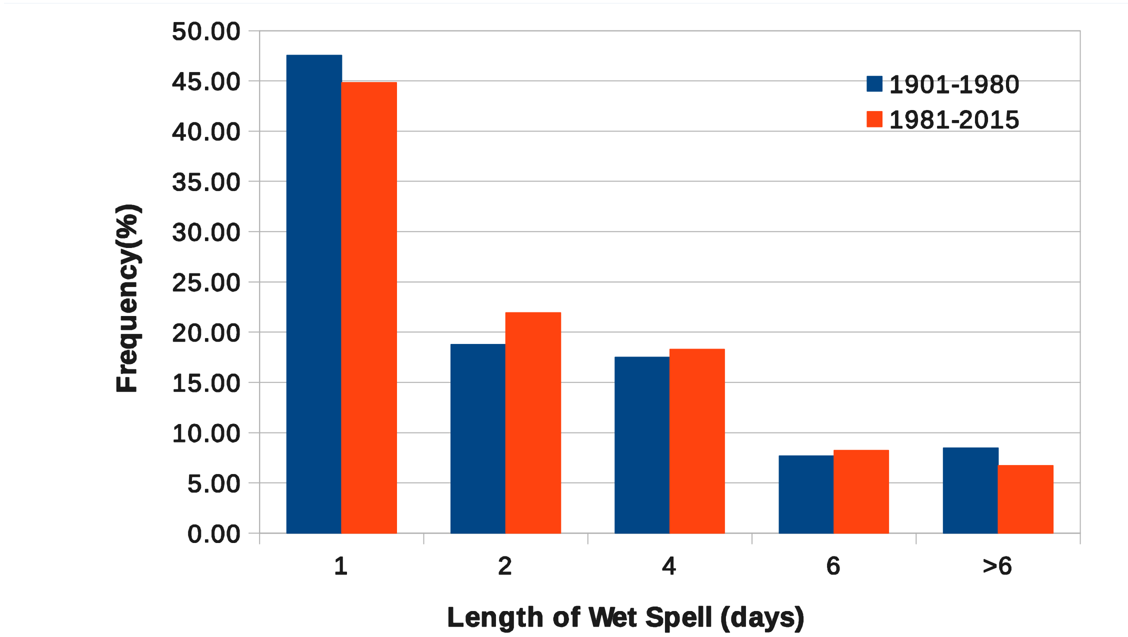

Fig 4: Distribution of Wet spell

Distribution of the length of wet spells, is shown in Fig. 4. To examine the temporal changes in such heavy spells, frequency of wet spells of various lengths (in days) are shown for two different time periods 1901-1980 (past shown in blue color) and 1981 onwards (recent shown in red color). It is seen from the figure that in recent years (1981 onwards) frequency of wet spells ranging from 2-4 days has increased, while that for spells of 6 days or more is reduced indicating that continuous rainfall a long period has been reduced in recent years.

3.6 Hourly rainfall analysis:

3.6.1 Diurnal Cycle of rainfall

Diurnal cycle of the rainfall at a place is defined here as the average distribution of hourly rainfall on a rainday (non-zero rainfall amount). Based on the available data period of 1969-2010, an average diurnal cycle has been evaluated for 4 monsoon months separately and shown in Fig. 5.

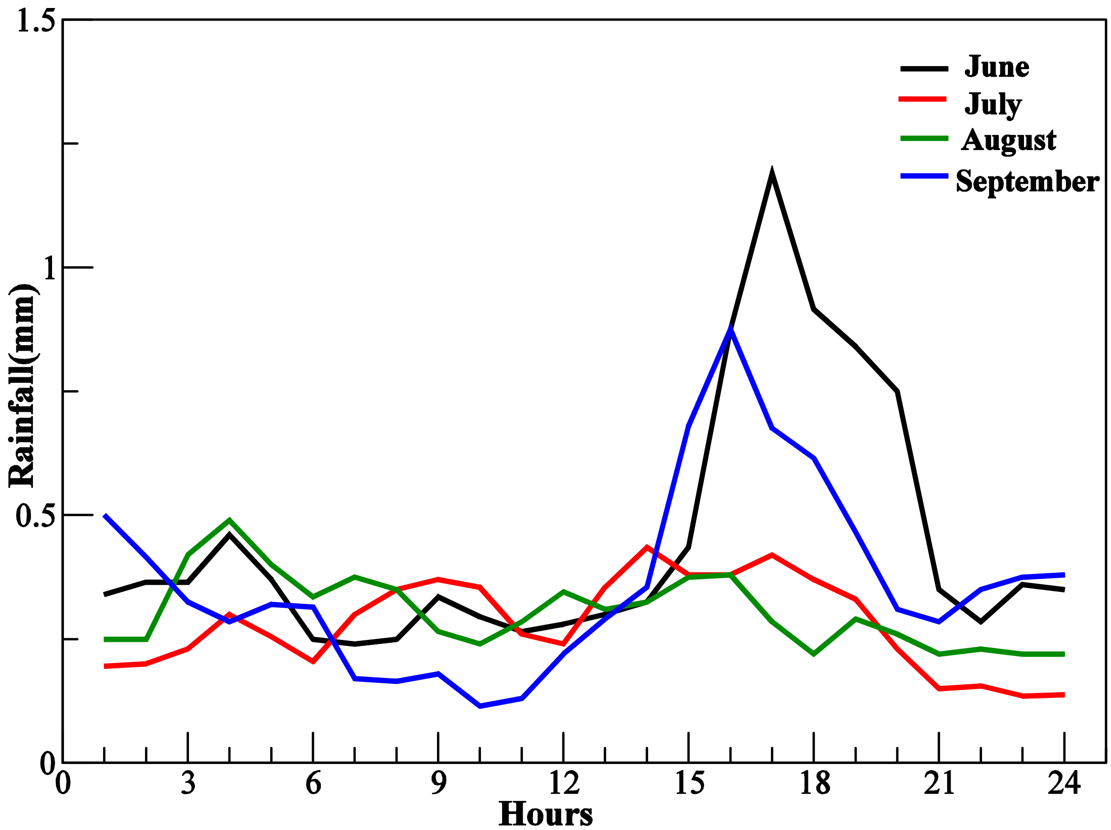

Fig.5: Diurnal Cycle of Rainfall at Pune

Figure 5 shows that, during the months of June and September, i.e. during onset and withdrawal phase of monsoon, rainfall maximum is observed in the afternoon hours, due to convection by local heating, while during the month of July-August, i.e. when monsoon sets in over this region, diurnal variation is less marked throughout the 24 hours. Second maximum during the day is observed in the early morning hours in June and August months.

3.6.2 Distribution of light rain and intense rainfall during the day of monsoon months

To examine the contribution of intense rain-spells to the daily rainfall total during different monsoon months, hourly rainfall data at Pune, has been classified into 2 categories as light rain (<5mm/hr) and intense rain (>5mm/hr). Composite of these 2 categories for each of the 4 monsoon months are shown in Fig. 6. Light rainfall activity is indicated by dotted line in the figure. While intense rainfall has been indicated by thick continuous line. Various colors indicate different time of the day.

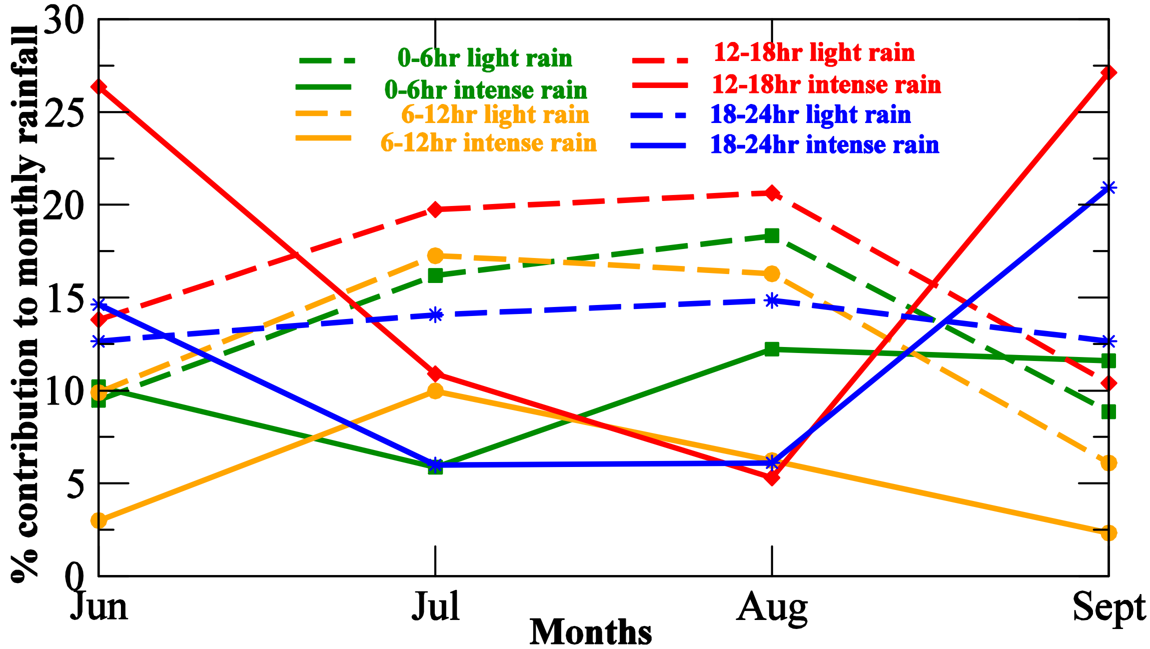

Fig.6. Distribution of Light rain and intense rain hours during monsoon season

From figure 6 it is seen that during June and September, intense rain hours during the afternoon period are contributing more to the monthly rainfall total (red continuous line). While during morning hours, such intense rain hours do not contribute much to the monthly total (yellow continuous line). During July and August months light rainfall activity of afternoon hour contributes more to the monthly total (red dash line).

Cloudburst events are defined by IMD, as intense rainfall hour with rainfall of 10cm or more in 1 hour. Such activities are common in Himalayan region. Yet there are intense rainfall activities observed in different parts of the country. Though they do not fulfill the criteria of cloudburst, but rainfall of few centimeters have been recorded in an hour or two. To have such information on intermediate intense rain-spells of few hours, Deshpande et al (2018) defined a "Minicloudburst" (MCB) event (rainfall of 5cm or more in consecutive 2 hours with both the hours as rain hours). Scrutinizing the hourly rainfall data at Pune shows that 13 such minicloudburst events (rainfall of 5cm and more in 2hours duration) have been observed during the 1969-2010 (42 yrs) and most of them have been recorded in the month of July or September end or October start.

Summary and Conclusions

From the analysis of daily and hourly rainfall data it is seen that,

1. Seasonal (June-September) rainfall of Pune is 554 mm (SD 179 mm), Lowest rainfall was recorded in 1918 (108 mm), while highest rainfall was recorded in 2005 (1150 mm). Seasonal rainfall of Pune shows significant increase during the period 1901-2016.
2. On an average, out of 87 rain days, rainy days are 41 only and hardly one day records heavy rainfall (>65mm/day).
3. Extreme rainfall of 18.1 cm was recorded in 1-day duration on 4th October 2010**.**
4. Seasonal rainfall starts around 1st or 2nd week of June. During this onset phase rainfall activity is intense. Maxima in rainfall activity is observed in July. Number of rainy days are more in this month. Whole month experiences good rainfall activity. Further it decreases upto September mid. Second maximum in the rainfall is generally observed in September end or October beginning.
5. Intense period of 2 days can contribute 10% of the annual rainfall and generally observed in July or Sept end or Oct start. 90% of the annual rainfall is contributed by 141 days starting with 9th June to 27th Oct
6. Afternoon maxima in seen in the diurnal cycle while second peak occurs in early morning hours during June and September while diurnal variation is very small during July and August. In all around 13 MCB are observed in Pune during the period 1969-2010.

Acknowledgements:

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References

Deshpande NR and Singh N. (2011): Spatial and temporal variations in the wet periods of major river basins in India, JESS, 119, 5, 561-578

Deshpande NR, Kulkarni A and Krishnakumar K. (2012): Characteristic features of hourly rainfall in India. Int. Jr Climatol.32: 1730–1744. DOI: 10.1002/ joc.2375

Deshpande , Kothawale DR, Vinaykumar and Kulkarni JR. (2018): Statistical Characteristics of Cloudburst and Minicloudburst events during monsoon season in India, IJOC, DOI: 10.1002/joc.5560.

Gadgil S. (2003): The Indian Monsoon and its variability, Annual Review of Earth Planet. Sci., 31, 1, 429 – 467.

Guhathakurta P and Rajeevan M. (2008): Trends in the rainfall pattern over India Int. J. Climatol.28: 1453 – 1469

Kothawale, DR. and Rajeevan, M. (2017): Monthly, seasonal and annual rainfall time series for all India, homogeneous regions and meteorological subdivisions: 1871–2016. (IITM,RR-

Research Highlights

Operational monsoon forecast: Are high-resolution models any better?

Advance and accurate forecast of monsoon rainfall is in a great demand by the users for the proper management of water resources, agricultural crops, etc. But predicting monsoon is a tricky job. For a country like India that is almost fully dependent on monsoon for its agriculture-based economy, exploring better and more efficient ways for forecasting monsoon are a necessity.

Starting with statistical and numerical ways of weather prediction, India has moved ahead to match with the best practices in the world for monsoon forecasts. Efforts of the Indian meteorological community in exploring the general circulation models for predicting monsoon and the technological advances in super-computing have led India in using the dynamical coupled forecast system models for forecasting monsoon. Use of dynamical coupled climate models has shown a hope for developing better and more accurate forecast systems for the Indian Monsoon. Researchers at the Indian Institute of Tropical Meteorology (IITM), Pune have recently developed an operational extended range prediction (ERP) system. The ERP system predicts the Indian Summer Monsoon Rainfall (ISMR) about three weeks in advance.

The skill in ERP of the Indian monsoon is dominated mainly by the travelling waves like intra-seasonal oscillations (ISOs). The simulation and real-time prediction skill of ISOs-driven precipitation depends on the capturing capacity of active/break cycles by the model, among other things. Therefore, there are demands that increasing resolution of a model can lead to better prediction skill. However, enhancing model resolution requires enhanced computational resources, which is a costly affair.

Such demands inspired the ERP group at IITM to conduct a study for evaluating whether increasing resolution in climate models leads to any improvement in forecast skill of the model.

Presently, the operational ERP system at IITM is operating on experimental basis and is evolved by adopting the coupled Climate Forecast System model version 2 (CFSv2) developed by National Centre for Environment Prediction (NCEP), USA. The ERP group at IITM led by Dr. A.K. Sahai is using CFSv2 model at its two horizontal resolutions: 1) the low resolution version T126 (~ 100 km) and 2) the high resolution version T382 (~ 38 km) at the Institute's high performance computing system (IITM-IBM HPC).

The ERP system developed at IITM produced 11 member ensemble forecasts for 25 days lead time at every 5-day interval starting from 16th May to 28th September during 2001-2012 at both the resolutions (T126 and T382). For ease of comparison of the forecast from both the resolutions, the Indian landmass was divided into four different homogenous regions based on climatology and rainfall variances. These regions are: central India (CEI), northwest India (NWI), northeast India (NEI) and southern peninsular India (SPI). To check the monsoon ISO (MISO) variability, a slightly broader region *i.e.,* Monsoon core zone of India (MZI) was also selected. The prediction was evaluated at the pentad mean scale. The MISO indices method, as proposed by Suhas *et al.* (2012) was used to monitor the temporal evolution and amplitude of ISO. Extended empirical orthogonal functions (EOFs) analysis and significance test were conducted. The scatter plots of the first two principal components (PC1 and PC2) of the extended EOFs were plotted.

The results of this study reveal that the high-resolution model (T382), as compared to low resolution model (T126), does not show any significant improvements in real-time forecast and monitoring of MISO and the rainfall over the homogeneous regions of India, or over the broader regions of Indian subcontinent. The lower resolution version of CFSv2 (T126) has the similar potential to give operational extended range forecasts as compared to T382. The area averaged forecast and the temporal evolution of MISO in the extended range show statistically similar skill in T382 as well as T126 run. Thus, by just increasing the resolution of CFSv2, any significant improvement in forecast skill of MISO is not observable. However, it is also observed that the high-resolution coupled model forecasts using NCEP CFSv2 are more computer intensive than the low-resolution ones. It is found that the CFSv2 T382 takes approximately three times more computational time and four times more storage space as compared to the CFSv2 T126 in the IITM IBM HPC system. Therefore, keeping in view the high computational and storage requirements of the high-resolution model (T382) and, that, no significant improvement in prediction skill from increasing the resolution is observable in forecasted MISO amplitude or rainfall variability, in general, as compared to the low-resolution model (T126); increasing the horizontal resolution for the real-time dissemination of operation forecasts is not a viable option at this juncture.

However, increasing the resolution may be useful in better representing (simulating) orography induced fields, vertical velocity and rainfall. Further research efforts on high resolution coupled models are advocated for improving our understanding of MISO, climatological dry bias, etc.

(Source: Sahai A.K., Abhilash S., Chattopadhyay R., Borah N., Joseph S., Sharmila S, Rajeevan M., High-resolution operational monsoon forecasts: an objective assessment, Climate Dynamics, online, June 2014, DOI:10.1007/s00382-014-2210-9)

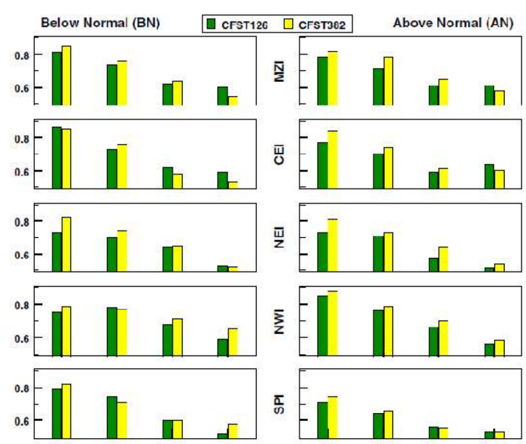

Fig.: Area under curve (AUC) of ROC for CFST126 and CFST382 for two categories: below normal (BN) and above normal (AN) over MZI, CEI, NEI, NWI and SPI. Higher the AUC value, better the prediction skill. Both the model versions show comparable values.

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IITM, Pune

Meteorlogical News

Waterspout at Nazare dam area near Jejuri town.

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Vaintey, Rajyog Society, Baner, Pune

People nearby Nazare dam area witnessed a surprising phenomenon of dam water going up on 8 June 2018. This event was captured in the mobile camera and circulated on social media. This has raised curiosity among the people. Therefore a brief details of phenomenon are given here.

Water spout

The meteorological phenomenon observed by villagers is called as "Water Spout" in meteorological parlance. Literary meaning of waterspout is the pipe carrying water from roof. In meteorological terms, it is intense rotating column of air above the water body. A column of air descends down from the base of deep convective cloud. The wind shear exists in the atmosphere in the monsoon season. The deep convective clouds have regions of updraft and downdraft in the base region. The wind shear causes rotational motion in the cloud base air due existence of updraft and downdrafts. This is called generation of vorticity due to tilting term in the equation of vorticity. Due to weight of the raindrops, a small part of the cloud base descend down towards the surface of water. It looks like trunk of an elephant. The radius of the trunk is a few meters. Under the conservation of momentum principle, rotation with high velocity is generated in the trunk air. Bournoli's theorem states that sum of potential, kinetic and pressure of the air is conserved. When the speed of rotation increases, then its kinetic energy increases. As a result there is a fall of pressure in the trunk air. Outside pressure is high, and there is low pressure in the trunk, so all the objects are sucked in the trunk air. The surface water is sucked upwards in the waterspout. This what has been seen by the villegers from Nazare dam area.

Intensity

Depending on the spped of rotation, animals in the water viv. Fish, frog, turtise are sucked upwards along the water. These go the cloud base and fall some distance away, Such rains are called as fish rain. People at distance of 100 km have experienced raining fish.

Waterspout is counterpart of Tornado which occurs over land.

Intensity of waterspout is measured in terms of Fujita scale. It ranges from F0 to F5. The intensity is determined from the damage it caused to surrounding trees, houses etc. A team of people from Center of Citizen Science (CCS) Pune, went to the site interviewed the villagers and recorded the damages caused by the waterspout. From that reports, it was determined that the waterspout which occurred on 8 June at Nazare was of F0 scale.

Social awareness

This phenomenon might have been skied from the attention of meteorologists had it not been captured by the camera. This is the first time that such phenomenon is documented. The strong wind shear exists throughout the monsoon season. The deep convective clouds with strong updrafts and downdrafts exist in the monsoon season especially during break periods, So there is a high probability of occurrence of such events in the monsoon season. People in the country need to be educated of such events and should be advised to collect and record meteorological information in case such event occurs in their area which will be useful for research to meteorologists in future.

IMSP NEWS

AGM on 3 July 2018 at IITM

Announcement of new committee

Welcome of new IMSP chairman