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RESEARCH ARTICLE

Trends in precipitation indices at Akola

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ABSTRACT : Climate warming observed over the past several years is consistently associated with changes in a number of components of the hydrological cycle. Precipitation is one of the important component of this cycle. Changes in mean and extreme values of precipitation will impact on rivers, agriculture, environment etc., which may be the serious issue. Therefore predicted trends of precipitation indices can be used to take proper decision for future. In this study the trends in different rainfall indices for the period 1974-2013 were examined for Akola rain gauge station. The meteorological data of rainfall were collected from Agro-Meteorological Observatory, Dr. PDKV Akola. The trends in monthly and annual precipitation indices were calculated statistically and represented graphically. The results showed that there were no significant changes in annual total precipitation within the last few years. In one day maximum rainfall, the decreasing trend was observed during months of monsoon and winter seasons, whereas increasing trends were found during summer months. Maximum number of months showed decreasing trend, especially during monsoon months in respect of consecutive 5-days maximum rainfall. The precipitation decrease in August was compensated by a precipitation increase in September. The lengths of wet spells were increased with increase in length of dry spells.

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Over the twentieth century, changes in global and land precipitation have been observed across different time scales, which are expected to result from the variability and change in the climate. Particularly, changes in extreme precipitation are of general concern because of the expected impact on society and ecosystems; an extreme (weather or climate) event is generally defined as the occurrence of a weather or climate variable above (or below) a given threshold near the upper (or lower) endpoints of the range of observed values of the variable (e.g. IPCC, 2012).

Changes in mean and extreme values of precipitation will impact river flows, lake and wetland levels, and evaporation. More intense precipitation events will affect agriculture by damaging crops, increasing soil erosion, and contaminating surface and groundwater, which may increase the risk of diseases and may include loss of property. On the other hand, an increase in drought events may lead to lower yields and possible failure in agriculture and livestock development and consequent food and water shortage, increase of wildfires, and also loss of property. Integration of information on climate variability in to water resources management would help to adopt to long-term climate change impacts (Bates *et al.*, 2008).

In India, some studies have addressed this important issue. Kumar *et al.* (1992) examined the trends in the total precipitation during 1871-1984 and found increasing trends in the precipitation amounts all along the west coast and northwest India. The study also revealed a decreasing trend in the overall precipitation in the eastern Madhya Pradesh. The study of Chhabra *et al*. (1997) indicates a decrease in the precipitation in hilly stations and an increase in the precipitation in the urbanized/industrialized cities. The recent studies have reported that there is an increasing trend of extreme precipitation events in USA and Australia (Easterling *et al.*, 2000; Haylock and Nicholls, 2000 and Kunkel *et al.*, 1999).

The studies generally focused on climatic change detection by estimating linear trends and relations between different indices (Easterling and Kates, 1995; Groisman *et al.*, 1999; Nicholls and Murray, 1999; Frich *et al.*, 2002; Wijngaard *et al.*, 2003; Klein and Konnen, 2003). Most of studies are based on calculations of days with very heavy rainfall (Palmer and Raisanen, 2002).

The objective of this study is to provide insight on trends in monthly and annual precipitation indices (total precipitation, duration of wet and dry spells, maximum1-day rainfall, maximum 5-days continuous rainfall), that may be affected by climate change at a local rain gauge station at Akola in Vidarbha region (Maharashtra, India), for the period of 1974-2013.

EXPERIMENTAL METHODOLOGY

Data collection :

In this study, Akola rain gauge was selected for analysis of different precipitation indices, which comes in western vidarbha region of Maharashtra in India. Akola station is located at 20° 40' N and 77° 2' E, at an altitude of 307.415 m above mean sea level. The average annual rainfall is 750 mm. Akola comes under semi-arid climatic region.

In order to carry out study, data regarding daily rainfall and rainy days were collected from Agro-Meteorological observatory, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, for the duration of 40 years (1974-2013).

The set of precipitation indices :

Precipitation indices used in the study were related to total number of rainy days, one day and consecutive five days maximum precipitation, total precipitation and duration of dry and wet spell. Extreme precipitation indices examined to find the trends in precipitation at Akola station are described below :

Number of wet days, P ≥ 2.5 (W)

The number of wet days calculated by counting days with greater than or equal to 2.5 mm precipitation per day.

W=count [days (RR_{ij}) ≥2.5]

where, j- Period in analysis

RR_{ij} - Daily precipitation amount on day i, mm.

One day maximum precipitation (Rx 1-day) :

The one day maximum precipitation is the maximum rainfall occurred for a day in the month and it is the calculated by the following formula :

Rx 1-day = max (RR_{ij}).

where, RR_{ij} = Daily precipitation amount on day i, mm.

Consecutive 5-days maximum precipitation (Rx 5-day) :

The consecutive 5-days maximum precipitation is the maximum value of cumulative of consecutive 5-days precipitation during each month of the year.

Rx 5-days = max (RR_{kj})

where, RR_{kj} - Precipitation amount of consecutive 5-days interval, mm.

Continuous dry days (CDD) :

The continuous dry days are the count of maximum number of consecutive days with no rainfall or rainfall less than 2.5 mm during each month of year.

CDD = max (days (RR_{ij}) <2.5 mm.)

where, RR_{ij} = Daily precipitation amount on dry days, mm.

Continuous wet days (CWD) :

The continuous wet days are the count of maximum number of consecutive days with rainfall greater than or equal to 2.5 mm during the month of year.

CWD = max [days (RR_w) ≥ 2.5 mm.]

where, RR_w = Daily precipitation amount on wet days (RR_w ≥2.5 mm.)

Annually total precipitation in wet days (PTOT) :

Annual total precipitation is the sum of the daily rainfall year wise for the period of 40 years (1974-2013).

Trend evaluation :

A linear trend was evaluated using following statistical measures.

Regression analysis :

It is the statistics for a line by using the "least squares" method to calculate a straight line that best fits the data, and then returns an array that describes the line.

The equation for the line is:

y = mx + b

where, the dependent variable y is a function of the independent x variable. 'm' represents the slope of line *i.e.* increasing or decreasing trend. 'b' is a constant value and shows intercept.

Co-efficient of determination (R^2) :

R^2 indicates the statistic that will give information about the goodness of fit.

$$R^2 = \left[\frac{\sum_{i=1}^{n}(XTi - \overline{XTi})(XPi - \overline{XPi})}{\sqrt{\sum_{i=1}^{n}(XTi - \overline{XTi})^{-2}}\sqrt{\sum_{i=1}^{n}(\overline{XPi} - XPi)^2}} \right]^2$$

EXPERIMENTAL FINDINGS AND DISCUSSION

A linear trend was evaluated using regression analysis on indices for both monthly and annual time series. The co-efficient of determination (R^2), slope and its significance (p-value) were estimated for all indices and presented in Table 1. The statistically significance were tested at 5 per cent level of significance *i.e.* p-value < 0.05. The positive or negative slopes of different rainfall indices are presented in the Table 2.

Table 1 : Co-efficient of determination (R^2) values for different precipitation indices

Months	Co-efficient of determination (R^2)					
	W	PTOT	Rx1 day	Rx 5-day	CDD	CWD
January	6E-05	0.000	0.008	0.000	0.004	0.001
February	0.051	0.089*	0.090*	0.052	0.121**	0.086*
March	0.000	0.014	0.031	0.011	0.004	0.000
April	0.050	0.002	0.004	0.000	0.070*	0.045
May	0.023	0.033	0.047	0.036	0.004	0.026
June	0.010	0.016	0.024	0.017	0.000	0.006
July	0.061	0.013	0.060	0.028	0.000	0.052
August	0.008	0.040	0.037	0.054	0.000	0.010
September	0.023	0.019	0.010	0.039	0.014	0.075*
October	2E-07	0.000	0.002	0.001	0.000	0.000
November	0.001	0.001	0.001	0.004	0.000	0.000
December	0.129**	0.100**	0.105**	0.077*	0.123**	0.000

* and ** indicate significance of values at P=0.01 and 0.05, respectively

Table 2 : Trends of different precipitation indices

Months	Trends of indices, +: increase, –: decrease					
	W	PTOT	Rx1 day	Rx 5-day	CDD	CWD
January	0.000	+ 0.015	+ 0.082	+ 0.021	+ 0.033	+ 0.002
February	- 0.015	- 0.305	- 0.267	- 0.302	+ 0.116	- 0.016
March	- 0.001	+ 0.247	+ 0.224	+ 0.180	+ 0.035	+ 0.002
April	+ 0.015	+ 0.030	- 0.034	- 0.017	- 0.100	+ 0.010
May	+ 0.017	+ 0.314	+ 0.182	+ 0.237	- 0.041	+ 0.009
June	- 0.025	- 0.912	- 0.493	- 0.594	+ 0.012	- 0.008
July	+ 0.075	- 0.917	- 0.863	- 0.839	- 0.005	+ 0.028
August	- 0.024	- 1.452	- 0.454	- 1.076	- 0.011	- 0.016
September	+ 0.050	+ 0.930	+ 0.230	+ 0.642	- 0.067	+ 0.038
October	9E-05	+ 0.086	+ 0.127	+ 0.146	+ 0.011	+ 0.001
November	- 0.005	- 0.118	- 0.060	- 0.160	+ 0.011	- 0.002
December	- 0.026	- 0.378	- 0.319	- 0.462	+ 0.138	- 0.021
Annual	0.061	-2.459	-1.248	-1.061	-	-

The results obtained from the study have been presented and discussed under the following heads:

No. of wet days, P ≥ 2.5 (W)

On the analysis of number of rainy (wet) days in annual series, the non-significant positive trend was found (p-value=0.548) with the co-efficient of determination 0.009 and the rate of increase was very low as 0.061 days year^{-1} (Fig. 1).

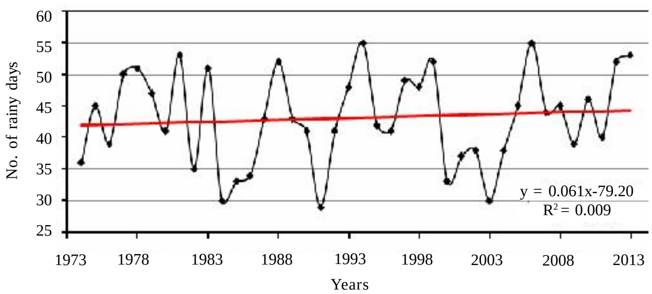

Fig. 1: Annual rainy days time series

The significant decrease in number of wet days was found for the month of December (p-value=0.022) with the maximum rate of decrease of -0.026 days year^{-1}. However, non-significant increase in number of wet days was found for the month of July (p-value=0.122) with the maximum slope of 0.075 days year^{-1}. The months of June and August showed non-significant negative trends in number of wet days. The co-efficients of determinations (R^2) were found to be statistically non-significant for all the months except December at 5 per cent level of significance.

Total precipitation (PTOT) :

Annual total precipitation is the sum of the daily rainfall year wise for the period of 40 years (1974-2013). Annual total precipitation did not show a significant linear trend (Fig.2) during the period in analysis (p-value=0.387), with an average value of 784 mm.

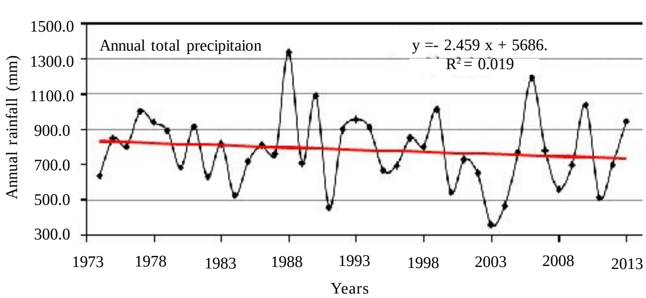

Fig. 2: Annual total precipitaion time series

The month of August showed a non-significant negative trend (Fig. 3) in total precipitation (p-value=0.214) with the slope of -1.452 mm year^{-1}, whereas the month of September showed a non-significant increase trend (Fig. 4) (p-value=0.396) with slope of 0.93 mm year^{-1}. Similarly, the decreasing trends were found for the months of monsoon and pre-winter season *i.e.* for the months of June, July, August, November and December and increasing trends were observed for the months of summer (Table 2). The co-efficients of determinations were found to be statistically non-significant for most of the months in analysis except February at 10 per cent significance level and December at 5 per cent significance level.

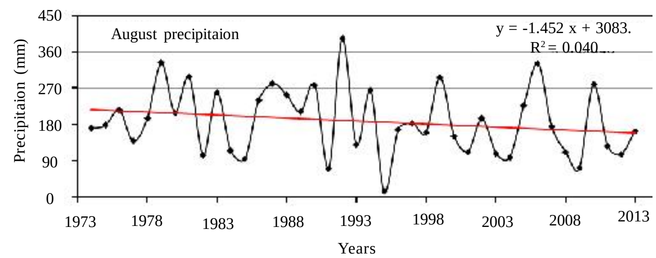

Fig. 3: August precipitaion time series

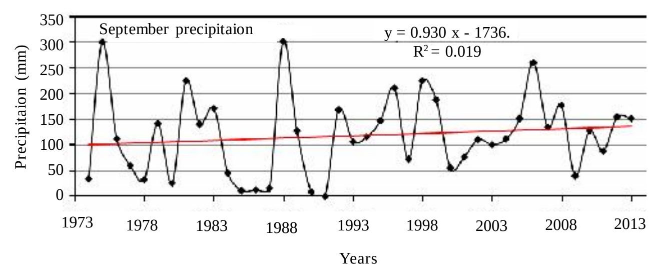

Fig. 4: September precipitaion time series

Therefore, it may be concluded that total precipitation showed non-significant but decreasing trend. However, the precipitation decrease in August was compensated by a precipitation increase in September.

One day maximum daily precipitation (Rx1-day) :

The one day maximum precipitation showed significant decreasing trend (p-value=0.014) with the slope of -1.248 mm year^{-1} annually over the period of study. However, for the month of July there was a non-significant decrease in maximum daily precipitation (p-value=0.125) with the slope of -0.863 mm year^{-1}, whereas the month of September showed non-significant increase (p-value=0.524) with the maximum slope of 0.230 mm $year^{-1}$. The decreasing trend was observed during months of monsoon and winter seasons, whereas increasing trends were found during summer months.

The co-efficient of determination were found to be statistically non-significant for all the months except February at 10 per cent and December at 5 per cent significance level.

It may be concluded from trend analysis that 1 day maximum daily precipitation showed slight variation with decreasing trend for most of the months during the period.

Consecutive 5-days maximum precipitation (Rx 5-days) :

The month of August showed non-significant decreasing trend (p-value=0.148) in respect of consecutive 5-days maximum precipitation, with the maximum slope of -1.076 mm.$year^{-1}$, while September showed non-significant increasing (p-value=0.221) trend with the slope of 0.642 mm $year^{-1}$. Maximum number of months showed decreasing trend, especially during monsoon months.

The co-efficient of determination were found to be statistically non-significant for all the months except December at 10 per cent significance level. Therefore, it may be concluded from analysis that there was slight decrease in consecutive 5-days maximum precipitation.

Continuous dry days (CDD) :

Annual continuous dry days showed non-significant linear trend during the period in analysis, with an average value of 21 days (p-value=0.800) and slope of 0.005 days $year^{-1}$. The month of April showed non-significant decreasing trend (p-value=0.098) with the maximum slope of -0.10 days $year^{-1}$. On the other hand, December showed significant increasing trend at 5 per cent significance level (p-value=0.026) with the maximum slope of 0.138 days $year^{-1}$. Month of July showed shorter dry spell with average value of 8 days.

The decreasing trend was obtained for the months of monsoon and summer, whereas winter showed slightly increasing trend in continuous dry days. The co-efficient of determination was found to be statistically non-significant for all the months except February and December at 5 per cent significance level and April at 10 per cent significance level.

It may be concluded from analysis that there were unsteady variation in continuous dry days and showed increasing trend in winter and early summer whereas decreasing trend for monsoon months.

Continuous wet days (CWD) :

Annual continuous wet days showed non-significant increasing trend during the period in analysis, with the slope of 0.002 days $year^{-1}$ (p-value=0.614). A non-significant decreasing trend (p-value= 0.065) was found for the month of February with the maximum slope of -0.016 days $year^{-1}$. The month of September also showed non-significant increasing trend (p-value=0.087) with the maximum slope of 0.038 days $year^{-1}$ at 5 per cent level of significance. Month of July showed longer wet spell with average value of 28 days.

The decreasing trend was obtained for winter, whereas summer shows slightly increasing trend in continuous wet days. The co-efficient of determination were found to be statistically non-significant for all the months except February and September at 10 per cent significance level.

It may be concluded that there was slight variation in continuous wet days and showed increasing trend in summer whereas decreasing trend in winter and unsteady trend for monsoon months.

As referred by Nastos and Zerefos (2009), a decrease in wet spells was observed annually. On the other hand, for Akola, length of dry spells as well as wet spells were increased along with the decrease in total annual precipitation, decrease in maximum one day-precipitation, decrease in 5-day precipitation annually. For the month of September, there was increase in total annual precipitation, increase in maximum one day-precipitation, increase in 5-day precipitation were observed. The decrease in length of dry spells and increase in length of wet spells were found in the month of September.

Conclusion :

No significant changes in annual precipitation totals were observed within the last few years, whereas decrease in the monthly precipitation for August is compensated by a precipitation increase in September. In one day maximum rainfall, the decreasing trend was observed during months of monsoon and winter seasons, whereas increasing trends were found during summer months. Maximum number of months showed decreasing trend, especially during monsoon months in respect of consecutive 5-days maximum rainfall. The length of wet spells was increased with increase in length of dry spells. Month of September showed increase in wet spells, whereas, December showed increase in dry spells.

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