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To cite this article: R Sivajothi and K Karthikeyan 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **263** 042146

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Spatial and temporal variation of precipitation trends in Andhra Pradesh, India

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Abstract. Long-term samples of meteorological data are periodically necessary to assess the long standing effects of future hydrological changes. The evaluations are repeatedlyundertaken using deterministic statistical analyzewhich requires daily weather data as input. Andhra Pradesh had experienced frequent disasters like cyclones, floods, droughts etc. The frequency and intensity of the hazardous events hasbeen significantly increasing in therecent decades due to climatic changes and global warming. This model is being applied to all the districts of the state to evaluate the results of abnormally low rainfall and to evaluate possible adjustmentpolices. The final results shows that the lack of rainfall has larger influence on the living society and the major adaptation sustained by irrigation and the ecosystem which illustrates the potential of hydrological modelling for multiple dimensions of water resources. No significant trend has been detected for annual and seasonal precipitation in the entire state, some of the district's annual and monsoon precipitation has decreased, and has increased during post monsoon and winter seasons.

1. Introduction
Andhra Pradesh is a disaster-prone state in India; the state is more prone to hurricanes and catastrophes. A modest to dreadful vigorous hurricane is awaited to cause a stormwith in short span of time, more than 45 percentage of Andhra Pradesh is exposed to hurricanes and its hazards. Most of the economic sector in [1] Bangladesh is affected by climate change. Changing in extreme events has a more impact on the increasing economy of India, [2]most of the studies showed long term trend of significant changes of southwest monsoon and annual precipitation[3].Long term trends of precipitation for the last 50 years showed a significant decrease over all regions of the country : Dash et al.[8] and Naidu et al.[9] Mostly Andhra Pradesh experienced has the flood problems for the major causes are no proper drainage in the coastal delta zones. Estimated future climate change impacts and present scenario of drought in arid and semiarid provinces, the regions have experienced very vigorous and repeated dry spell and also irrigation is too unfavourable IPCC [4] Phillips introduced a mathematical model which is the first climatic successful model it shows monthly and seasonal patterns in the troposphere : Cox [5],Phillips [6] after that Phillips had started more number of scientific works started and created general circulation models and global climate projection models :Lync [7]. The simulated rainfall response to increasing

earth temperature is due to decrease of southwest monsoon: Kripalani et al.[11], Krishnan et al. [12], Sabadeetal.[16], Stowasser et al.[21] and Ueda et al.[22]About 2.11% of land area of the world is occupied by the Indian subcontinent which has a geographical area of 329 m ha. It receives an yearly mean precipitation of 1150mm, which receives maximum rainfall for this geographical area and second wettest country in the world: Muruganetal[13]. The evaluation results has showed significant decrease in southwest monsoon and increase in post monsoon season in Indian cardamom hills of Kerala: Sivajothi et al.[19],[14] Tamil Nadu showed extreme variation in precipitation pattern over the last hundred years (1905-2004) as well as the humid tropics rainfall climatology. More distributions are fitted for the precipitation but Gamma distribution is the best fit for wet and dry sequences and obtained good results: Sivajothi et al [20].

Analysis of observed rainfall data across the stations of TMCFs area in southern India depict greater variation and rain forest site of Gavi, the average and seasonal rainfall changed significant downwards for the period of (1994-2007): Murugan et al [15].This includes the application of the mathematical model for the area and an analysis of the scaling methodology and its applicability to precipitation data, and finally assessment of the future impacts on the state due to climate change. The outline of conceptual solution of the climate problem in the sense ensuring obliging behaviour in large portions, the objective of this study is to apply the statistical analyzeto simulate precipitation data series for the state, that are capable of producing long series of rainfall data without errors in the results. This study covers a 102-year period from 1901 to 2002 and includes 12 districts in Andhra Pradesh state; scrutinize the spatial variation of seasonal and annual and precipitation shift of Andhra Pradesh in this period.

2. Study area
Andhra Pradesh hasvarious topography extended the hills of Eastern Ghats and Nallamala Hills to the coast of Bay of Bengal, covering an area of 162,760 sq. km.It lies between 15.9129° N and 79.7400° E is in the tropic of cancer (Figure1). Agriculture has been main resource of revenue and major livelihood for the state with more than 60% of people involved cultivation and related works. Rice is the major staple food of state, agriculture contributes more than 12.12% to the Net state domestic product (NSDP). In Andhra Pradesh state, there are 12 districts, viz, Anantapur, Chittor, East Godavari, Guntur, Kadapa, Krishna, Kurnool, Nellore, Prakasam, Srikakulam, Visakhapatnam, Vizianagaram and West Godavari. However, in the past five decades or so, there have been significant changes in the structure and performance of the agricultural sector in Andhra Pradesh

Figure1. Location of the study area and distribution of meteorological stations

2.1. Data Used

The analyses were based on Monthly rainfall data for period of 1901 to 2002 for the 12 districts of Andhra Pradesh. The data were collected from the IMD website (http:// www.indiawaterportal.org). The climatic seasons are divided in to four seasons which are summer (March–May), winter (December – February), monsoon (June–September), and post-Monsoon (October–November).

3. Methodology

TheSen's estimator method was used to determine the magnitude of the trend in the forecast and it is also used to analyze hydrologicalprediction. Mann-Kendall test was used to determine the statistical significance of the trend in monthly, seasonal and annual rainfall data.

3.1 Non- Parametric Mann-Kendall test

The test is widely to use to calculate the current trends of seasonal and annual rainfall, and this is a non-parametric test. Kendall [10]
The MK test calculated as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_j - x_i)$$

The data values are said to be n, x_i and x_j are the data points i and j $(i > j)$ respectively, $sign(x_i - x_j)$ functions as follows

$$sign(x_j - x_i) = \begin{cases} +1, \text{if } x_j - x_i > 0 \\ 0 \ \ , \text{if } x_j - x_i = 0 \\ -1, \text{if } x_j - x_i < 0 \end{cases}$$

3.2Spearman's rho rank correlation

The rank correlation between the data series and two variables is measured using spearman's rho rank correlation which is non- parametric test: Siegel et al. [18]

Where rank correlation denoted by R, the difference in the rank defined by d, and n is the total number of data values.

3.3 Sen's slope estimator

The test used to calculate the slope for the linear trend is found in the time series, it was developed by Sen [17]. It is a non- parametric test

$$T_i = \frac{(x_j - x_i)}{j - i}$$

T_i Defined as Sen's slope estimator, where x_i and x_j are taken as the data points at time j and i ($j \geq i$) correspondingly.

3.4 Coefficient of variation

The ratio of the standard deviation to the mean is called as CV and it is calculated as:

$$CV\ (\%) = \frac{s}{\overline{x}} \times 100$$

where $\overline{x}$ is mean of the data and s is the standard deviation.

4. Results and Discussion

4.1 Statistical analysis of annual and seasonal rainfall

Evaluation of annual and seasonal precipitation data showed, such as mean, SD, and CV, of annual and seasonal rainfall measures for the period of 102 years (1901–2002) of Andhra Pradesh State were analysed from Table 1. Mean and SD of annual rainfall data of different districts varied from 542.08 to 1022.89mm respectively. In the case of seasonal rainfall, their values varied from 315.25 to 751.41 mm (monsoon), from 148.92 to 355.82 mm (post-monsoon), from 10.52 to 49.81 (winter), and from 60.85 to 120.30 mm (summer) and from 153.72 to 327.38mm (monsoon), from 103.87 to 206.80 mm (post-monsoon), from 18.11 to 59.78 mm (winter), and from 45.53 to 113.47 mm (summer), respectively, The Andhra Pradesh State is characterized by coastal plains, the Eastern Ghats, and the Western pen plains topography. Finally the mean annual rainfall of Andhra Pradesh State showed increasing and decreasing trends.

4.2 Trend analysis

The trends of rainfall for 13 stations in Andhra Pradesh were detected using MK, Sen's slope, Spearman's rho

4.2.1 Non parametric Mann–Kendall test

From table 2 it showsannual and seasonal statistical values for rainfall data series of certainstations for the period of 1901 to 2002. The seasonal statistical values have increased during the post-monsoon and summer seasons except Kadapa, Krishna, Kurnool and Visakhapatanam. The decreasing trends found using the MK test at significant 5 and 1 % levelsare 8 stations during monsoon season. There are two stations showing an increasing insignificant trend during the monsoon season. Except Ananthapur, Chittor, East Godavari and Guntur all other stations has showed a decreasing trend during post-monsoon season. At summer, increasing insignificant trend was showed by 10 stations and decreasing insignificant

trends by three stations. During winter, insignificant decreasing trends were shown by four station and insignificant increasing trends by seven stations.

4.2.2Magnitude of trend in rainfall series for Spearman's rho test and Sen's Slope estimator
From the table 3 and 4 the annual rainfall data series is known the magnitude of negative trend has been in between the range of 0.19 in Krishna District to 0.87 in KadapaDistrict (Table 3). An increasing trend of rainfall was found in the districts of Chittoor(0.11) and East Godavari (0.57). Increasing trends of Sen's estimator during the post-monsoon season were shown for all the station except Guntur and Kadapa. All the station has showed positive trend during summer season except two stations, the rainfall data showed both increasing and decreasing trends in the winter season. From the table 3 and 4, Spearman's rho test shows the same evaluation as Sen's slope estimator except for the Post-monsoon and summer season.In the winter season spearman's rho shows positive trends in all the 13 stations and Sen's slope estimator shows positive trends in four out of 13 stations.

4.2.3 Coefficient of variation for annual and seasonal rainfall
The rainfall data form CV for a period of 1901–2002 (102 years) for the state of Andhra Pradesh showed that interannualvariability was the maximum for the entire state. The minimum showed 10.23 % for annual rainfall and 13.67% (monsoon), 58.43 % (post-monsoon), 38.45 % (winter), and 42.14 % for summer rainfall.

Table1. Statistical analysis of annual and seasonal rainfall in Andhra Pradesh state

Station		Monsoon			Post Monsoon			Summer			Winter			Annual		
		M	SD	CV	M	SD	CV	M	SD	CV	M	SD	CV	M	SD	CV
A		351.41	177.9	18.32	179.8	133.98	13.43	112.95	72.66	12.22	10.52	22.09	9.32	654.68	406.63	34.54
C		428.11	205.34	21.23	269.07	152.02	15.3	120.3	90.82	16.43	49.81	59.78	8.20	867.29	507.96	36.56
E		675.39	265.49	40.43	257.9	173.82	34.54	64.38	61.47	12.43	25.22	37.98	13.43	1022.89	538.76	16.76
G		452.05	187.5	12.34	284	206.8	13.45	62.64	58.07	12.76	22.78	34.42	14.98	821.41	486.79	40.32
K		342.32	162.21	11.32	243.32	135.43	12.32	58.54	45.53	17.32	24.32	31.21	15.43	668.50	374.38	38.76
KR		534.24	231.97	13.45	256.47	181.37	14.49	63.48	461.29	13.48	23.49	37.16	12.56	877.68	911.79	44.89

KU	N	P	S	V	VI	W
315.25	315.25	377.74	602.66	727.22	751.41	629.43
153.94	153.72	174.17	250.63	289.16	327.38	264.51
13.22	13.45	11.32	12.56	14.51	16.32	13.23
149.06	148.92	258.72	243.03	355.82	228.68	244.15
103.87	103.89	167.45	178.9	182.48	173.21	168.94
13.43	14.51	14.34	14.56	13.32	14.32	7.89
67.29	67.38	56.90	84.06	95.06	108.74	60.85
54.04	103.89	57.37	85.54	79.69	113.47	61.21
14.45	11.76	12.89	12.78	15.61	14.56	15.76
10.53	18.93	23.89	22.14	26.19	25.89	22.39
18.11	27.45	32.04	31.38	36.75	39.82	35.02
13.97	9.32	14.65	11.53	8.65	11.41	13.56
542.13	542.08	717.25	951.89	1204.29	1114.72	956.82
329.96	388.13	413.03	546.45	588.08	653.88	529.68
39.68	40.72	41.23	45.56	20.65	19,02	43.32

Here, A- Anantapur, C-Chittoor ,E-East Godavari, G-Guntur, K-Kadapa, KR-Krishna, KU-Kurnool, N-Nellore, P-Prakasam, S-Srikakulam, V-Visakhapatnam, VI-Vizianagram, W-West Godavari.

Table 2. Statistic values of seasonal and annual rainfall data using Mann-Kendall for Andhra Pradesh

Station	Monsoon	Post-Mon	Summer	Winter	Annual
Ananthapur	-2.52	2.12	1.35	-0.92	1.78
Chittoor	1.02	1.37	1.98	-0.73	1.92
East Godavari	1.73	0.92	1.42	-0.42	-2.54
Guntur	-1.88	0.73	0.37	-0.75	-3.12
Kadapa	-2.12	-0.42	0.68	1.32	-1.02
Krishna	-3.13	-0.73	0.45	1.05	-1.92
Kurnool	-1.57	-0.68	0.92	1.92	-1.43
Nellore	-2.48	0.59	0.79	-0.49	-0.69
Prakasam	-1.48	0.54	0.23	-0.53	-0.48
Srikakulam	-2.51	0.63	0.45	0.59	-0.79
Visakhapatnam	-1.49	-0.79	-1.72	-0.48	-0.81
Vizianagaram	-2.54	1.22	-0.32	-0.59	-0.65
West Godavari	-1.37	0.89	-1.28	-0.61	-0.53

Table3. Statistic values of seasonal and annual rainfall data using Spearman's Rho for Andhra Pradesh

Station	Monsoon	Post-Mon	Summer	Winter	Annual
Ananthapur	-0.73	0.19	-0.07	0.93	-1.72
Chittoor	0.11	0.17	0.42	0.72	-0.45
East Godavari	0.57	0.23	0.97	0.11	-1.91
Guntur	-0.42	-0.46	0.18	-0.73	1.73

Kadapa	-0.87	-0.53	-0.72	-0.42	2.42
Krishna	-0.19	0.49	-0.51	0.72	2.97
Kurnool	-0.43	0.56	-0.17	-0.51	-2.31
Nellore	-0.58	0.11	-0.51	-0.31	-1.71
Prakasam	-0.69	0.42	-0.09	-0.42	-1.92
Srikakulam	-0.72	0.49	-0.19	-0.57	-2.59
Visakhapatnam	-0.81	0.54	-0.72	-0.72	-2.45
Vizianagaram	-0.92	0.62	-0.04	-0.91	-1.79
West Godavari	-0.17	0.31	-0.09	-0.38	-2.60

Table4. Statistic values of seasonal and annual rainfall data using Sen's Slope estimator for Andhra Pradesh

Station	Monsoon	Post-Mon	Summer	Winter	Annual
Ananthapur	-0.72	0.11	-0.15	-0.72	-1.09
Chittor	-0.92	0.18	0.07	-0.41	-1.52
East Godavari	0.79	0.57	0.05	-0.39	-2.35
Guntur	1.12	0.25	0.17	-0.28	-2.13
Kadapa	0.23	0.42	0.03	-0.15	-0.92
Krishna	-0.49	0.59	0.09	-0.04	-1.79
Kurnool	0.92	0.48	0.42	-0.09	-1.88
Nellore	-0.78	0.23	0.52	0.20	-2.05
Prakasam	-0.65	0.27	-0.92	-0.15	-2.51
Srikakulam	-0.59	0.45	-0.72	-0.12	-3.12
Visakhapatnam	-0.72	0.67	-0.92	-0.30	-2.53
Vizianagaram	-0.68	0.53	-0.42	-0.19	-2.91
West Godavari	-0.49	0.91	0.29	-0.16	-3.52

5.Conclusions

For 13 station in the state of Andhra Pradesh during the period of 1901- 2002, Mann–Kendall test, Spearman's rho test, and Sen'sslope estimator were used to analyze the annual and seasonal rainfall time series. The shows notable changes in the both annual and seasonal rainfall series in the Andhra Pradesh state during the past 102 years. The final results of annual rainfall data shows there is decreasing trend at 5 and 1% level of significance for all the stations except the districts of Srikakulam, Visakhapatnam and Vizianagaram which show non-significantly downward and upward trends. In the Post-monsoon season, seasonal rainfall has increased in the region. All station show notable decreasing trends at 5 and 1% level of significance except three stations (Srikakulam, Visakhapatnam and Vizianagaram) during the monsoon. This study of rainfall series would be very useful for cultivation, irrigation and data scientist and would play a major role for the organization of efficient use of water. This study is showed to understand the next level of research further and variation associated with each part.

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