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Short communication

Application of non-parametric tests for long-term trend analysis of rainfall over north-eastern region of India

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Precipitation is one of the most important parameter which influences the climatic variability. Hence several studies have been carried out to understand the rainfall variability in of its probability distribute and trend (Chandniha and Kausal 2016, Chandniha *et al.* 2017) using long term rainfall data. Detection of the cause of climate change is very tedious and complex phenomenon. Have applied Mann-Kendall test to study rainfall variability in Odisha Prabhakar *et al.,* (2017). In present study, eight north-eastern states i.e., Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim are considered. Further, 115 years rainfall data have been extracted from India Meteorological Department (IMD) fine resolution (0.25deg. x 0.25deg.) gridded database. Initially, basic statistical analysis *i.e.*, maximum, minimum, mean, standard deviation, and coefficient of variations have been adopted for annual, monthly (January to December) and seasonal (pre-monsoon, monsoon, post-monsoon and winter) time series during 1901-2015. Climate variability has been assessed in terms of trend and its magnitude using the non-parametric Mann-Kendall, Modified Mann-Kendall and Sen's slope estimators. Non-parametric tests have been tested at the 5% level of significance (Mann, 1945). Thereafter, maximum climatic variability or climate change point have been detected for all states using the two well-known approaches *viz.* standard normal homogeneity test (SNHT) and Mann-Whitney-Pettitt (MWP) test at 5% level of significance (Alexandersson and Moberg, 1997). From this study, it was noticed that, annual, monsoon and winter rainfall showed decreasing trend whereas pre-monsoon rainfall showed increasing trends for all north-eastern states.

Preliminary data analysis

Annual rainfall varies between 857.3 mm (Manipur) to 6345 mm (Meghalaya) over the entire states. Weighted annual average rainfall of the entire state is calculated as 2203.6 mm. From the analysis, it has been observed that the standard deviation varies between 234.6 mm (Assam) to 821.2 mm (Meghalaya) shown in Table 1.

Change point detection during 1901-2015

The change point year in Arunachal Pradesh, Assam,

Table 1: General statistics of annual rainfall time series during 1901-2015 over North-East states

S. No.	States	Minimum	Maximum	Mean	Std. deviation
1.	Arunachal Pradesh	1227.1	4426.3	2634.6	622.2
2.	Assam	1474.6	2744.3	2218.6	234.6
3.	Manipur	857.3	2248.1	1515.6	246.5
4.	Meghalaya	1300.3	6345.0	2781.5	821.2
5.	Mizoram	1071.1	3089.7	1881.9	369.8
6.	Nagaland	1162.4	2453.0	1929.5	270.1
7.	Sikkim	1640.6	3814.0	2765.1	386.4
8.	Tripura	1294.2	3508.2	2331.2	377.3

Table 2: Results of Mann-Kendall and Modified Mann-Kendall test with Sen's slope estimator for different NE states of India during 1901-2015

MK	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
Arunachal Pradesh	-0.435	1.267	1.849	0.169	-0.479	-2.086[a]	-2.105[a]	-3.075[a]	-1.46	-0.655	-0.525	0.179	-1.281	1.027	-2.816[a]	-0.861	0.972
Assam	-1.839	-1.165	-0.653	-1.603	-0.759	-2.180[a]	-0.744	-2.872[a]	-1.532	-0.527	-1.184	0.196	-3.423[a]	-1.736	-3.360[a]	-1.025	-2.391[a]
Manipur	-0.743	-1.682	-0.706	-0.817	2.318[b]	-0.331	0.863	-0.106	1.216	0.065	-1.540	0.254	0.024	0.515	-0.019	-0.452	-1.690
Meghalaya	0.111	-0.848	0.167	0.029	2.780[b]	4.066[b]	4.153[b]	1.387	1.750	2.412[b]	-0.321	2.149[b]	4.165[b]	2.175[b]	3.657[b]	2.490[b]	-1.317
Mizoram	-0.885	-0.585	-0.184	-1.218	2.246[b]	2.507[b]	4.041[b]	2.582[b]	2.161[b]	2.586[b]	-0.094	1.176	3.867[b]	0.742	4.544[b]	2.151[b]	-1.124
Nagaland	-2.707[a]	-2.545[a]	-1.994[a]	-4.196[a]	-1.769	-3.147[a]	-0.981	-2.282[a]	-1.929	-1.327	-2.071[a]	-0.888	-5.383[a]	-3.887[a]	-3.846[a]	-2.064[a]	-3.72[a]
Sikkim	1.429	1.939	3.785[b]	4.249[b]	1.905	-2.480[a]	-2.891[a]	-5.032[a]	-1.421	1.912	1.354	2.629[b]	-1.871	4.467[b]	-4.641[a]	1.830	2.407[b]
Tripura	-1.561	-0.952	-1.472	-2.093[a]	1.245	-1.697	1.199	-0.273	-0.764	0.249	-0.878	2.714[b]	-1.148	-0.877	-0.887	-0.285	-1.806
MMK	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**	**Pre-Monsoon**	**Monsoon**	**Post-Monsoon**	**Winter**
Arunachal Pradesh	-0.435	1.397	1.793	0.196	-0.479	-1.765	-1.97[a]	-3.283[a]	-1.46	-0.556	-0.637	0.175	-1.281	1.198	-2.605[a]	-0.816	0.858
Assam	-1.839	-1.165	-0.693	-2.140[a]	-0.698	-2.116[a]	-0.744	-2.782[a]	-1.675	-0.496	-1.266	0.172	-5.673[a]	-2.441[a]	-2.717[a]	-1.282	-4.25[a]
Manipur	-0.687	-1.701	-0.706	-0.817	3.115[b]	-0.262	0.863	-0.106	1.171	0.068	-1.217	0.106	0.021	0.514	-0.019	-0.485	-1.690
Meghalaya	0.096	-0.848	0.181	0.029	2.565[b]	2.224[b]	2.406[b]	0.829	0.890	2.412[b]	-0.321	0.929	1.549	2.404[b]	1.446	2.478[b]	-1.207
Mizoram	-0.540	-0.723	-0.197	-1.072	2.819[b]	2.882[b]	5.915[b]	2.582[b]	2.161[b]	2.087[b]	-0.135	0.292	4.066[b]	0.765	4.060[b]	1.842	-1.768
Nagaland	-2.707[a]	-6.095[a]	-1.717	-5.372[a]	-2.133[a]	-2.638[a]	-0.923	-3.988[a]	-1.929	-1.327	-2.685[a]	-1.150	-14.927[a]	-3.283[a]	-3.846[a]	-1.982[a]	-3.72[a]
Sikkim	1.429	1.274	3.785[b]	4.249[b]	1.580	-2.204[a]	-2.891[a]	-5.032[a]	-1.577	2.946[b]	1.278	2.022[b]	-1.985[a]	3.811[b]	-5.026[a]	1.989[b]	2.059[b]
Tripura	-0.737	-0.688	-1.167	-2.641[a]	2.078[b]	-2.115[a]	1.012	-0.269	-0.764	0.249	-0.804	0.377	-1.875	-0.877	-1.324	-0.971	-2.000[a]
Sen's Slope	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**	**Pre-Monsoon**	**Monsoon**	**Post-Monsoon**	**Winter**
Arunachal Pradesh	-0.026	0.141	0.331	0.050	-0.173	-0.838	-0.830	-1.321	-0.477	-0.129	-0.022	0.004	-2.304	0.565	-3.225	-0.194	0.137
Assam	-0.056	-0.071	-0.085	-0.305	-0.184	-0.508	-0.162	-0.615	-0.302	-0.076	-0.045	0.003	-2.332	-0.564	-1.339	-0.176	-0.164
Manipur	-0.007	-0.090	-0.086	-0.133	0.477	-0.073	0.182	-0.020	0.200	0.016	-0.067	0.000	0.021	0.145	-0.011	-0.105	-0.124
Meghalaya	0.000	-0.037	0.023	0.008	1.039	2.344	2.408	0.519	0.544	0.656	-0.010	0.011	9.241	1.060	6.404	0.721	-0.085
Mizoram	-0.002	-0.025	-0.022	-0.300	0.630	0.728	0.961	0.494	0.499	0.467	0.000	0.000	3.732	0.314	2.932	0.443	-0.070
Nagaland	-0.110	-0.172	-0.264	-0.724	-0.321	-0.634	-0.206	-0.451	-0.334	-0.223	-0.100	-0.015	-3.956	-1.356	-1.973	-0.408	-0.303
Sikkim	0.053	0.118	0.531	0.821	0.411	-0.984	-1.414	-1.805	-0.506	0.357	0.041	0.031	-2.027	1.782	-4.764	0.445	0.232
Tripura	-0.007	-0.050	-0.223	-0.716	0.471	-0.621	0.350	-0.056	-0.165	0.051	-0.019	0.000	-1.333	-0.478	-0.494	-0.081	-0.142

Where, [a] Negative significant at the level of 5% and [b] Positive significant at the level of 5%

Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura are 1991, 1959, 1922, 1969, 1937, 1959, 1991 and 1936 respectively using the MWP test. Similarly, using SNHT test shows 1991, 1993, 1909, 1970, 1937, 1966, 1991, 2004, and 2008 for respective states

Rainfall trend analysis during 1901-2015

From the results of the study, it is concluded that annual, monsoon and winter rainfall decreasing in northeastern region. During the study period, the monthly time series are showed decreasing trends except the December. Overall, annual, monsoon and winter precipitation indicate declining trends whereas pre-monsoon rainfall shows increasing trends at all stations. In monthly time steps, the lowest value (Sikkim) for the slope of rainfall (-1.805 mm/year) trend line was found in August, and the highest value (Meghalaya) for the slope of rainfall (2.408 mm/year) trend line was found in July. In annual and seasonal time steps, the lowest value (Sikkim) for the slope of rainfall (- 4.764 mm/year) trend line was found in the monsoon season, and the highest value (Meghalaya) for the slope of rainfall (9.241 mm/year) trend line was found in the annual time scale. The entire trend analysis results are summarized in Table 2. It can be concluded from the analysis that the zone of usually heavy rainfall shows complex variability and zone of low rainfall indicates less variability. Thus, decreasing trends in annual and seasonal rainfall indicates the increasing possibility of drought condition or water scarcity. These will have an adverse effect on rain-fed agriculture as well as sustainable development of the state. The results from the study can be useful for planning and managing the water resources, agriculture and sustainable development of the state and also important for any strategic planning for future adaptation and mitigation.

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