Journal of Agrometeorology 19 (2) : 160-163 (June 2017)

Short Communication

Spatio-temporal trends and change point detection in rainfall in different parts of North-eastern Indian states

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Anthropogenic activities often perturbed the normal behaviour of our natural climate system at ecosystem level, forcing it to change over the last centuries.The nature and magnitude of change have a high degree of spatiotemporal variability. At the local level and over short period, the adverse impacts are expected to be more intense.The natural resource rich north eastern region of India receive about 2.6 times more rainfall than other agro-climatic zone of the country (Dash *et al*, 2009). At present, the region is facing the negative consequences of the environmental changes that is challenging the environmental security and ecological sustainability of this region having unique limitations of landscape, trans-boundary river basins and inherent socio-economic instabilities. In the recent years, the variations in rainfall events have increased along with the frequent occurrence of extreme events (Dash *et al*, 2009). In this high rainfall receiving zone apart from flood it has faced some unprecedented drought like situation due to rainfall anomalies in the recent years.

The projected change in the mean annual rainfall of NE India was estimated to vary about 0.3–3 per cent by 2050 as compared to 1970s under A1B emission scenario (Anonymous, 2010). The simulations projected towards a substantial decrease in winter rainfall (January & February) in 2030s as compared to 1970s without affecting the rainfall from March to May and October to December (Jain *et al*, 2013).Saikia *et al* (2013) observed the decreasing trend in the monsoon rainfall during 1951-2007 over all the states of North-east India after analysing the 1° x 1° gridded data from IMD. Saha *et al*. (2015) acquired the high degree of spatiotemporal variability in rainfall in the hilly tracks of the Mizoram state with the significant increase in monsoon rainfall in several places of Mizoram mostly during the month of August with significant decrease in winter precipitation.

Though several studies have been reported, regarding the rainfall trend over North east India, they often suffered from two limitations. Either they were analyzed using the gridded data product without ground validation over the undulating difficult topography and issues of interpolation or they lacked proper distribution of meteorological observatories i.e. did not have the proper representation from each states. Hence, our present study, explored the weather data from several stations of the region, which are mostly reported for the first time.

Rainfall observations were acquired from the seven meteorological observatories installed at the seven sister states of North-eastern India namely, Arunachal Pradesh, Sikkim, Nagaland, Meghalaya, Manipur, Mizoram and Tripura were used for the analysis. The detailed descriptions with the specific period of data availability are presented Table 1.

To analyze the monotonic trend for any specific time

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Table 1: Detail information about the location and duration of the meteorological data points.

State	Location	Latitude	Longitude	Altitude (meter)	Data Duration	Missing Value
Arunachal Pradesh	Basar	27°59'N	94°42'E	725	1979-2014	-
Sikkim	Gangtok	27°19' N	88°36'E	1322	1983-2014	-
Nagaland	Jharnapani	25°45' N	93°50'E	250	1998-2014	-
Meghalaya	Umiam	25°41' N	91°55'E	1010	1983-2014	-
Manipur	Imphal	24°45' N	93°54' E	774	1954-2014	-
Tripura	Kailashahar	24°19' N	92°00'E	29	1980-2014	1998-1999
Mizoram	Kolasib	24°12'N	92°40'E	635	1980-2014	-

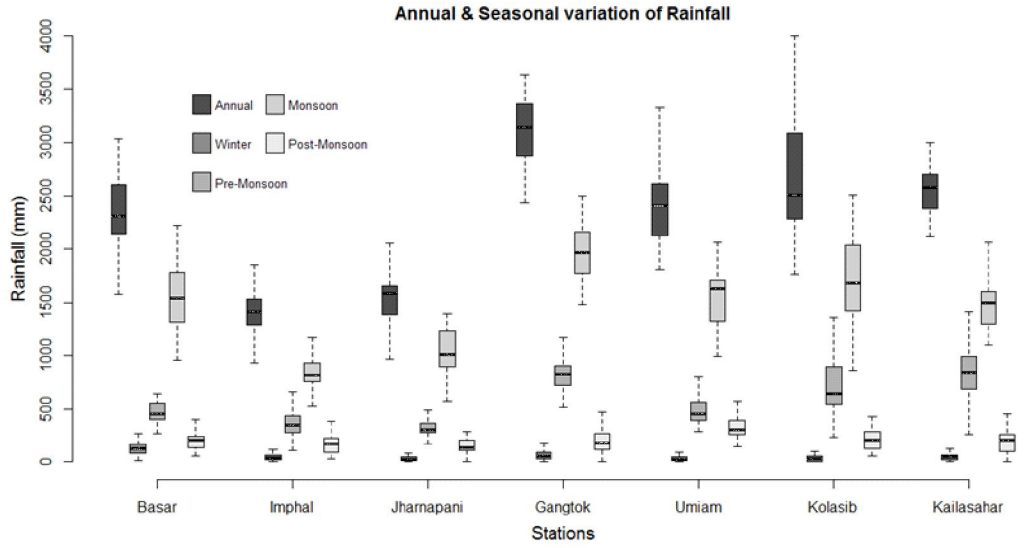

Fig. 1: Annual and seasonal variation in rainfall (mm) at different places of NE India.

series, generally parametric tests are statistically more robust than non-parametric tests. Time series of rainfall does not follow normal distribution. Therefore the non-parametric test yields better results than the former. We used the non-parametric Mann Kendall test (MK test) with Sen's slope estimator for the analysis of monotonic trend in the climatological rainfall data series that rarely follow non-normal distribution. The test also haslow sensitivity to abrupt breaks due to inhomogeneous time series. Change point detection test was carried out to assess the presence of sudden shift in the time series data,using two non-parametric tests namely Pettit's test (P-Test) and Buishand's Test (B-Test) using the R software (R Core Team, 2016). These testswere recommended by the European Climate Assessment & Data set project (ECA&D).

The annual and seasonal variation in mean rainfall for each meteorological stations are displayed in the form of a box and whisker plot (Fig. 1). The north eastern hill region of India possess a large spatial variation in normal rainfall. With the highest annual rainfall in Gangtok of over 3000 mm to lowest at Imphal (~ 1400 mm). It is quite clear from the figure that, the variation in annual rainfall is much greater than seasonal values. Kolasib had the inherent maximum variability in the annual rainfall and it was minimum for Kailasahar. Variation in monsoon rainfall may be the main contributing factor having similar type of variation. But, the coefficient of variation of rainfall is quite low in monsoon and pre-monsoon season. The monsoon season contributes about 60% of total annual rainfall followed by pre-monsoon (about 20%) and post-monsoon (about 10%).In spite of large variation, the NE Indian states receive sufficient amount of annual rainfall that majorly starts from April and continues till November (Saha *et al*., 2015).

The spatiotemporal variability in seasonal rainfall pattern was evident and significant in some occasions only (Table 2). The monsoon rainfall significantly increased at Kolasib and pre-monsoon shower at Imphal. The post-monsoon and winter rainfall has decreased in the majority of the stations, but for winter the values were significant in three stations (Gangtok, Umiam and Kolasib) and one station

Table 2: Trends of monthly rainfall (RF) at different locations of North East India.

Year	Basar	Imphal	Jharnapani	Gangtok	Umiam	Kolasib	Kailashnagar
Winter	-1.3(-12.9)	-0.6(-1.0)	-0.1(0.0)	-2.3***(-19.1)	-1.7*(-10.0)	-1.9**(-10.3)	-1.5(-6.5)
Pre-Monsoon	1.4(36.8)	1.5*(15.2)	-0.4(-24.0)	-0.4(-13.9)	1.4(39.8)	0.6(31.5)	-1.4(-56.3)
Monsoon	-0.4(-26.5)	0.1(0.7)	-0.4(-38.1)	0.9(65.7)	-0.7(-32.5)	2.5***(167.0)	0.3(23.4)
Post-monsoon	-0.5(-7.2)	0.2(1.9)	-2.1**(-80.4)	-1.3(-27.7)	-0.1(-0.1)	0(1.5)	-0.4(-11.6)
Annual	-0.1(-8.3)	1.3(23.5)	-0.2(-62.9)	-0.5(-36.2)	-0.2(-12.1)	1.6*(173.5)	0(-2.5)

(Note: ***, ** and * denote trends at 1%, 5% and 10% signiûcance level, respectively. Values indicate Mann Kendall's Z statistics and in the parentheses Sen's Slope represent the rate of change per decade (mm per decade)).

Table 3: Change point detection of mean monthly rainfall (RF) at different places of North East India.

Station	Test	Winter	Pre-Monsoon	Monsoon	Post-monsoon	Annual
Basar	P-Test	163**(1997)	90(NO)	80(NO)	105(NO)	94(NO)
	B-Test	8.1**(1997)	5.1(NO)	3.8(NO)	4.4(NO)	4.6(NO)
Imphal	P-Test	220(NO)	386**(1979)	230(NO)	190(NO)	348**(1985)
	B-Test	4.4(NO)	10.9**(1979)	5.9(NO)	5.2(NO)	9.3*(1985)
Jharnapani	P-Test	28(NO)	24(NO)	26(NO)	48**(2008)	22(NO)
	B-Test	3.2(NO)	2.3(NO)	2.8(NO)	4.9**(2008)	2.7(NO)
Gangtok	P-Test	182***(2005)	85(NO)	81(NO)	115(2003)	91(NO)
	B-Test	9.1***(2005)	4.3(NO)	4.1(NO)	6.1(NO)	5.1(NO)
Umiam	P-Test	147***(1997)	89(NO)	57(NO)	71(NO)	57(NO)
	B-Test	6.8*(1997)	3.7(NO)	3.1(NO)	3.6(NO)	2.7(NO)
Kolasib	P-Test	157*(2001)	80(NO)	230***(1999)	103(NO)	198**(1999)
	B-Test	1.2(NO)	0.8(NO)	1.9***(2001)	1.4(NO)	1.7***(2000)
Kailashnagar	P-Test	146*(2001)	92(NO)	76(NO)	80(NO)	88(NO)
	B-Test	1.3(NO)	0.9(NO)	1.2(NO)	1.4(NO)	1.3(NO)

(Note:***, ** and * denote trends at 1%, 5% and 10% signifcance level, respectively. Values indicate Pettit's test (P Test) and Buishand's test (B Test) statistics and in the parentheses the year of change in the time series if the test was significant).

for post-monsoon (Jharnapani). The seasonal analysis clearly indicates towards the increasing dryness during the post-monsoon and winter months across many places in the north eastern hill region. The increasing trend in annual rainfall was significant only at Kolasib, which was mainly due to the increase in the monsoon rainfall.

Change point detection tests were used to assess the shift in the time series of rainfall data. The test depicts the year of significant change, if any. In spite of the high degree of spatio-temporal variability, our results of Pettit's test and Buishand's test showed several significant changes in the time series of the rainfall data in the majority of meteorological stations (Table 3). The results of seasonal analysis reveals that, the monsoon rainfall series significantly sifted at Kolasib, pre-monsoon at Imphal and post-monsoon at Jharnapani. The changes in the Kolasib occurred in around 1999-2001 while, for Imphal it was quite early i.e. in between 1979-1985. Jharnapani had faced the change in the last decade only. The winter rainfall series significantly changed for the majority of the stations viz. Basar, Gangtok, Umiam, Kolasib and Kailasnagar. The temporal shift in monthly rainfall occurred during late 1990 to early 2000. In general, the shift in winter rainfall mostly occurred during the decade of 1995-2005.

Thus it can be concluded that the rainfall data analysis of seven different meteorological stations spanning over all the north-eastern states, clearly indicated towards a change. The winter rainfall showed the significant reducing trend in the majority of the stations namely Basar, Gangtok, Umiam and Kolasib. The change point shift dominated in the winter

rainfall series, which significantly shifted in Basar, Gangtok, Umiam, Kolasib and Kailasahar over the time period from the late 1990s to mid-2000s.

ACKNOWLEDGEMENT

The research work was a part of the institute project of ICAR Research Complex for NEH Region entitled "Analysis of historical weather variables and accuracy assessment of the weather forecast for improving the agro advisory" (PIMS code- IXX11363). The authors are thankful to the Director of the institute for providing the project and all the respective Joint directors from the regional centre for providing their assistance for smooth functioning of project activitiesanddata sharing.

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Received : June 2016; Accepted: April 2017