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Critical comparison of north east monsoon rainfall for different regions through analysis of means technique

K. V. NARASIMHA MURTHY, R. SARAVANA and P. RAJENDRA

Department of Mathematics, Madanapalle Institute of Technology and Science,

Madanapalle – 517 325, India,

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e mail : murthy.koundinyas@gmail.com

सार - कृषि, बीमा, उद्योग तथा इनसे संबंधित क्षेत्रों से जुड़े अनेक लोगों पर वर्षा का सीधे या परोक्ष रूप से महत्वपूर्ण प्रभाव पड़ता है। अलग-अलग क्षेत्रों में वर्षा कि विविधता और महत्वपूर्ण तुलनाओं का अध्ययन सरकार द्वारा सूखे कि स्थिति का आकलन करने और आवश्यक योजना तैयार करने के लिए किया जाता है। भारत में ऋतुनिष्ठ पूर्वोत्तर मॉनसून वर्षा हर साल अक्तूबर, नवम्बर और दिसम्बर के महीनों के दौरान होती है। इस शोध पत्र में भारत के विभिन्न क्षेत्रों में पूर्वोत्तर मॉनसून वर्षा पैटर्न की विभिन्नताओं और महत्वपूर्ण तुलनाओं के लिए एक पद्धति आधारित संसाधनों के विशेलषण (ANOM) तकनीक के लिए प्रस्ताव दिया गया है और प्रत्येक क्षेत्र में वर्षा वितरण प्रक्रियाओं के संचयी संभाव्यता को बताया गया है। विश्लेषण से पता चलता है कि पूर्व और पूर्वोत्तर क्षेत्रों में अधिक भिन्नता के साथ औसत वर्षा होती है। दक्षिण प्रायद्वीपीय भारत में लगातार समान वर्षा होती है, जबकि पश्चिमोत्तर भारत और मध्य भारत में क्रमशः कम वर्षा हुई है। सभी चार क्षेत्रों में अक्तूबर के महीने में अधिक और दिसम्बर के महीने में कम वर्षा रिकार्ड की गई है।

ABSTRACT. Rainfall has critical importance directly or indirectly on many people in the sectors of agriculture, insurance, industry and other allied fields. The study of variations and critical comparisons of rainfall in different regions helps the Government to assess drought situations and to take necessary planning. The seasonal Northeast monsoon rainfall in India occurs during the months of October, November and December of every year. The study proposes a methodology based Analysis of Means (ANOM) technique on the variations and critical comparisons of Northeast monsoon rainfall patterns in different regions of India and observes the cumulative probability distribution function of rainfall for each region. Analysis reveals that the East and Northeast region receives the highest average rainfall with high variation, South Peninsular India sustain with the consistent rainfall, Northwest India and Central India experience low rainfalls respectively. All the four regions record the high rainfall in the month of October and low in the month of December.

Key words – Rainfall, ANOM, Upper decision line, Central line, Lower decision line, Multiple comparisons.

1. Introduction

The economy of Indian is largely dependent on agriculture and 70% of the Indian population depends on farming, either directly or indirectly. The agricultural sector in our country contributes around 18% of the GDP. The livelihood of the Indian farmer majorly depends on the Monsoon rainfall and around 58% of the total employment in the country takes place through agriculture. The success of agriculture primarily depends on the proper amount and distribution of rainfall during the monsoon seasons. In India, there are two types of monsoons: the Southwest monsoon and the Northeast monsoon. The Southwest monsoon in India is a four month long affair from June to September and the Northeast monsoon is a smaller spatial scale monsoon modulating the rainfall activity over South Peninsular India (Amudha *et al.*, 2016). The duration of the Northeast monsoon is for three months, October to December and this is short but intense monsoon.

Understanding the behaviour of rainfall is a critical phenomenon for the solution of several regional environmental problems of integrated water resources management at regional scales such as agriculture, climate change and natural hazards (floods and droughts). Hence there is a need to study and analyze the behaviour of monsoons rainfall.

Statistical analysis is one of the key techniques for the analysis of rainfall records over a long period and provides information of rainfall patterns and variability. Analysis of Means (ANOM) technique is one of the statistical techniques for studying variations and critical

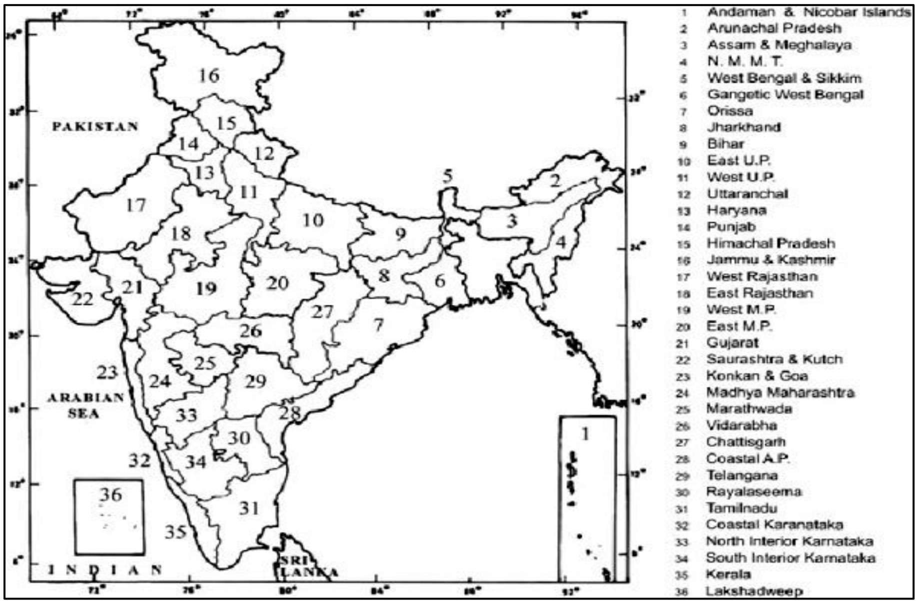


Fig. 1. Meteorological sub-regions of India

comparisons of rainfall in different regions as well as different time periods. The Analysis of Means (ANOM) is a useful alternative to the Analysis of Variance (ANOVA) in comparing the group of treatments. An ANOM chart conceptually similar to a control chart. The attractive attributes of ANOM includes the inherent ease of interpretation, graphical presentation, depicts decision lines, assessment of magnitude differences and Statistical significance of the treatments.

Walpole and Myers (1972) applied the Analysis of Means (ANOM) technique to the data resulted from an experiment which reported how the mean absorption of moisture in concrete was affected by different aggregates. Tomlinson and Lavigna (1983) presented an application of ANOM for percent defective data obtained from silicon crystal growing, the first processing step in semiconductor manufacturing. Ullman (1989) has expanded the area of application by providing factors for ANOM on ranges suitable for use in the analysis of Taguchi signal-to-noise ratio. Parra and Loaiza (2003) applied the ANOM technique to a case study data from chemical and pharmaceutical industries and demonstrated the essentiality of ANOM through powerful visualization and communication tool, to complement the conventional analysis of nested designs. The ANOM has been extended in transforming the data to make it approximately normal. Transformation of attribute data has been discussed by Nelson (1983a). Ohta (1981) have been explained the procedure for pooling data by the Analysis of Means. Ramig (1983) presented the applications of the Analysis of Means. Murthy & Ismail (2014) used ANOM technique for classification and comparison company share prices. Murthy *et al.* (2017) studied variations of Southwest monsoon rainfall of sub regions in North East India using ANOM chart.

The main objective of the paper is to study the variations and critical comparisons of rainfall patterns in different regions and seasonal months of Northeast monsoons from October to December using ANOM technique. The ANOM chart, Box plot and statistical cumulative distribution function of Northeast monsoon rainfall for each region and month has been observed.

2. Data and research objective

For the purpose of analysis, we have collected the rainfall data of Northeast monsoon for four regions in India during 1971-2014 from Open Government Data (OGD) Platform, India and processed the data by SAS Software.

The list of meteorological sub regions of India are shown in Fig. 1 and the corresponding regions are mentioned below:

(*i*) *East & North-East India (E&NEI)*: Arunachal Pradesh (ARUN), Assam and Meghalaya (ASME), Nagaland, Manipur, Mizoram & Tripura NMMT), Sub-Himalayan West Bengal & Sikkim (HWBS), Gangetic West Bengal (GWEB), Bihar (BIHA) and Jharkhand (JHAR).

(*ii*) *North-West India (NWI)* : East Uttar Pradesh (EUP), West Uttar Pradesh (WUP), Uttaranchal (UTTAR), Haryana, Delhi & Chandigarh (HDCh), Punjab (PUN), Himachal Pradesh (HP), Jammu & Kashmir (JK), West Rajasthan (WRAJ) and East Rajasthan (ERAJ).

(*iii*) *Central India (CI)* : Orissa (ORI), West Madhya Pradesh (WMP), East Madhya Pradesh (EMP), Gujarat, Dadra & Nagar Haveli (GUJ), Saurashtra Kutch & Diu (SAU), Konkan & Goa (KGOA), Madhya Maharashtra (MMAH), Marathwada (MARA), Vidarbha (VID) and Chhattisgarh (CHA).

(*iv*) *South Peninsular India (SPI)* : Andaman and Nicobar Islands (ANNI), Coastal Andhra Pradesh (CAP), Telangana (TEL), Rayalseema (RAY), Tamil Nadu& Pondicherry (TNP), Coastal Karnataka (CKA), North Interior Karnataka (NIKA), South Interior Karnataka (SIKA), Kerala (KER) and Lakshadweep (LAK).

3. Methodology

The ANOM technique was developed by Ott (1967) to compare whether any one of the group treatment means differ significantly from the overall mean or not. This technique has been extended by Schilling (1973) to the analysis of means for treatment effects (ANOME). This is important to notice that the Analysis of Means procedure is appropriate for factors involving fixed effects but inappropriate for factors involving random effects. For fixed effects, the model assumes the factor level means to be constant. However, for random effects, the factor level means are random variables and in that case the aim is to estimate the variance rather than mean.

3.1. *Variables data*

The one-way classification model results when an experimenter obtains 'k' independent random samples of size n_i (i = 1, 2, 3,…, k) each from a different population. These 'k' populations may represent 'k' treatments (or) 'k' methods of production (or) 'k' groups. The data consist of a quantitative measurement of some characteristic for each experimental unit sampled from the different populations.

For comparison of the mean responses by the ANOM procedure, we consider the simplest case of 'k' groups of equal size 'n'. Here 'k' groups mean $\bar{X}_i$ are assumed to be normally distributed populations with common variance σ^2. Let $\bar{\bar{X}}$ represent the grand mean and s^2 the pooled estimate of the common but unknown variance. These quantities are defined mathematically by

$$\bar{\bar{X}} = \frac{1}{k}\sum_{i=1}^{k} \bar{X}_i \qquad (1)$$

$$s^2 = \frac{1}{k}\sum_{i=1}^{k} s_i^2 \qquad (2)$$

where,

$$s_i^2 = \sum_{j=1}^{n} (X_{ij} - \bar{X}_i)^2 \Big/ (n-1)$$

X_{ij} = j^{th} observation from i^{th} population.

Other estimates of σ^2 have been acceptable.

The steps to carry out ANOM are:

(*i*) Compute the group means, $\bar{X}_i \; (i = 1, 2, 3, ..., k)$.

(*ii*) Compute the grand mean, $\bar{\bar{X}}$ using equation (1).

(*iii*) Compute s, an estimate of the standard deviation of an individual observation. This is the square root of s^2 computed using equation (2).

(*iv*) Obtain the value h_α from the table in Nelson (1983b) for Type I risk level (α), number of means k and degrees of freedom $(n-1)k$.

(*iv*) Compute the upper and lower decision lines, UDL and LDL, where

$$\text{UDL} = \bar{\bar{X}} + h_\alpha s\sqrt{(k-1)/kn} \qquad (3)$$

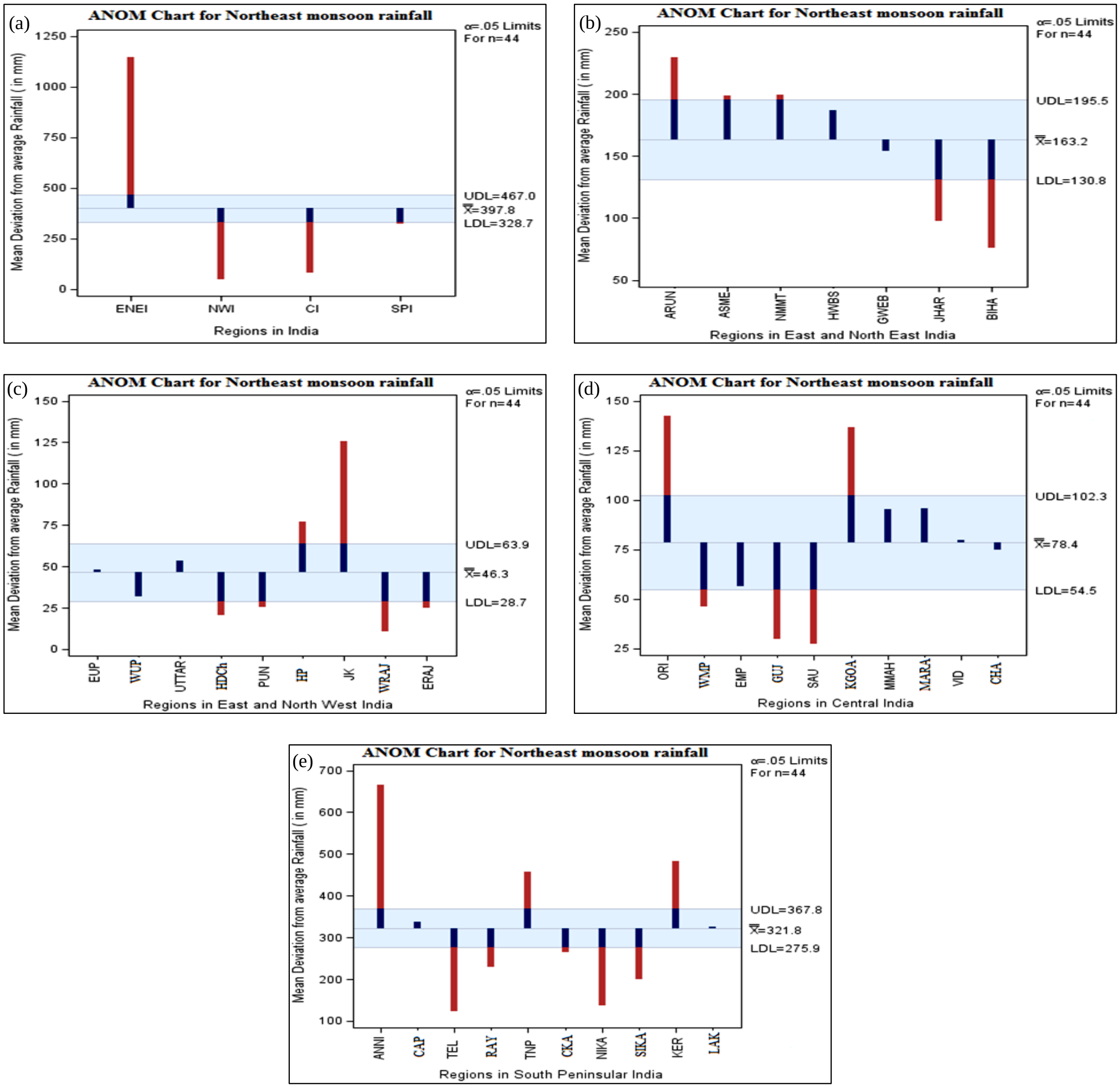
$$\text{C. L.} = \bar{\bar{X}} \qquad (4)$$

$$\text{LDL} = \bar{\bar{X}} - h_\alpha s\sqrt{(k-1)/kn} \qquad (5)$$

The means are plotted with the decision lines. If any mean falls outside the decision lines then there is a statistically significant difference among the means.

3.2. *ANOM with unequal sample sizes*

For the set of means each of which is based on the sample size, Eqs. (3-5) provide the exact results of decision lines. When the means are based on unequal sample sizes their deviations from the grand mean are no longer equi-correlated & decision limits, the decisions limits in this case are:



Figs. 2(a-e). Rainfall variations of northeast monsoon (a) for different regions in India (b) in sub regions of East and Northeast India (c) in sub-regions of the Northwest India (d) in sub-regions of the Central India (e) in sub regions of the South Peninsular India

$$\overline{\overline{X}} \pm h^{*}_{\alpha,k,v}\, s\sqrt{(k-1)/kn} \qquad (6)$$

The equation (6) is computed using critical values that are upper bounds on the true but not available values of h.

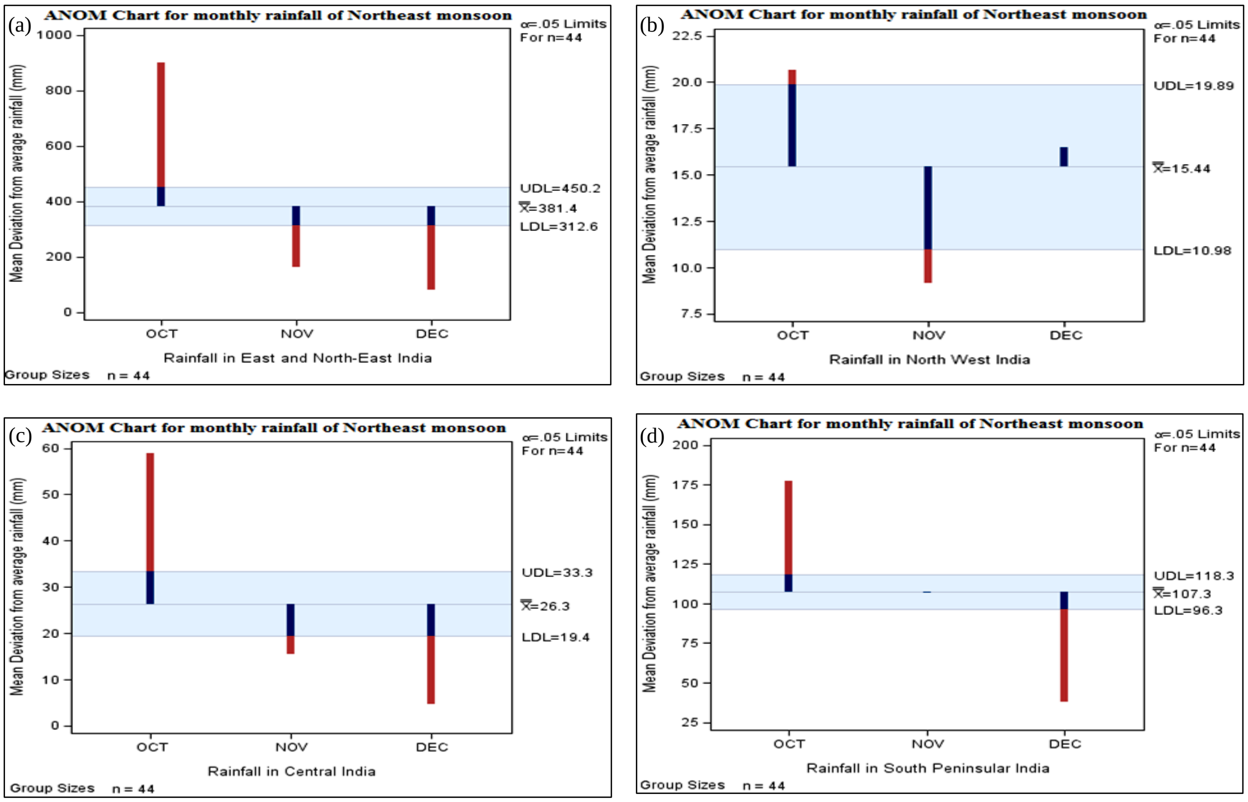
Here, $N = \sum_{i=1}^{k} n_i$ is total number of observations and n_i is number of observations in the i^{th} mean.

The necessary values of h^* can be calculated as the upper $\alpha^*/2$ percentage points of *t-distribution* by following Sidak (1967), in which

$$\alpha^* = 1-(1-\alpha)^{1/k} \qquad (7)$$

α is desired significance level and

k = number of means.



Figs. 3(a-d). Monthly rainfall variations of northeast monsoon in (a) East & Northeast India (b) Northwest India (c) Central India (d) South Peninsular India

The upper bounds obtained by the use of equation (7) are slightly less than the factors given by Nelson (1974). Remember that in the use of equation (6) it is necessary to calculate as many pairs of decision lines as there are different sample sizes.

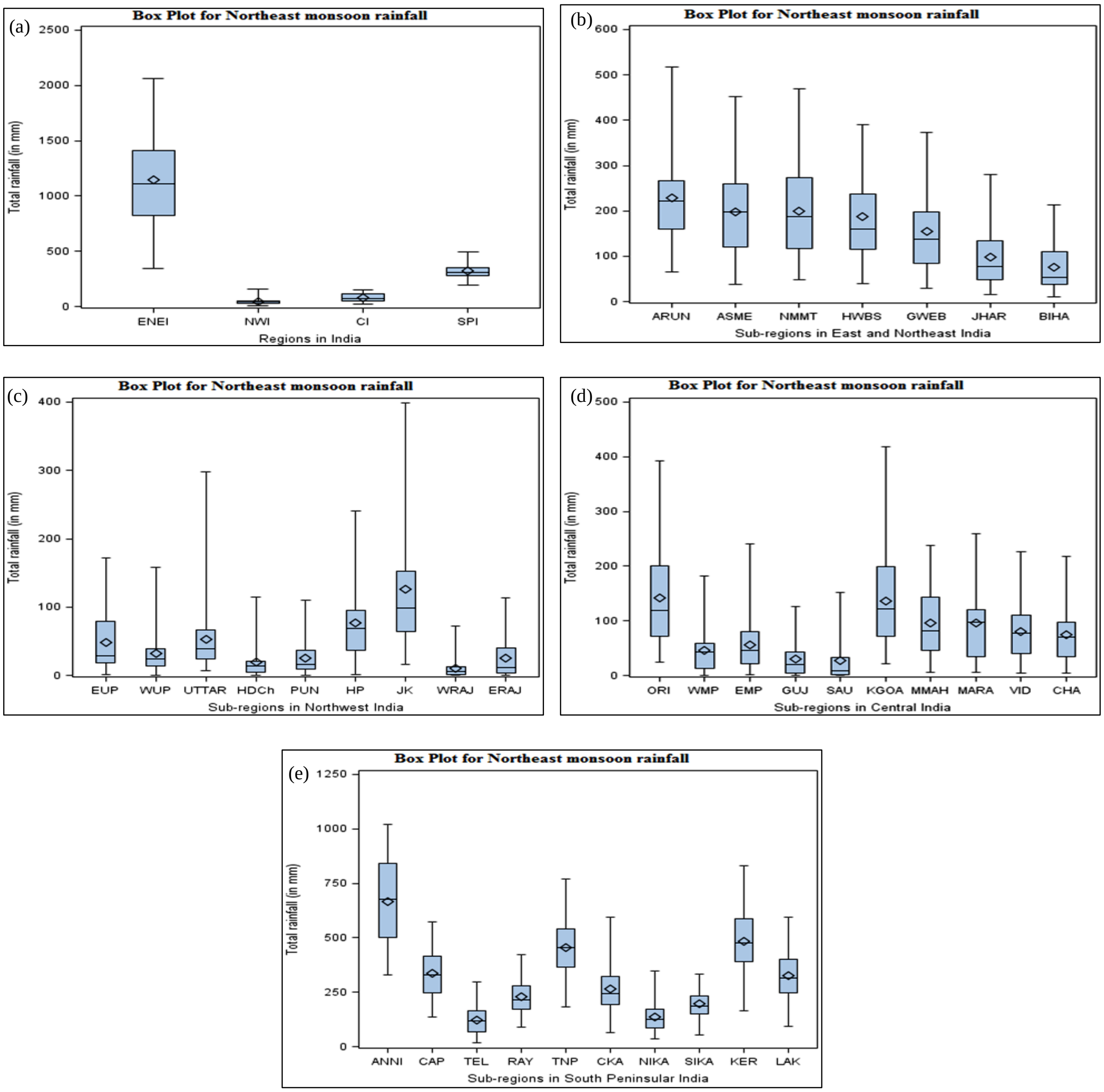
4. Results and discussion

ANOM Chart has three horizontal lines namely Upper Decision Line (UDL), Central Line (CL) the mean and Lower Decision Line (LDL). The sub-regions whose average rainfall fall within the decision lines, *i.e.*, between LDL and UDL indicates the results of receiving consistent rainfall. When the average rainfall of a particular sub-region below the LDL results of receiving low rainfall whereas above the UDL indicates of high rainfall among the sub-regions of the region.

Fig. 2(a) represents that the rainfall variations of northeast monsoon for four meteorological regions of India. From the Fig. 2(a), E&NEI receives the highest Northeast monsoon rainfall while NWI receives the lowest amount of rainfall among the four regions. The ANOM chart in Fig. 2(a) depicts that E&NEI shows upward tendency and the remaining three regions show downward tendency. Further, the SPI receives consistent rainfall from the average Northeast monsoon rainfall.

Figs. 2(b-e) depict the rainfall variations of Northeast monsoon in the Sub-regions for four meteorological regions of India. In Fig. 2(b), we notice that the sub-regions Arunachal Pradesh, Assam & Meghalaya, Nagaland, Manipur, Meghalaya & Tripura and Sub-Himalayan west Bengal & Sikkim shows upward tendency and Gangetic West Bengal, Jharkhand and Bihar shows downward tendency from the average rainfall of E&NEI. The Sub-Himalayan, West Bengal & Sikkim and Gangetic West Bengal receives consistent Northeast monsoon rainfall. Further the Arunachal Pradesh sustain with the highest and Bihar sustain with the lowest rainfall in the region.

From Fig. 2(c), we observe that the Jammu & Kashmir receives the highest and West Rajasthan receives the lowest benefit of Northeast monsoon rainfall in the NWI. Jammu & Kashmir, Himachal Pradesh, Uttaranchal and East Uttar Pradesh shows upward tendency whereas West Uttar Pradesh, Punjab, Haryana, Delhi and Chandigarh, West & East Rajasthan shows downward

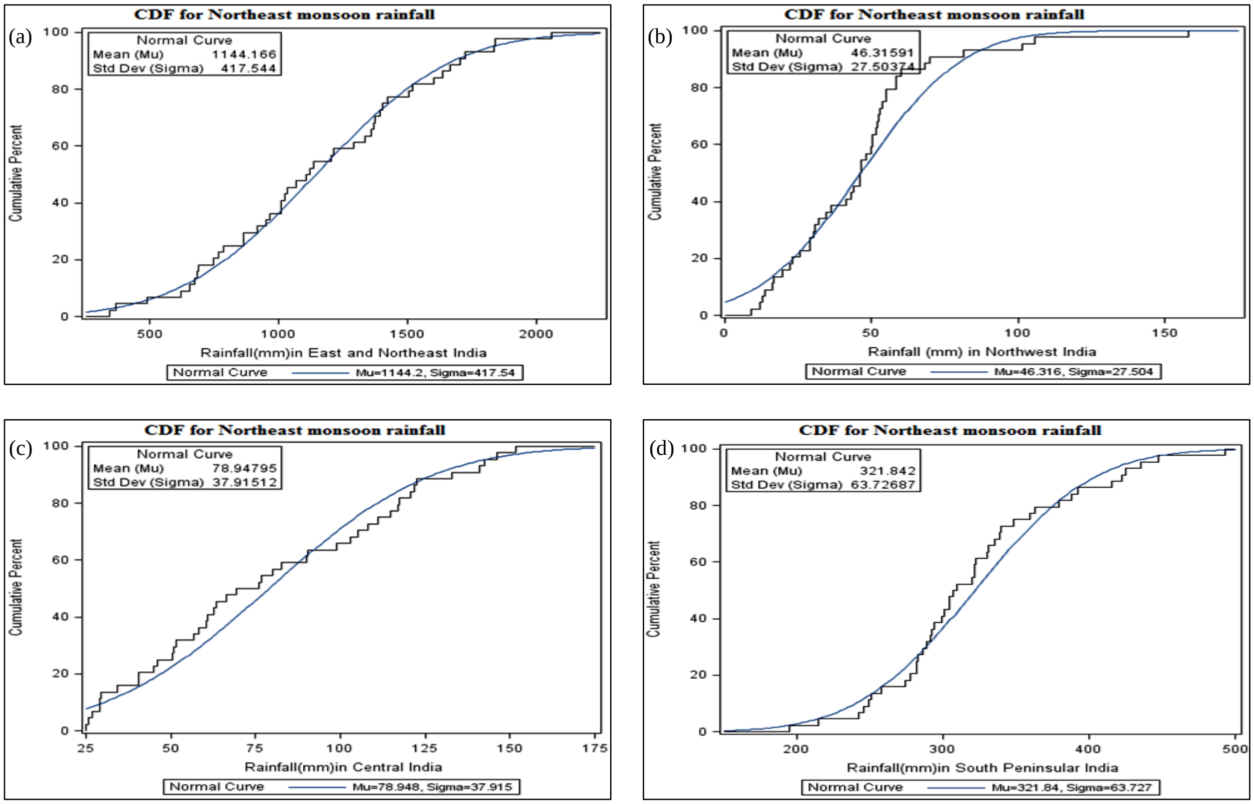


Figs. 4(a-e). Box Plot for Northeast monsoon rainfall series for (a) India (1971-2014) (b) East and Northeast India (c) Northwest India (d) Central India (e) South Peninsular India

tendency. The regions East Uttar Pradesh, West Uttar Pradesh & Uttaranchal have steady rainfall.

Fig. 2(d) reveal that the Orissa, Konkan & Goa, Madhya Maharashtra, Marthwada and Vidarbha have upward tendencies and West Madhya Pradesh, East Madhya Pradesh, Gujarat region, Dadra & Nagar Haveli, Saurashtra, Kutch & Diu and Chhattisgarh have downward tendencies of Northeast monsoon rainfall the from the average of CI. Orissa undergo the highest rainfall and Saurashtra, Kutch & Diu undergo the lowest rainfall whereas the East Madhya Pradesh, Madhya Maharashtra, Marthwada, Vidarbha and Chhattisgarh have consistent rainfall among sub regions of CI.

Fig. 2(e) of ANOM chart indicate that the Andaman & Nicobar, Coastal Andhra Pradesh, Tamil Nadu & Pondicherry and Kerala have upward tendencies while Telangana, Rayalaseema, Coastal Karnataka, North Interior Karnataka and South Interior Karnataka have downward tendencies from the SPI average Northeast monsoon rainfall. Among all the regions of SPI, Andaman



Figs. 5(a-d). Cumulative distribution function of northeast monsoon rainfall in the region of (a) East and Northeast India (b) Northwest India (c) Central India (d) South peninsular India

and Nicobar receives the highest rainfall whereas the sub-regions Coastal Andhra Pradesh and Lakshadweep undergo the consistent Northeast monsoon rainfall in SPI.

Figs. 3(a-d) of ANOM charts represents monthly variations of Northeast monsoon season for four meteorological regions of India. From the Figs. 3(a-d), that the E&NEI, CI and SPI experience the highest Northeast monsoon rainfall in the month of October and the lowest in the month of December while NWI undergo the highest rainfall in October and the lowest monsoon rainfall in November.

Box plots from Figs. 4(a-e) indicates the mean, median, inter quartile range & extremes for the Northeast monsoon rainfall of regions and sub-regions of India. Cumulative distribution functions for Northeast monsoon rainfall of different regions of India are presented in Figs. 5(a-d). It is noticed that the Northeast monsoon rainfall almost normally distributed except in the NWI.

5. Conclusions

In this study, an ANOM technique incorporates the variability and critical comparisons rainfall patterns for various regions as well as sub regions during the Northeast monsoon season. Based on the technique, the following are critically compared:

(*i*) E&NEI receives the highest average Northeast monsoon rainfall but not consistent. Among the sub regions, Sub Himalayan West Bengal and Gangetic West Bengal receives consistent rainfall.

(*ii*) NWI undergo the lowest Northeast monsoon rainfall with the highest variability. The sub regions East Uttar Pradesh, West Uttar Pradesh and Uttaranchal experience the consistent rainfall.

(*iii*) CI sustain with the lowest Northeast monsoon rainfall with the significant variability. In this region Madhya Maharashtra, Marthwada, Vidarbha and Chhattisgarh encounter the consistent monsoon rainfall.

(*iv*) The SPI experiences the consistent Northeast monsoon rainfall during the season. Coastal Andhra Pradesh and Lakshadweep show in consistent monsoon rainfall. The sub-regions Andaman & Nicobar Islands, Tamil Nadu & Pondicherry and Kerala exhibits upward tendency with the significant variation and the remaining sub regions Telangana, Rayalaseema, Coastal Karnataka, North Interior Karnataka and South Interior Karnataka downward tendency with the remarkable variation in Northeast monsoon rainfall.

(*v*) The regions E & NEI, CI and SPI encounter the highest Northeast monsoon rainfall in the month of October and the lowest in the month of December while NWI receives the highest rainfall in October and the lowest monsoon rainfall in November.

(*vi*) The CDF for northeast monsoon rainfall of all the regions are almost normally distributed except NWI.

(*vii*) Maximum, minimum, mean, median and inter Quartile range for Northeast monsoon rainfall has been delineated with the help of Box plot chart.

The study reveals that the ANOM technique may be apply for various geographical regions in different time periods for analyzing rainfall behaviour.

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