Chapter 2

Regional Annual Maximum Rainfall Frequency Analysis of North East India using L-moment.

2.1 Introduction

In this chapter regional annual maximum rainfall analysis of North East India has been carried out using L-moment. For this purpose, five extreme probability distributions namely the generalized extreme value (GEV), generalized logistic (GLO), generalized Pareto (GPA), generalized log normal (GNO) and Pearson type III (PE3) are used.

2.2 L-moments

For a random variable X with cumulative distribution function (CDF), $F(.)$, Greenwood et al. [20] defined the probability weighted moments (PWMs) as follows:

$$\beta_r = M_{1,r,0} = E[X\{F(X)\}^r]. \qquad (2.2.1)$$

where, $M_{p,r,s} = E[X^p\{F(X)\}^r\{1 - F(X)\}^s]$, (2.2.2)

and β_r can be rewritten as:

$$\beta_r = \int_0^1 x(F)F^r dF, \qquad r = 0,1,2 \ldots \qquad (2.2.3)$$

where $x(F)$ is the inverse CDF of x evaluated at the probability F.

Hosking [23] defined L-moments in terms of PWMs as follows:

$$\lambda_{r+1} = \sum_{k=0}^{r} p_{r,k}^{*} \beta_k \quad (2.2.4)$$

where, $p_{r,k}^{*}$ is given by

$$p_{r,k}^{*} = \frac{(-1)^{r-k}(r+k)!}{(k!)^2(r-k)!} \quad (2.2.5)$$

The first four L-moments can be defined as:

$$\lambda_1 = \beta_0, \quad (2.2.6)$$

$$\lambda_2 = 2\beta_1 - \beta_0, \quad (2.2.7)$$

$$\lambda_3 = 6\beta_2 - 6\beta_1 + \beta_0, \quad (2.2.8)$$

$$\lambda_4 = 20\beta_3 - 30\beta_2 + 12\beta_1 - \beta_0. \quad (2.2.9)$$

Hosking and Wallis [25] defined L-moments ratios (LMRs) as:

Coefficient of L-variation, $\tau = \lambda_2/\lambda_1$,

Coefficient of L-skewness $\tau_3 = \lambda_3/\lambda_2$, (2.2.10)

Coefficient of L-kurtosis $\tau_4 = \lambda_4/\lambda_2$.

Hoking and Wallis [25] defined sample L-moment as follows:

$$l_{r+1} = \sum_{k=0}^{r} p_{r,k}^{*} b_k \quad (2.2.11)$$

where $b_k$is given by

$$b_r = \frac{1}{n} \sum_{j=r+1}^{n} \frac{(j-1)(j-2)\dots(j-r)}{(n-1)(n-2)\dots(n-r)} x_{j:n} \quad (2.2.12)$$

2.3 Probability Distribution used for the study:

The probability distributions used for this study are found in Hosking and Wallis [25] and Bhuyan [4]. The probability density functions (PDFs), quantile functions, L-moments and parameters for each of the five distributions used for this study are given below.

2.3.1 GPA Distribution

The PDF of GPA distribution is given by

$$f(x) = \alpha^{-1} e^{-(1-k)y}, y = \begin{cases} -k^{-1} log\left\{1 - \frac{k(x-\xi)}{\alpha}\right\}, & k \neq 0 \\ \frac{x-\xi}{\alpha}, & k = 0 \end{cases} \quad (2.3.1)$$

where ξ, α and $k$are the location, scale and shape parameters of the distribution and the range of x are $\xi \leq x \leq \xi + \alpha/k$ if $k > 0$ and $\xi \leq x <\propto$ if $k \leq 0$.

The quantile function is given by

$$Q(F) = \xi + \frac{\alpha}{k}\{1-(1-F)^k\}, k \neq 0. \quad (2.3.2)$$

L-moments for GPA distribution defined by Hosking and Wallis [25] are as follows:

$$\lambda_1 = \xi + \alpha/(1+k), \quad (2.3.3)$$

$$\lambda_2 = \alpha/\{(1+k)(2+k)\}, \quad (2.3.4)$$

$$\tau_3 = (1-k)/(3+k), \quad (2.3.5)$$

$$\tau_4 = (1-k)(2-k)/\{(3+k)(4+k)\}. \quad (2.3.6)$$

where $k > -1$

Parameters of GPA distribution for L-moment, given by Hosking and Wallis [25] are as follows:

If $\xi$is known

$$k = (\lambda_1 - \xi)/\lambda_2 - 2, \quad (2.3.7)$$

$$\alpha = (1+k)(\ (\lambda_1 - \xi). \quad (2.3.8)$$

If $\xi$is unknown

$$k = (1 - 3\tau_3)/(1+\tau_3), \quad (2.3.9)$$

$$\alpha = (1+k)(2+k)\ \lambda_2, \quad (2.3.10)$$

$$\xi = \lambda_1 - (2+k)\lambda_2. \quad (2.3.11)$$

2.3.2 GEV Distribution

The PDF of GEV distribution is given by

$$f(x) = \alpha^{-1}e^{-(1-k)y - e^{-y}}, y = \begin{cases} -k^{-1}\log\left\{1 - \frac{k(x-\xi)}{\alpha}\right\}, & k \neq 0 \\ \frac{x-\xi}{\alpha}, & k = 0 \end{cases} \quad (2.3.12)$$

where ξ, α and k are the location, scale and shape parameters of the distribution and the range of x are $-\propto < x \leq \xi + \alpha/k$ if $k > 0$, $-\propto < x < \propto$ if $k = 0$ and $\xi + \alpha/k \leq x < \propto$ if $k < 0$.

Its quantile function is given by

$$Q(F) = \xi + \frac{\alpha}{k}\{1 - (-logF)^k\},\ k \neq 0. \quad (2.3.13)$$

L-moments for GEV distribution are defined by Hosking and Wallis [25] are as follows:

$$\lambda_1 = \xi + \frac{\alpha}{k}\{1 - \Gamma(1+k)\}, \quad (2.3.14)$$

$$\lambda_2 = \frac{\alpha}{k}(1 - 2^{-k})\Gamma(1+k), \quad (2.3.15)$$

$$\tau_3 = 2(1 - 3^{-k})/(1 - 2^{-k}) - 3, \quad (2.3.16)$$

$$\tau_4 = \{5(1-4^{-k}) - 10(1-3^{-k}) + 6(1-2^{-k})\}/(1-2^{-k}), \quad (2.3.17)$$

where $k > -1$ and $\Gamma(.)$ denotes gamma function.

Parameters of GEV distribution for L-moment, given by Hosking and Wallis [25] are as follows:

$$k \approx 7.8590c + 2.9554c^2, \text{ where } c = \frac{2}{3+\tau_3} - \frac{log2}{log3} \quad (2.3.18)$$

$$\alpha = \lambda_2 k/((1-2^{-k})\Gamma(1+k)), \quad (2.3.19)$$

$$\xi = \lambda_1 - \alpha\{1-\Gamma(1+k)\}/k. \quad (2.3.20)$$

2.3.3 GLO Distribution

The PDF of GLO distribution is given by

$$f(x) = \frac{\alpha^{-1}e^{-(1-k)y}}{(1+e^{-y})^2}, y = \begin{cases} -k^{-1}\log\left\{1 - \frac{k(x-\xi)}{\alpha}\right\}, & k \neq 0 \\ \frac{x-\xi}{\alpha}, & k = 0 \end{cases} \quad (2.3.21)$$

where ξ, α and k are the location, scale and shape parameters of the distribution and the range of x are $-\propto < x \leq \xi + \alpha/k$ if $k > 0$, $-\propto < x < \propto$ if $k = 0$ and $\xi + \alpha/k \leq x < \propto$ if $k < 0$.

The quantile function of GLO distribution is given by

$$Q(F) = \xi + \frac{\alpha}{k}\left[1 - \left\{\frac{(1-F)}{F}\right\}^k\right], \ k \neq 0 \quad (2.3.22)$$

Hosking and Wallis [25] defined L-moments for GLO distribution as:

$$\lambda_1 = \xi + \alpha(\frac{1}{k} - \frac{\pi}{sink\pi}), \quad (2.3.23)$$

$$\lambda_2 = \alpha k\pi/sink\pi, \quad (2.3.24)$$

$$\tau_3 = -k, \quad (2.3.25)$$

$$\tau_4 = (1+5k^2)/6, \quad (2.3.26)$$

where $-1 < k < 1$

Parameters of GLO distribution given by Hosking and Wallis [25] as:

$$k = -\tau_3, \quad (2.3.27)$$

$$\alpha = (\lambda_2 sink\pi)/k\pi, \quad (2.3.28)$$

$$\xi = \lambda_1 - \alpha(\frac{1}{k} - \frac{\pi}{sink\pi}). \quad (2.3.29)$$

2.3.4 GNO Distribution

The PDF of GNO distribution is given by

$$f(x) = \frac{e^{ky-y^2/2}}{\alpha\sqrt{2\pi}}, y = \begin{cases} -k^{-1}\log\left\{1 - \frac{k(x-\xi)}{\alpha}\right\}, & k \neq 0 \\ \frac{x-\xi}{\alpha}, & k = 0 \end{cases} \quad (2.3.30)$$

where ξ, α and k are the location, scale and shape parameters of the distribution and the range of x are $-\propto < x \leq \xi + \alpha/k$ if $k > 0$, $-\propto < x < \propto$ if $k = 0$ and $\xi + \alpha/k \leq x < \propto$ if $k < 0$.

The quantile function of GNO distribution can be written as

$$Q(F) = \zeta + exp\{\mu + \sigma\emptyset^{-1}(F)\} \quad (2.3.31)$$

where $\emptyset^{-1}(F)$ is the quantile function of standard normal distribution.

The standard parametrization may be obtained from the parametrization by setting

$$k = -\sigma, \quad \alpha = \sigma e^{\mu}, \quad \xi = \zeta + e^{\mu}.$$

L-moments for GNO distribution, defined by Hosking and Wallis [25] are as follows:

$$\lambda_1 = \xi + \frac{\alpha}{k}\left(1 - e^{\frac{k^2}{2}}\right) \quad (2.3.32)$$

$$\lambda_2 = \frac{\alpha}{k} e^{k^2/2}\{1 - 2\emptyset\left(-\frac{k}{\sqrt{2}}\right)\} \quad (2.3.33)$$

$$\tau_3 \approx -k\frac{A_0 + A_1k^2 + A_2k^4 + A_3k^6}{1 + B_1k^2 + B_2k^4 + B_3k^6} \quad (2.3.34)$$

$$\tau_4 \approx \tau_4^0 + k^2\frac{C_0 + C_1k^2 + C_2k^4 + C_3k^6}{1 + D_1k^2 + D_2k^4 + D_3k^6} \quad (2.3.35)$$

The coefficients used in the approximations are calculated by Hosking and Wallis [25]. Calculated value of coefficients are given in Table A.1.

Parameters of GNO distribution for L-moment given by Hosking and Wallis [25] are as follows:

$$k \approx -\tau_3\frac{E_0 + E_1\tau_3^2 + E_2\tau_3^4 + E_3\tau_3^6}{1 + F_1\tau_3^2 + F_2\tau_3^4 + F_3\tau_3^6} \quad (2.3.36)$$

$$\alpha = \left(\lambda_2 k e^{-k^2/2}\right)/\left\{1 - 2\emptyset(-\frac{k}{\sqrt{2}})\right\} \quad (2.3.37)$$

$$\xi = \lambda_1 - \frac{\alpha}{k}\left(1 - e^{\frac{k^2}{2}}\right) \quad (2.3.38)$$

Coefficients used in the approximations are given in Table A.1.

2.3.5 PE3 Distribution

The PDF of PE3 distribution is given by

$$f(x) = \frac{(x-\xi)^{\alpha-1}e^{-(x-\xi)/\beta}}{\beta^{\alpha}\Gamma(\alpha)} \quad (2.3.39)$$

where Parameters μ (location), σ (scale) and γ (shape) are the standard parameterizations which can be obtained by setting $\alpha = \frac{4}{\gamma^2}$, $\beta = \frac{1}{2}\sigma|\gamma|$ and $\xi = \mu - \frac{2\sigma}{\gamma}$.

The quantile function of PE3 distribution is given by

$$Q(F) = \mu + \sigma\left[\frac{2}{\gamma}\left[1 + \frac{\gamma\emptyset^{-1}(F)}{6} - \frac{\gamma^2}{36}\right]^3 - \frac{2}{\gamma}\right] \quad (2.3.40)$$

where $\emptyset^{-1}(.)$ has a standard normal distribution with zero mean and unit variance.

L-moments of PE3 distribution, given by Hosking and Wallis [25] are as follows:

$$\lambda_1 = \xi + \alpha\beta, \quad (2.3.41)$$

$$\lambda_2 = \pi^{-\frac{1}{2}}\beta\Gamma(\alpha + \tfrac{1}{2})/\Gamma(\alpha), \quad (2.3.42)$$

For $\alpha \geq 1$,

$$\tau_3 \approx \alpha^{-1/2}\frac{A_0+A_1\alpha^{-1}+A_2\alpha^{-2}+A_3\alpha^{-3}}{1+B_1\alpha^{-1}+B_2\alpha^{-2}}, \quad (2.3.43)$$

$$\tau_4 \approx \frac{C_0+C_1\alpha^{-1}+C_2\alpha^{-2}+C_3\alpha^{-3}}{1+D_1\alpha^{-1}+D_2\alpha^{-2}}. \quad (2.3.44)$$

For $\alpha < 1$,

$$\tau_3 \approx \frac{1+E_1\alpha+E_2\alpha^2+E_3\alpha^3}{1+F_1\alpha+F_2\alpha^2+F_3\alpha^3}, \quad (2.3.45)$$

$$\tau_4 \approx \frac{1+G_1\alpha+G_2\alpha^2+G\alpha^3}{1+H_1\alpha+H_2\alpha^2+H\alpha^3}. \quad (2.3.46)$$

The coefficients used in the approximations are given by Hosking and Wallis [25]. Coefficients are given in Table A.2.

The parameters of PE3 distribution for L-moment, given by Hosking and Wallis [25] are as follows:

If $0 < |\tau_3| < \frac{1}{3}$, let $z = 3\pi\tau_3^2$ and

$$\alpha \approx \frac{1+0.2906z}{z+0.1882z^2+0.0442z^3}, \quad (2.3.47)$$

If $\frac{1}{3} < |\tau_3| < 1$, let $z = 1 - |\tau_3|$and

$$\alpha \approx \frac{0.36067z-0.59567z^2+0.25361z^3}{1-2.78861z+2.56096z^2-0.77045z^3}. \quad (2.3.48)$$

The parameters of the parametrization may be found from

$$\gamma = 2\alpha^{-\frac{1}{2}}sign(\tau_3), \quad (2.3.49)$$

$$\sigma = \lambda_2 \pi^{\frac{1}{2}} \alpha^{\frac{1}{2}} \Gamma(\alpha) / \Gamma\left(\alpha + \frac{1}{2}\right), \quad (2.3.50)$$

$$\mu = \lambda_1. \quad (2.3.51)$$

2.4 Index-Flood Procedure

Index-flood procedures developed by Dalrymple [14] are a convenient way of pooling summary statistics from different data samples. Early applications of the procedure were to flood data in hydrology but the method can be used with any kind of data (Hosking and Wallis [25]).

Suppose that data are available at a homogeneous region having N sites, with site i having sample size n_i and observed data $Q_{ij}, j = 1,2, \ldots n_i$. Let $Q_i(F), 0 < F < 1$, be the quantile function of the frequency distribution at site i. We may then write

$$Q_i(F) = \mu_i q(F), \ i = 1,2, \ldots N \quad (2.4.1)$$

Here μ_i is the index-flood, we shall take it to be the mean of the at site frequency distribution. $q(F)$ is the regional growth curve, a dimensionless quantile function common to every site.

2.5 Regional Rainfall Frequency Analysis using L-moment

According to Hosking and Wallis [25], regional frequency analysis using an index flood procedure involves four steps. They are

1. Screening of the data.
2. Identification of homogeneous regions.
3. Choice of a frequency distribution
4. Estimation of the frequency distribution.

For all calculation Fortran Package developed by Hosking (2005) has been used.

2.5.1 Screening of Data:

Hosking and Wallis [25] proposed the Discordancy test D_i to screen out data from stations whose point sample L-moments are markedly different from other stations. The objective is to check the

$$D_i = \frac{1}{3} N (u_i - \bar{u})^T S^{-1} (u_i - \bar{u}) \quad (2.5.1)$$

where $S = \sum_{i=1}^{N}(u_i - \bar{u})(u_i - \bar{u})^T$ and $u_i = \left[t_2^i, t_3^i, t_4^i\right]^T$ for i-th station, N is the number of stations , S is covariance matrix of u_i and $\bar{u}$ is the mean of vector, u_i . Critical values of discordancy statistics are tabulated by Hosking and Wallis [25]. For $N = 12$, the critical value is 2.757. If the D-statistics of a station exceeds 2.757, its data is discordant from the rest of the regional data.

2.5.2 Identification of Homogeneous Region

An essential task in regional frequency analysis is the determination of homogeneous regions. Hosking and Wallis [25] suggested the heterogeneity test, H, where L- moments are used to assess whether a group of stations may reasonably be treated as belonging to a homogeneous region. The proposed heterogeneity tests are based on the L-coefficient of variation L-skewness and L-kurtosis. These tests are defined respectively as

$$V_1 = \sqrt{\sum_{i=1}^{N} n_i (t_2^{(i)} - t_2^{R})^2 / \sum_1^N n_i}, \quad (2.5.2)$$

$$V_2 = \sum_{i=1}^{N} \{n_i [(t_2^{(i)} - t_2^{R})^2 + \left(t_3^{(i)} - t_3^{R}\right)^2]^{\frac{1}{2}}\} / \sum_{i=1}^{N} n_i, \quad (2.5.3)$$

$$V_3 = \sum_{i=1}^{N} \{n_i [(t_3^{(i)} - t_3^{R})^2 + \left(t_4^{(i)} - t_4^{R}\right)^2]^{\frac{1}{2}}\} / \sum_{i=1}^{N} n_i. \quad (2.5.4)$$

The regional average L-moment ratios are calculated using the following formula:

$$t_2^R = \sum_{i=1}^{N} n_i\, t_2^i / \sum_{i=1}^{N} n_i,$$
$$t_3^R = \sum_{i=1}^{N} n_i\, t_3^i / \sum_1^N n_i, \quad (2.5.5)$$
$$t_4^R = \sum_{i=1}^{N} n_i\, t_4^i / \sum_1^N n_i.$$

where N is the number of stations and n_i is the record length at i-th station. The heterogeneity test is then defined as

$$H_j = \frac{V_j - \mu_{V_j}}{\sigma_{V_j}} \quad , \quad j = 1,2,3 \quad (2.5.6)$$

where μ_{V_j} and σ_{V_j} are the mean and standard deviation of simulated V_j values, respectively. The region is acceptably homogeneous, possibly homogeneous and definitely heterogeneous with a corresponding order of L-moments according as $H<1$, $1 \le H < 2$ and $H \ge 2$.

2.5.3 Choice of a Frequency Distribution

In this step the best fit distribution is selected from several probability distributions. For this purpose, Hosking and Wallis [25] proposed two goodness of fit measures.

(a) Z-statistic Criteria

The Z-test judges how well the simulated L-Skewness and L-kurtosis of a fitted distribution matches the regional average L-skewness and L-kurtosis values. For each selected distribution, the Z-test is calculated as follows

$$\mathrm{Z}^{\mathrm{DIST}} = (\tau_4^{\mathrm{Dist}} - \mathrm{t}_4^{\mathrm{R}})/\sigma_4 \qquad (2.5.7)$$

where DIST refers to a particular distribution, τ_4^{DIST} is the L-kurtosis of the fitted distribution while the standard deviation of $\mathrm{t}_4^{\mathrm{R}}$ is given by

$$\sigma_4 = \left[(N_{sim})^{-1} \sum_{m=1}^{N_{sim}} (t_4^{(m)} - t_4^{R})^2\right]^{1/2}$$

$\mathrm{t}_4^{\mathrm{m}}$is the average regional L-kurtosis and has to be calculated for the m^{th} simulated region. This is obtained by simulating a large number of kappa distribution using Monte Carlo simulations. The value of the Z-statistics is considered to be acceptable at the 90% confidence level if $\left|\mathrm{Z}^{\mathrm{DIST}}\right| \leq 1.64$. If more than one candidate distribution is acceptable, the one with the lowest $|Z^{DIST}|$ is regarded as the best fit distribution.

(b) L-Moment Ratio Diagram

It is a graph of the L-skewness and L-kurtosis which compares the fit of several distributions on the same graph. According to Hosking and Wallis [25], the expression of τ_4 in terms of τ_3 for an assumed distribution is given by

$$\tau_4 = \sum_{k=0}^{8} A_k \tau_3^k \qquad (2.5.8)$$

where the coefficients A_k are tabulated by Hosking and Wallis [25]. The coefficients are given in Table A.3.

2.5.4 Estimation of Frequency Distribution

In this step the regional parameters of the best fit distribution are calculated. For this purpose, regional average L-moments are used in the expressions of L-moments (in section 2.3) of the best fit distribution. Putting the parameters of the best distribution in the quantile function, growth factors are calculated.

2.6. Results and Discussion

Using discordancy test discussed in the section 2.5.1 the D_i values of all the twelve stations are calculated. From Table 2.1 it is observed that the D_i values of all the twelve stations are less than critical value 2.757. Therefore, all the data of twelve stations are considered for the development of regional maximum rainfall estimation.

Table 2.1: Discordancy measures of each sites of the NE region using L-moments.

Name of sites	No. of observations	τ	τ_3	τ_4	D_i
1. Guwahati	30	0.1509	0.2298	0.1551	0.27
2. Mohanbari	30	0.1458	0.1521	.1011	0.09
3 Silchar	28	0.1449	0.1420	0.1345	0.61
4 Lakhimpur	30	0.1394	0.2107	0.0976	0.93
5 Passighat	30	0.2224	0.3773	0.3455	1.82
6 Agartala	30	0.1763	0.1421	0.0529	1.30
7 Imphal	30	0.1772	0.2015	0.1711	0.19
8 Shillong	30	0.1863	0.1569	0.1778	1.32
9 Itanagar	26	0.1710	0.3629	0.2452	1.45
10 Dhubri	22	0.1798	0.1620	0.0904	0.75
11 Jorhat	25	0.1196	-0.0514	-0.0832	1.72
12 Lengpui	13	0.1166	0.1523	0.1265	1.56

(D_i values of 12 stations are less than the critical value 2.757)

Using heterogeneity measures, H_1, H_2 and H_3 are calculated. From Table 2.2 it is observed that the value of H_1 lies between 1 and 2, that of H_2 and H_3 are less than 1. Hence the study region can be considered as a possibly homogeneous one.

Table 2.2: Heterogeneity measures using L-moments.

H_1	H_2	H_3
1.54	-0.35	0.40

($1<H_1<2$, $H_2<1$ and $H_3<1$)

The calculated values of Z-statistics are given in Table 2.3. From Table 2.3 it is observed that the absolute values of Z-statistics for GEV, GNO and PE3 distributions are less than 1.64 respectively. But the absolute values of Z-statistics for PE3 distribution is the lowest. Therefore, PE3 distribution has been selected as the best fitting distribution for regional rainfall analysis of North East India.

Also from the L-moment ratio diagram (Figure 2.1) it is observed that the regional average is nearer to the PE3 distribution curve. Hence PE3 distribution is selected as the best fit distribution.

Table 2.3: Z-statistics values of the distributions using L-moment

Sl. No.	Name of the probability distribution	Z-Statistics values
1	GLO	2.58
2	GEV	0.87
3	GNO	0.55
4	**PE3**	**0.19**
5	GPA	2.97

($|Z^{GEV}| < 1.64$, $|Z^{GNO}| < 1.64$ and $|Z^{PE3}| < 1.64$. But $|Z^{PE3}|$ is the lowest.)

The Parameters of the best fit distribution are given in Table-2.4. Substituting the regional parameters of the best distributions in respective quantile function the quantiles are estimated. Estimated quantiles are given in Table-2.5.

Table 2.4: Regional parameters of best fitting distribution using L-moments.

Best fitting distribution	Parameters		
	Location	Scale	Shape
PE3	1.000	0.302	1.155

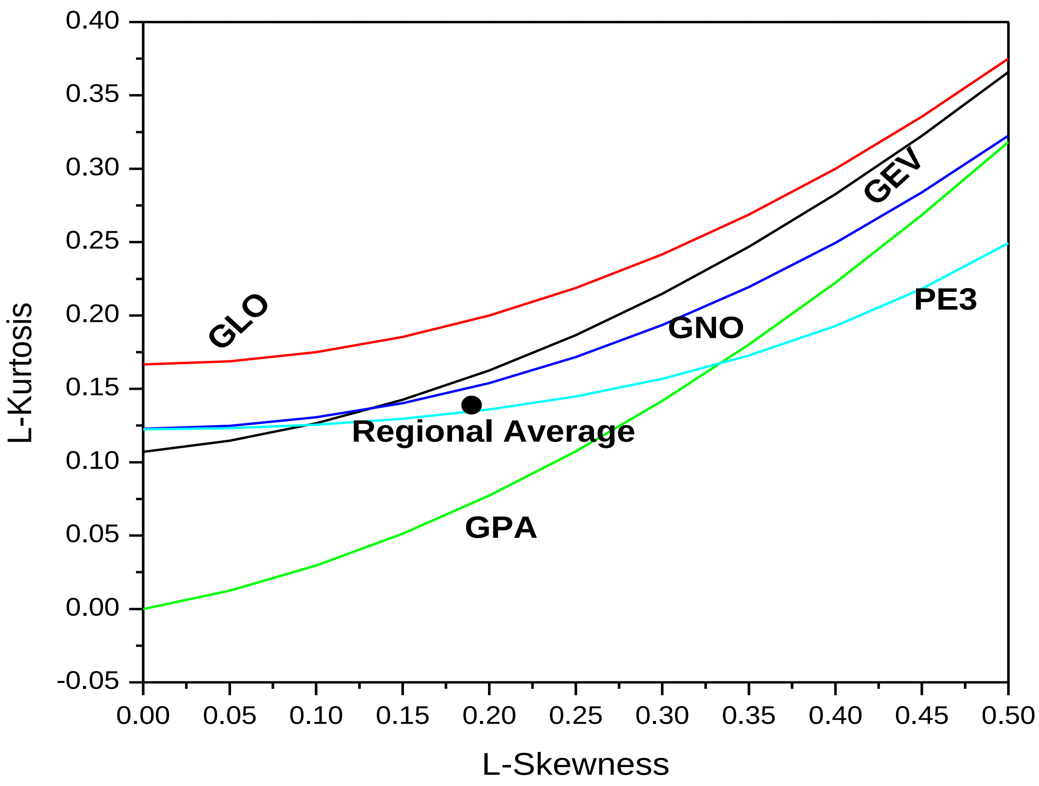

Figure 2.1 L-moment ratio diagram for NE region

(Regional value of L-skewness and L-kurtosis is nearer to the PE3 distribution curve)

Table 2.5: Quantile estimates by using best fitting distribution.

Best fit Distribution	Return period (in years)				
	2	10	20	100	1000
PE3	0.943	1.450	1.574	1.942	2.434

2.7 Development of Regional Rainfall Frequency Relationship

The regional rainfall frequency relationship is developed using flood index procedure discussed in section 2.4 for our study region.

The form of regional rainfall frequency relationship or growth factor for the best fit distribution PE3 can be expressed as

$$Q_T = \left[\mu + \sigma \frac{2}{\gamma}\left\{\left\{1 + \frac{\gamma\emptyset^{-1}(F)}{6} - \frac{\gamma^2}{36}\right\}\right\}^3 - \frac{2}{\gamma}\right] * \mu_i \qquad (2.7.1)$$

where Q_T is the maximum rainfall at return period T, μ_i is the mean annual maximum rainfall of the ith site of the region, $F = 1 - 1/T$, $\emptyset^{-1}(.)$ has a standard normal distribution with zero mean and unit variance. Parameters γ, μ and σ are the standard parameterizations which are given in the Table 2.4. Substituting these values in expression (2.3.40) rainfall frequency relationship for gauged sites of study area is expressed as:

$$Q_T = \left[1.000 + \frac{0.604}{1.155}\left\{\left\{1 + \frac{1.155\emptyset^{-1}(F)}{6} - \frac{1.334}{36}\right\}\right\}^3 - \frac{2}{1.155}\right] * \mu_i \qquad (2.7.2)$$

For estimation of maximum rainfall for a desired return period above regional flood frequency relationship may be used.

2.8 Conclusion

Discordancy measure shows that data of all gauging sites of our study area are suitable for using regional frequency analysis. Also from homogeneity test, the region has been found to be possibly homogeneous. Regional rainfall frequency analysis has been performed using five extreme probability distributions: viz. GLO, GEV, GPA, GNO and PE3. Using L-moment ratio diagram and Z-statistic it is found that PE3 distribution is the best fit distribution for regional rainfall frequency analysis of North East India. The parameters of PE3 distribution are calculated and using the quantile function of PE3 distribution regional growth factors are calculated. The regional rainfall frequency relationship for gauged stations has been developed for the region and can be used for estimation of maximum rainfalls at desired return periods.

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