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Orographic Effects on the Distribution of Rainfall in North-East India

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Abstract

The present paper gives a description on the nature of landscape of N.E. India and analysis of the distribution of rainfall on a SW-NE axis from Cherrapunjee at the edge of the Meghalaya Plateau to Majbat at the foot hills of Arunachal Himalayas. This axis gives the actual distributional pattern of rainfall along the movement of south - west monsoons influencing these areas. Cherrapunjee is extremely humid (12000mm annually).

This paper tries to explain how far distribution of rainfall along this axis is progressively reduced due to the location of Meghalaya Plateau as a physical barrier resulting in a rain shadow area in the Brahmaputra valley. Seasonal variations in the distribution patterns indicate how far physiography plays an important role in the distributional patterns.

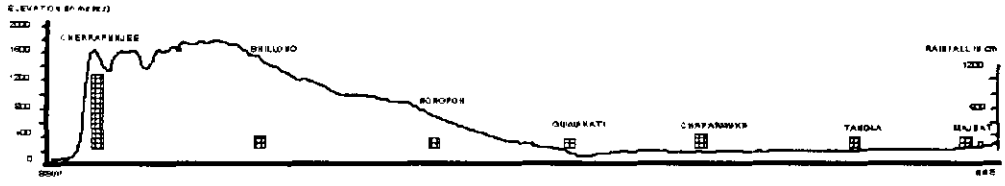
Introduction

The North Eastern Region of India is under the influence of monsoon circulation (Starkel, 1998) and perhaps with much vigour because of its proximity to the Bay of Bengal and its exposure to the south-west monsoon winds (Anonymous,1982). A major role is being played by the mountainous Himalayan and hilly barrier in the north and eastern borders that enclose the region and not allowing the moisture laden winds to escape. Besides these, this region is also under the influence of the western disturbances in winter (Anonymous,1982).

Over North-East India, the air flow in the lower levels is not generally consistent with the pressure distribution as can be seen from the Climatological Atlas. It follows, therefore, that the prevailing wind over the region is the result of super-imposition of local factors on the air flow resulting from the existing pressure distribution (Mukherjee and Ghosh, 1965).

The unique physiographic features of North-East India and its surrounding mountain and hill ranges along its border greatly affect the rainfall distribution and variation pattern. The region has an east-west alignment of the Himalayan mountain chain in the north. The eastern hills comprising of the Dibang-Lohit-Patkai-Naga-Manpur ranges running along the northeast-southwest direction while the part of the Patkai range and the Mizo Hills (Chin Hills) take a north-south arrangement (Taher,1986). In the midst of this the Meghalaya plateau lying south of the Himalayan mountain chain and separated by the Brahmaputra plain is positioned along an east-west axis before joining the plains of Bangladesh with a steep

Fig. 1 **Rain Shadow effect of Meghalaya Plateau**



Source: Modified after Singh, 1996

faulted slope. This peculiar configuration greatly influences the air flow and modifies the rainfall distribution pattern over the region. The climatic conditions in the region are extremely variable from place to place (Barthakur, 1968) and this is reflected in rainfall too. Thus, the variable conditions are created by the following factors (Barthakur, 1968).:

(a) obstruction of the prevailing winds by the different barriers;

(b) deflection of the monsoonal currents due to the alignment of the barriers; and

(c) shearing and adiabatic lifting and development of orographic low.

In general, the hills and mountains of North-East India prevent the rain-bearing winds from escaping the region causing heavy precipitation in this part of India. More than 80% of the annual precipitation occurs during the summer (March to May) and monsoon (June to September) seasons. During the rest of the year (October to February), rainfall is very low. The pre-monsoonal rainfalls are mostly convectional. Rainfall during the monsoon season occurs in the region mainly due to the influence of the south-west monsoon winds associated at times with cyclonic disturbances (O'Hare, 1997). This normally sets in over the region in the middle of June and withdraws from there in the second week of October. So, the rainfall distribution in the region during pre-monsoon and monsoon seasons is determined by the direction of the moisture laden air masses coming to the region which are guided by its physiographic features. The Khasi Hills are an exceptional instance of the combined effect of relief, surface configuration and wind movement. Here, part of the monsoon current from the Bay of Bengal is channelled by the topography towards the high ground and the sharp-ascent, which follows the convergence of the air stream in the funnel-shaped lowland to the south results in some of the heaviest annual rainfall totals recorded anywhere. The control put into effect by surface elevation is significant. The presence of elevated barriers cause air convergence and vertical ascent thus resulting to highest rainfall yields of over 2500 mm in highland areas which lie directly in the path of the south-west monsoon winds (O'Hare, 1997). It is also important to note that the rain shadow effect of the Meghalaya plateau is prominent for both pre-monsoon and monsoon rainfall (O'Hare, 1997; Kalita and Sarmah, 1985). For example, Mawsynram (1400 m elevation) 16km west of the more famous station

Table 1 **Name, location and basic statistics of the stations under study**

Serial Number	Name of the Station	I.M.D. Station	Latitude	Longitude	Elevation (In meter from M.S.L.)	Annual Rainfall (in mm)
1.	Agartala	42724	23°5' N	91°25' E		2130
2.	Aizwal	42727				2234
3.	Chaparmukh	42414				2300
4.	Cherrapunjee	42515	25°17' N	91°47' E	1313	11500
5.	Dhubri	42406	26°02' N	90°02' E	35	2800
6.	Dibrugarh	42314	27°19' N	94°58' E	106	2600
7.	Guwahati	42410	26°11' N	91°47' E	55	1720
8.	Imphal	42623	24°44' N	93°58' E	798	1450
9.	Kailashahar	42618				2650
10.	Kohima	42527	25°38' N	94°10' E	1406	1880
11.	Lumding	42523	25°45' N	93°11' E	149	1210
12.	Majbat	42413	26°45' N	92°21' E	73	1930
13.	N.Lakhimpur	42309	27°14' N	94°07' E	102	3200
14.	Pasighat	42220	28°2' N	95°21' E	274	4480
15.	Shillong	42516	25°34' N	91°56' E	1600	2140
16.	Silchar	42619	24°50' N	82°51' E	29	3110
17.	Tangla	42409			75	1950
18.	Tezpur	42415	26°37' N	92°50' E	79	1900

Source: I. M.D. Guwahati & Survey of India

of Cherrapunjee, has a mean annual total (1941-69) of 1221 cm and can claim to be the wettest spot in the world. Cherrapunjee during the same period averaged 1102 cm (Barry and Chorley, 1987). Considering the transect from Cherrapunjee to Majbat for which data are available, it can be inferred that precipitation varies to a large extent due to the positioning of the barriers besides other factors.

Database

The rainfall statistics of 18 meteorological centres located in North-East India have been collected for the last 26 years (1975-2000) to analyse the annual and seasonal patterns of rainfall variability for which the monthly statistics were considered. These statistics were collected from India Meteorological Department, Pune and Regional Centre, IMD-Guwahati. It may be mentioned here that the rainfall statistics were available only for 18 stations in the region and hence cannot reflect the real patterns of variability. However our results are drawn from the available statistics of these stations whose locational characteristics are given in Table:1 and Figure:2

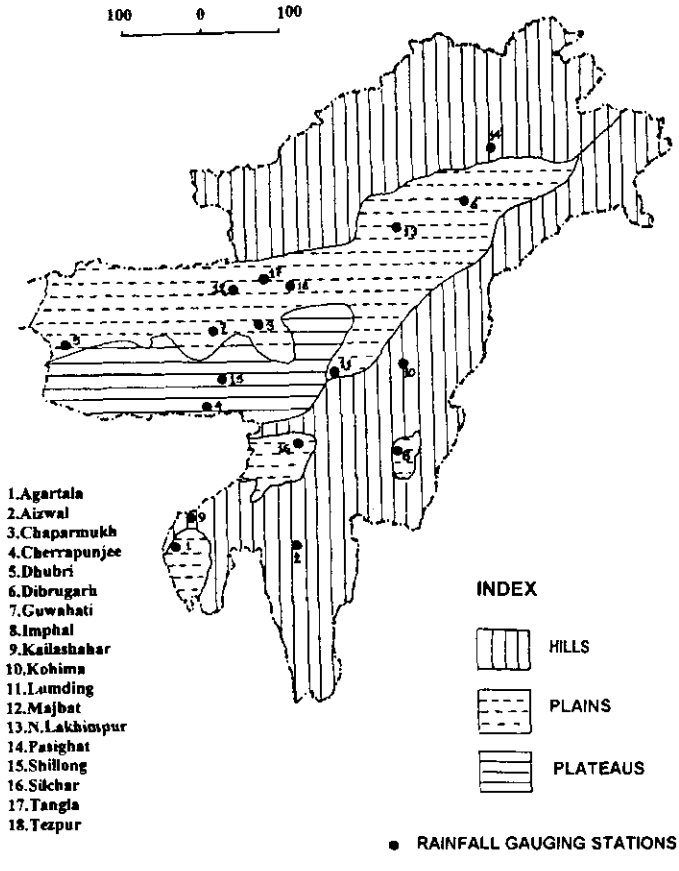


Fig. 2 **Location of the Rainfall Gauging Stations - North-East India**

Methodology

The monthly rainfall records of 18 stations distributed in the region for a period of 26 years (1975-2000) have been compiled on the basis of four distinct periods of the year. These are :

a) Monsoon season (June to September)

b) Autumn Season (October to November)

c) Winter Season (December to February) &

d) Pre-Monsoon Season (March to May).

The annual and seasonal fluctuations on a temporal scale have been calculated by using the Coefficient of Variability which is formulated as,

$$CV(\%) = [100(SD/Mean)]$$

Where C.V. = Coefficient of Variation in %

And S.D. = Standard Deviation

The areal patterns of variability are drawn through the distribution of stations using CV values and these patterns are compared with the terrain features to highlight the results.

Table 2 **Physiographic Sub-Division Wise Variability of Rainfall (Co-efficient of variation in %)**

Zones	Stations	Annual	Monsoon	Autumn	Winter	Pre-Monsoon
Hills	Pasighat	18.9	27.44	92.16	41.60	35.22
Plains	Cherrapunjee	24.57	23.21	81.43	123.32	45.81
	Kailashahar	18.95	20.76	68.11	76.83	37.87
	Kohima	18.71	19.83	58.12	101.08	47.81
	Shillong	18.71	23.88	67.10	60.53	38.95
	Aizawl	15.88	19.78	57.44	74.81	38.85
	N. Lakhimpur	18.9	27.44	92.16	41.60	35.22
	Agartala	20.86	25.57	61.21	80.12	43.38
	Dibrugarh	13.53	14.49	44.96	87.44	29.29
	Guwahati	15.27	19.44	66.79	73.33	29.41
	Majbat	23.48	23.38	50.27	75.83	36.48
	Tangla	23.32	23.09	50.46	83.18	39.35
	Chaparmukh	30.35	28.11	86.51	90.24	54.09
	Tezpur	17.93	24.22	46.43	75.04	28.49
	Dhubri	21.89	21.95	75.76	90.96	41.23
	Imphal	25.90	24.92	72.66	76.63	41.38
	Lumding	20.08	25.90	64.09	62.73	41.13
	Silchar	21.77	23.54	35.43	93.55	35.41

Source-I.M.D.Guwahati

Analysis and Discussion

The region can be broadly divided into two zones - the hilly and the plain areas. Six meteorological stations are located in the hills and twelve in the plains. The following table summarises the calculated values of variablitiy of rainfall of each station.

a) Annual Rainfall Variation Pattern

Rainfall variability values range between 15 to 30%. Places like Chaparmukh (C.V. = 30.35%), Majbat (23.48%) and Lumding (C.V. = 20%) show a variable pattern since they are located in the rain shadow areas of Meghalaya plateau. The areas south of the Meghalaya plateau like Agartala (20.86%), Silchar (21.77 %) including Cherrapunjee (24.57%) have a pronounced variability because of very high variability during autumn and/or winter most probably arising out of their locational attribute. On the other hand, rainfall variability is low in the Upper Brahmaputra valley (N.Lakhimpur, Dibrugarh and Tezpur). It is mainly due to the fact that rain bearing winds of the south west monsoon could not cross the Sadia loop. In general, the annual pattern does not portray a high fluctuating trend but is more pronounced in the plains of the region than in the hilly sections (fig. 3a&3b).

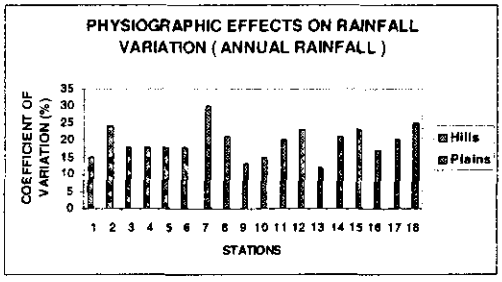


Fig. 3a

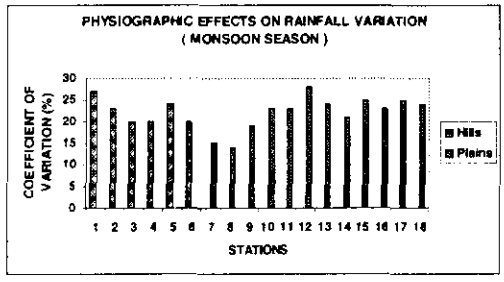


Fig. 4a

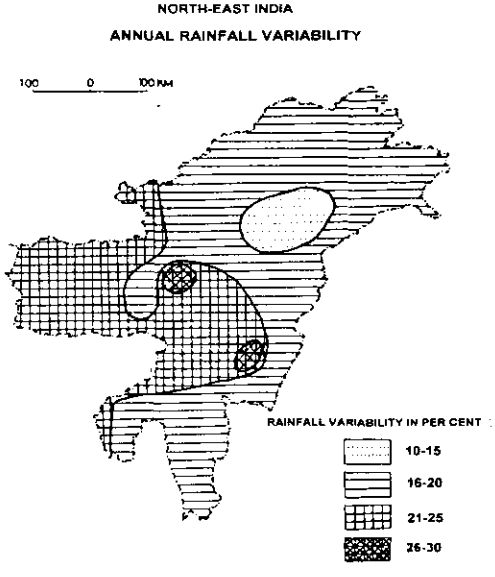


Fig. 3b

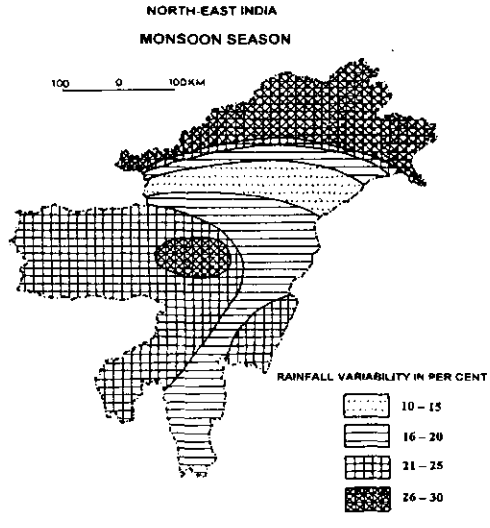


Fig. 4b

b) Seasonal Rainfall Variation Pattern

Monsoon

During monsoon season there is a semblance of uniformity in the rainfall patterns. Variability does not exceed 29% in any of the recording stations. The CV values are in fact slightly higher than the annual values except for Cherrapunjee where it is lower. It is on the higher side in rainshadow as well as hilly areas while it is low in plain areas (fig. 4a&4b). The rain shadow effect of Meghalaya plateau during this season is minimum. The pattern during this season is somewhat similar to the annual pattern.

Autumn

In the Post-Monsoon period (Autumn) not much contrast is seen in the variability patterns in both the hilly and plain zones of the

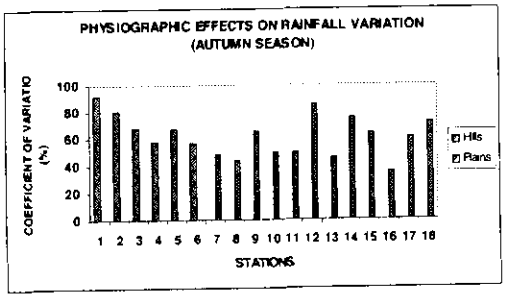


Fig. 5a

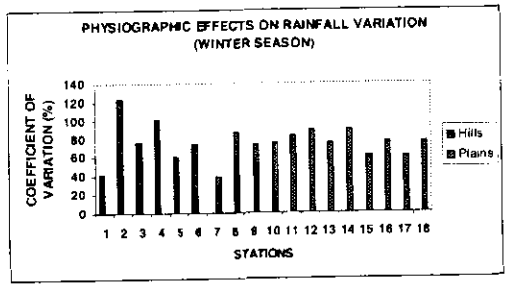


Fig. 6a

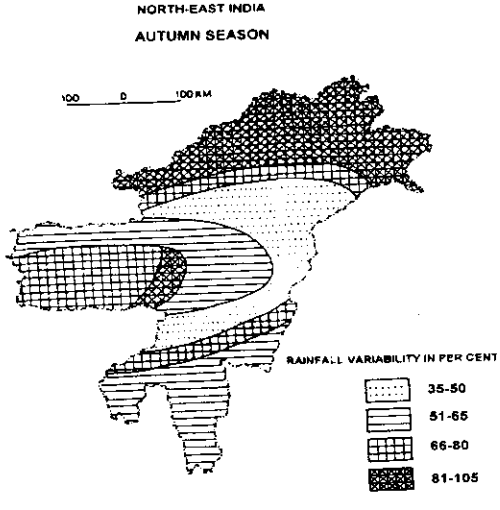


Fig. 5b

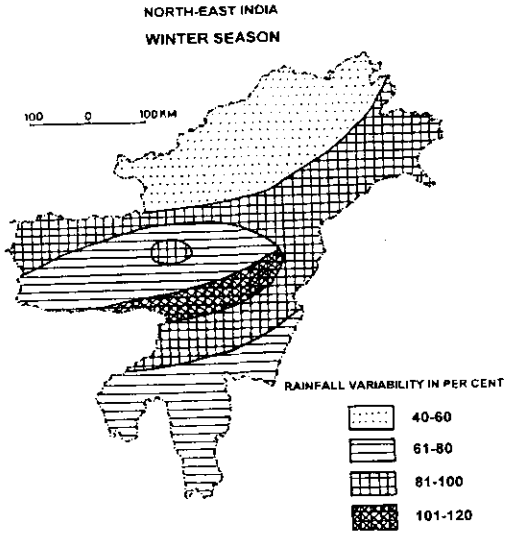


Fig. 6b

region (fig. 5a&5b). However there is an overall rise in the CV values when compared to the values during the monsoon season. This is significant as the south-west monsoon winds are now receding. Sometimes rains associated with cyclones in the Bay of Bengal bring heavy showers to the entire region during this season. The areas in the Upper Brahmaputra valley show a tendency towards a higher variability pattern. This is perhaps due to local influences.

Winter

In this season rainfall variability pattern is somewhat different from other seasons. As winter rainfall is low and erratic, rainfall variability is high to very high for all the stations. It is highest in hilly areas (fig. 6a&6b). Cherrapunjee (123.32%) and Kohima (101.88%) recorded very high rainfall variability. Only in north eastern part of the region, rainfall variability is low with CV value of about 42%. Pasighat and

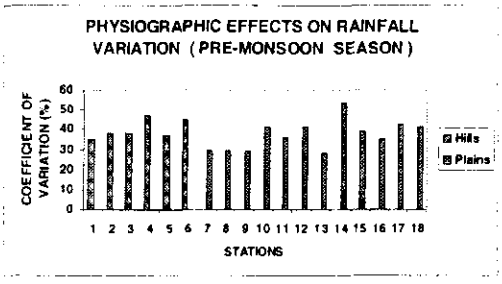


Fig. 7a

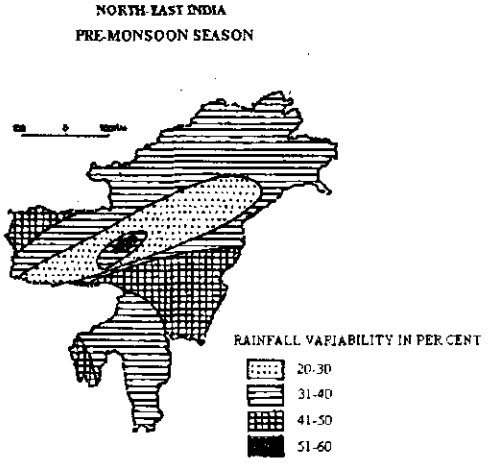


Fig. 7b

N.Lakhimpur which are located in this area receive rainfall with less variation perhaps due to the persistent influence of the western disturbances that happen to cross over the Himalayan barrier.

Pre-Monsoon

During pre-monsoon season, rains are mostly of convective type and are associated with storms, generally caused by the movement of the low pressure area developed in the Gangetic plains towards the Eastern Himalaya (Choudhury,1961). In this season also rainfall variability is highest in rain shadow areas (Chaparmukh C.V.= 54%) and high in hilly areas (Kohima 48%, Cherrapunjee 46%). On the other hand, rainfall variability is moderate to low in plain areas especially in NE Assam (fig. 7a&7b).

Conclusion

From the present discussion, it can be concluded that physiography plays a prominent role in rainfall variability pattern in North East India. The influence of orography on rainfall variation is most visible in rain shadow and hilly areas where rainfall variability is moderate to high. However, this is minimised during the monsoon season. The CV values are highest during the winter season since there is a minimum influence of rain bearing winds. The effect of Himalayan mountain ranges and Meghalaya plateau are especially significant and visible through the higher amount of precipitation. The deflection of winds as they enter this region also is an important point to consider as this is guided mainly by the landscape within the region. Last but not the least, it is felt that the rainfall data available for the whole region is inadequate considering the heterogeneity of terrain.

References

Anonymous, IMD,Pune (1982) : *Climate of North-East India*, Resource Potentials of North East India, Meghalaya Science Society, Shillong, pp. D-15-20.

Barry, R.G. and Chorley, R.J. 1987: *Atmosphere, Weather and Climate*, Methuen. London, p. 319.

Barthakur, M.1968: *Some Aspects of Weather in the Brahmaputra Valley*. Journal of Assam Science Society, pp. 92-99.

Choudhury, A.K.1961: *Pre-monsoon Thunderstorms in Assam, Tripura and Manipur.* Indian Journal of Meteorology and Geophysics, 12(1) pp.33-40.

Kalita, S. and Sarmah, S.K.1985: *Probable Effects of Orography on the rainfall distribution in the Brahmaputra Valley.* Journal of Assam Science Society. 27 (2), pp. 24-30.

Mukherjee, A.K. and Ghosh, S.K.1965: *Orographical influence on the air flow over Brahmaputra valley.* Indian Journal of Meteorology and Geophysics.25 (3) pp. 425-430.

O'Hare G (1997): *Indian Monsoon : Part II*, Geography, Vol. 82(4), pp. 335-352.

Starkel.L (1998) : *Geomorphic response to climatic and environmentasl changes along a Central Asian transect during the Holocene.* Geomorphology, Vol. 23, pp. 293-305.

Taher, M (1986) : *Physiographic framework of North - East India*, North Eastern Geographer, Vol. 18, pp. 1-19.

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