

## A generalized relationship between atmospheric pressure and precipitation associated with a passing weather system

ATANU SARKAR

*Flood Meteorological Office, Jalpaiguri – 735121, India*

*(Received 10 November 2015, Accepted 1 December 2017)*

**e mail : asarkarjpg@gmail.com**

**सार** - बादल का बनना और वर्षा का होना प्रायः मौसम प्रणाली के आरोहण गति के कारण होता है। इस शोध पत्र में वर्षा की मात्रा और किसी क्षेत्र के मौसम प्रणाली के वायुमण्डलीय दाबान्तर के अनुपात के महत्व की व्याख्या करता है। यदि इन दोनों राशियों के बीच एक रैखिक संबंध मानते हुए उप-हिमालय पश्चिम बंगाल के चुनिंदा घाटी क्षेत्र के पाँच वर्षों (2009-13) के दैनिक वर्षा आंकड़ों का विश्लेषण किया गया तो गया कि अनुपात के मासिक अंतर उस क्षेत्र में हुई वर्षा के संबंध में कुछ खास लक्षणों को दर्शाता है।

**ABSTRACT.** Formation of clouds and precipitation are usually caused by the upward vertical motions generated from a weather system. The paper describes the importance of the ratios of precipitation amount to the differences of pressure associated with a weather system passing over an area. Assuming a linear relationship between these two parameters and analyzing daily data for five years (2009 -13) of selected basin areas of Sub-Himalayan West Bengal it is found that monthly variations of the ratios depict typical characteristic of that area in terms of precipitation.

**Key words** – Weather system, Rain constant etc.

### 1. Introduction

The precipitation, undoubtedly, is the most significant meteorological phenomena in the daily life of common people. From drought to flood or from drinking water to raincoat, the keyword is precipitation or rainfall. It has a direct impact on our GDP also, as agriculture is the backbone of our economy. And here lies the importance of rainfall forecasting which helps us to prepare better for the worst. The rainfall forecasting includes intensity, spatial distribution and obviously the quantity with the extreme values. But it remains a great challenge to the forecasters to predict the extreme value as well as quantity of rainfall over an area. The outcome often involves significant uncertainty. For extreme precipitation event, forecasting becomes more complex. Moreover the topographical impact on precipitation has also to be taken into consideration. In spite of using highly sophisticated instruments and man power, it is observed that there exists a great amount of constraints in deterministic approaches as of now.

Efforts are continuously being made across the globe to get breakthrough and these are paving the way to improve accuracy. Without going to the previous works, let us look into the objective of this study directly. In this study a humble approach has been made to establish a

relationship between mean sea level pressure and precipitation amount, especially the extreme value, associated with a weather system which is believed to be helpful for quantitative precipitation forecasting. Now if we look into the rain making process, we certainly find that the vertical motion which takes the moistures above condensation level is the prime factor for this event, keeping in mind sufficient presence of moisture in the atmosphere. We also observe that the more number of closed isobars associated with a weather system, the higher amount of precipitation experienced. Again the number of the closed isobar represents the strength of the system. Thus the main intention has become to find the relationship between the amount of precipitation and strength of the weather system considering presence of other parameters on the average. It is considered that the precipitation is an end product of an active weather system and could occur anywhere of the zone for a particular meteorological condition.

The paper consists of two parts. One is to develop a working formula of the model and other is the application of the model over an area to find out the relationship between pressure values and precipitation amount over that particular area. The basin areas of the river Teesta, Mahananda, Jaldhaka, Torsa, Raidak and Sankosh situated in the Sub-Himalayan West Bengal sub-division,

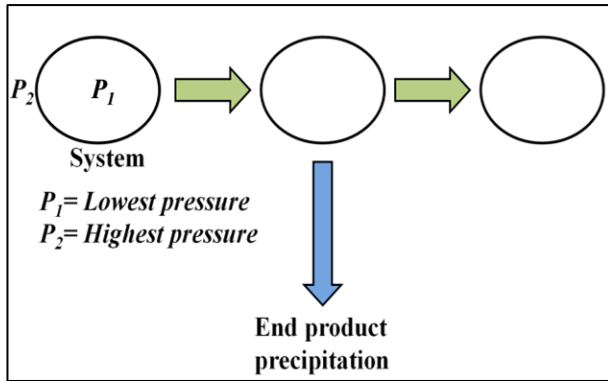


Fig. 1. Flow chart

according to the India Meteorological Department, have been selected. The topographic characteristic of this area varies from plain land to hilly terrain and receives a significant amount of rain fall throughout the year.

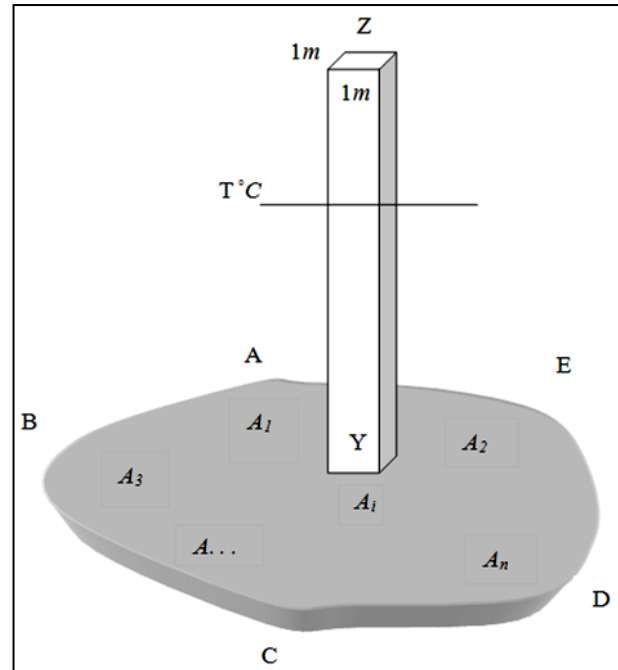
## 2. Data and methodology

### 2.1. Model development

It is evident that location of a place plays a key role in making the pattern of a weather system and its outcome. If there is an orographic barrier then obviously the pattern of the system would be different. Similarly vegetation has its own importance. Canopy of the forest trees transpire thousands of gallons of water throughout the year and thus keep the environment moist around the forest area. Moreover atmospheric pressure also varies from place to place. Keeping all of the things under consideration importance has been given on two points:

- (i) Positional effects *i.e.*, characteristics of the area related to weather and
- (ii) Pressure difference of a system. Here sufficient availability of all other meteorological parameters have been considered those can initiate maximum precipitation.

For a particular meteorological condition, it is reasonable to assume that there exists an upper limit of extreme value and total amount of precipitation over an area due to a particular system. At the surface, low-pressure systems are associated with convergent flow and if there is convergent flow at the ground, there must be an upward vertical motion which has the prime importance to the occurrence of precipitation. Because of this vertical motion moistures will be lifted upward and finally accumulate above condensation level. On the other hand there exists outflow also. Net balance of the inflow and outflow after saturation will result the rain. Now these flows are governed by the system. It is evident that for

Fig. 2. Surface area containing arbitrarily distributed different stations and imaginary air column over station  $A_i$ 

systems of identical strength and intensity in same climatic condition these inflow and outflow rates will be same over a particular place *i.e.* precipitation amounts will also be the same. Now if we increase the strength of the system assuming sufficient presence of other meteorological parameters then rain fall amount will also increase accordingly. Therefore, we can say that the upper limit of precipitation is proportional to the strengths of systems. And total amount of rain of that area will also be proportional to the strength of the system in same condition. Now the strength of a system is directly depends upon the pressure gradient force of the system *i.e.* difference in pressure associated with the system. The objective, therefore, has become to establish a relationship between the difference in pressure of a system and rainfall amounts.

Let us consider an area ABCDEA and  $A_1, A_2, \dots, A_i, \dots, A_n$  be the stations arbitrarily distributed in that area as shown in Fig. 2.

Let us assume that a system is active over only one station, say  $A_i$ , of that area and other stations are undisturbed. Let  $P_2$  hPa and  $P_1$  hPa be the highest and lowest mean sea level pressures of that system. It is also assumed that the system contains adequate moisture and the other factors those are favourable for any amount of rainfall as desired. Let us consider an imaginary air column YZ of uniform cross-section of area extending

from the surface of the earth to the top of the atmosphere over the rain receiving area at  $A_i$ . Now if condensation happens above the level denoted by its characteristic temperature  $T$  °C in the column YZ then amount of rainfall will be a function of the amount of accumulated moisture above the said level and that will be proportional to the pressure difference of the weather system.

Here, the pressure difference over  $1 \text{ m}^2$ , i.e., rain receiving area =  $10^4 (P_2 - P_1)$  hPa

Now, if  $R$  mm is the amount of rainfall occurred due to this system, then from above discussion we have :

$$R \propto 10^4 (P_2 - P_1) \tag{1}$$

Let us assume that the atmosphere considered, is homogeneous and  $\rho$  is its mean density and  $g$  is the acceleration due to gravity at  $A_i$ . Then  $P_1 = V_1 \rho g$  and  $P_2 = V_2 \rho g$ , where  $V_1$  and  $V_2$  are the respective volumes of air column over unit cross-section (1 sq. cm) extending to the top of the atmosphere.

Now from (1)

$$R \propto 10^4 \rho g (V_2 - V_1)$$

Or,  $R \propto (V_2 - V_1)$  [  $\rho$  and  $g$  constant ]

Or,  $\beta = \frac{R}{(V_2 - V_1)}$ , (2)

where  $\beta$  is a constant.

Now we know that 90% of the mass of the atmosphere is confined within 16 km from mean sea level and the standard pressure at msl is 1013.25 hPa and pressure at 16 km from msl is 102.87 hPa. Assuming homogeneity again, we get height of air column corresponding to 1 hPa atm pressure

$$= (16 \times 10^6) / (1013.25 - 102.87) \text{ mm}$$

$$= 17575.0785 \text{ mm}$$

and the corresponding volume is given by

$$= (10 \times 10 \times 17575.0785) \text{ mm}^3$$

$$= 1757507.85 \text{ mm}^3$$

Now, comparing with this standard atmospheric condition we can write,

$$V_2 - V_1 = (P_2 - P_1) \times 1757507.85 \text{ mm}^3$$

Now as  $R$  mm is the measurement of the rainfall occurred due to that system then volume corresponds to the rainfall over 1 sq. m rain receiving area

$$= R \times 10^6 \text{ mm}^3$$

Therefore from (2)

$$\beta = \frac{R \times 10^6 \text{ mm}^3}{(P_2 - P_1) \times 1757507.85 \text{ mm}^3}$$

Or,  $R = \beta \times (P_2 - P_1) \times 1.75750785$ ,

Without loss of generality we can introduce a new constant ' $r$ ' for the simplification of the calculation such that  $\beta = 100r$ , we call it  $r$ , as rain constant of rain receiving station such as  $A_i$ . After round-off, we get

$$R = r \times (P_2 - P_1) \times 175.75 \tag{3}$$

and

$$r = R / ((P_2 - P_1) \times 175.75) \tag{4}$$

Now if we consider that the system covers the whole area, ABCDEA, and all stations are affected then the accumulation of water vapour above condensation level will be according to the properties of the self governing system (as the atmosphere is free from any external forces). Thus precipitation amount will be varied from 0 to a maximum value at different stations over ABCDEA.

*Result* : Following the above equations, now we shall introduce three different rain constants corresponding to maximum rainfall over the area, total amount of rainfall received by all station over the area and rainfall over a particular station of that area.

Let  $i$  denotes number of day, varies from 1 to  $n$  and  $j$  indicates station number according to rainfall amount, varies from 1 to  $m$  (here  $m$  represent the maximum rainfall), then we get rainfall amounts for all stations arranged day wise as follows:

Day 1 =  $R_{11}, R_{12}, R_{13}, \dots, R_{1j}, \dots, R_{1m}$

Day 2 =  $R_{21}, R_{22}, R_{23}, \dots, R_{2j}, \dots, R_{2m}$

.....

Day  $i$  =  $R_{i1}, R_{i2}, R_{i3}, \dots, R_{ij}, \dots, R_{im}$

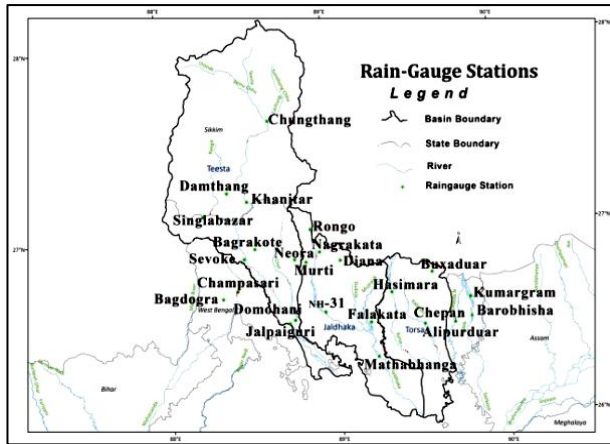


Fig. 3. Rain gauge stations and basin areas

where,  $R_{im}$  corresponds to the maximum rainfall of  $i^{th}$  day. Now from equation number (4) corresponding to each  $R_{ij}$  we get  $r_{ij}$  as follows:

$$\text{Day 1} = r_{11}, r_{12}, r_{13}, \dots, r_{1j}, \dots, r_{1m}$$

$$\text{Day 2} = r_{21}, r_{22}, r_{23}, \dots, r_{2j}, \dots, r_{2m}$$

.....

$$\text{Day } i = r_{i1}, r_{i2}, r_{i3}, \dots, r_{ij}, \dots, r_{im}$$

where  $r_{ij} = Rij / (175.75 \times (P_{2ij} - P_{1ij}))$ ,  $P_{2ij}$  &  $P_{1ij}$  are the highest and lowest pressure values of the system active over the station  $A_j$  on  $i^{th}$  day.

(i) According to discussion,  $R_{im}$ , for each  $i$ , will be proportional to the strength of the system under similar climatic conditions. Therefore  $r_{im}$ , the rain constants corresponding to maximum precipitations,  $R_{im}$ , of the area must have a unique value under similar climatic conditions. Let us denote this unique value as  $r_m$  and call as area maximum rain constant.

(ii) Now we introduce a new quantity  $\sum R_{ij}$  representing the daily total rainfall over all stations of the area on  $i^{th}$  day. It will, also, be proportional to the strength of the system. Consequently rain constant of daily total rainfall will be a unique value for similar conditions. Let  $r_{it}$  be the rain constant for daily total amount of rain on  $i^{th}$  day over ABCDEA, then following the equation (4) we get

$$r_{it} = \sum R_{ij} / (175.75 \times \sum (P_{2ij} - P_{1ij})), \tag{5}$$

where  $j = 1$  to  $n$  (inclusive of the stations having 0 rainfall),  $P_{2ij}$  &  $P_{1ij}$  are the highest and lowest pressure values of a system active over station  $A_j$  on  $i^{th}$  day. Let us call it  $r_{it}$  as the daily total rain constant of the area.

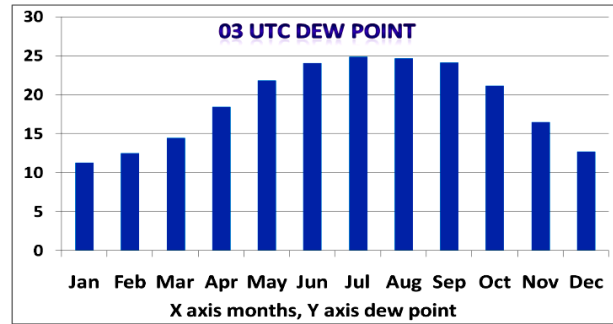


Fig. 4. Mean monthly 0300 UTC dew point (°C) of Jalpaiguri.

(iii) To incorporate the positional effects of a station, say  $A_j$ , in a specified area we define another new term  $r_j$  by  $r_j = \frac{\sum r_{jk}}{k}$ , where  $k$  varies 1 to  $i$ . This  $r_j$  may have values equal to  $r_{im}$  in any day.

In reality, we do not get systems having identical properties or similar climatic conditions in all aspect. Therefore, the average values of  $r_{im}$  and  $r_{it}$  for those periods, when the climatic conditions are nearly same over an area, have been calculated. Now  $r_{it}$  represents the daily total rain constant of  $i^{th}$  day and  $r_{im}$  represents the area maximum of rain constant of  $i^{th}$  day, therefore, the mean values of  $r_{im}$  and  $r_{it}$  are considered as  $r_m$  and  $r_t$  for the said periods, where,

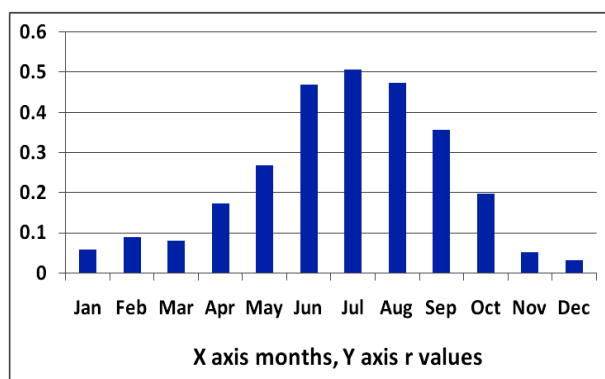
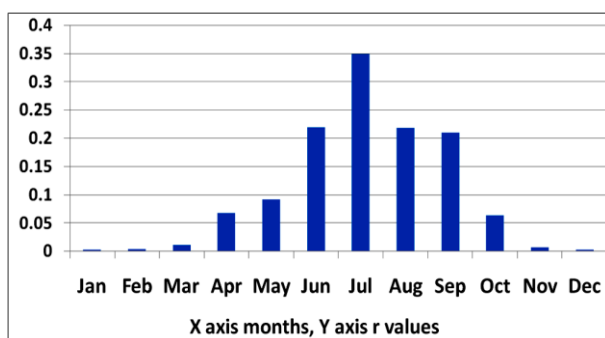
$$r_m = (\sum r_{im}) / i \quad \text{and} \quad r_t = (\sum r_{it}) / i$$

where  $i$  = number of days of the specified period having nearly same climatic condition. The same procedure has been followed to find the  $r_j$  value of an individual station also.

Next, an area and some rain gauge stations situated across that area have been selected to find mean of these rain constants month wise, assuming nearly same climatic conditions prevail during the period of one month. We shall observe that the monthly variations of these rain constants extract very significant characteristics of that area.

### 2.2. Application of the model

In this study 23 rainfall stations (Table 4 & Fig. 3) situated in Sub-Himalayan West Bengal and Sikkim have been selected. The 24 hours rainfall data of these stations measured from 0300 UTC to 0300 UTC next day have been considered. These stations receive significant amount of rainfall, especially in monsoon season, over the years. These 23 stations spread across the catchment area of about 17,937 sq. km, of which Teesta catchment 10205 sq. km, Jaldhaka 3823 sq. Km, Torsa Catchment

Fig. 5. Month wise mean  $r_m$  valueFig. 6. Month wise mean  $r_t$  value of daily total rain fall of 23 stations

2930 sq. km Raidak catchment 807 sq. km and Sankosh catchment 172 sq. km. Major portion of this area is hilly terrain region. Altitude of the stations varies from 46 m to 1981 m above mean sea level. Vegetation of this area is diversified. We observe presence of dense forest in many parts of this area which includes reserve forests also. The positions of the stations in the catchment area are shown in Fig. 3. Daily rainfall data for the period of 5 years from 2009 to 2013 of these 23 rainfall stations have been considered. All rainfall data, latitude and longitude of the stations have been obtained from FMO Jalpaiguri, IMD.

The rainfall stations under consideration are not equipped with soundings so the vertical profile of humidity and other parameters are not available. It is known that surface dew point can be used as moisture index (WMO, 2009) as the moisture in the lower layer of the atmosphere is the main source for production of rain. A pictorial representation of mean monthly surface dew point (at 0300 UTC, 30 years normal) of Jalpaiguri has been shown in Fig. 4, for estimation of the mean vertical humidity profile of the area on monthly basis. It is again to say that we have analyzed data month wise assuming that humidity, temperature profile and other climatic

TABLE 1

Data range of  $r_m$  for calculation of month wise mean value

S. No.	Month	Mean derived from the range
1.	January	$0.003 < r_m \leq 0.3$
2.	February	$0.007 < r_m \leq 0.4$
3.	March	$0.005 < r_m \leq 0.4$
4.	April	$0.03 < r_m \leq 0.6$
5.	May	$0.05 < r_m \leq 0.9$
6.	June	$0.05 < r_m \leq 1.5$
7.	July	$0.05 < r_m \leq 1.5$
8.	August	$0.05 < r_m \leq 1.5$
9.	September	$0.05 < r_m \leq 1.2$
10.	October	$0.02 < r_m \leq 0.7$
11.	November	$0.003 < r_m \leq 0.3$
12.	December	$0.005 < r_m \leq 0.1$

parameters are at an average over the area for a period of one month.

To find the pressure value of respective rain gauge stations, the mean sea level pressure values of whole India in the grid of  $0.50 \times 0.50$  resolutions with each grid value equals the pressure value have been considered firstly and then the grid of  $5' \times 5'$  resolution for the area under consideration *i.e.* where the rainfall stations are situated, with each grid equals the pressure value of the corresponding places has been considered. We have used extrapolation and interpolation method mostly averaging weighted mean. From these grids the mean sea level pressure value of each of the station can be obtained from latitude and longitude of the concerned station. In this method we have assumed the area as flat land. Now when a weather system passed over an area the sequence of the pressure of a particular station would be high-low-high (Fig. 1). As rainfall amount of 24 hours measured from 0300 UTC to 0300 UTC next day has been considered, mean sea level pressure at 0300 UTC of day-1 taken as  $P_1$  and mean sea level pressure at 0300 UTC of day-2 taken as  $P_2$  and so on, and  $\text{Mod}(P_2 - P_1)$  has been considered to find out the  $r$  values of a station. It is assumed that this 24 hours change in pressure is caused by the pressure field of the system passing over the station and is responsible for the 24 hours rainfall received at that station. To construct the required grid, daily mean sea level pressure of Jalpaiguri has been collected from FMO Jalpaiguri, IMD and that of other 84 number of stations for 5 years from 2009 to 2013 have been collected from website.

TABLE 2

Mean monthly  $r_m$  value over the basin area.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.06	0.09	0.08	0.17	0.27	0.47	0.51	0.47	0.36	0.20	0.05	0.03

TABLE 3

Mean monthly  $r_t$  value of daily total rain fall over the basin area

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.003	0.005	0.011	0.068	0.092	0.219	0.349	0.218	0.210	0.063	0.007	0.003

TABLE 4

Month wise mean daily  $r$  value for individual stations

Station name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Khanitar	0.053	0.034	0.049	0.091	0.086	0.126	0.174	0.112	0.120	0.110	0.060	0.012
Chungthang	0.029	0.059	0.057	0.060	0.052	0.116	0.109	0.095	0.111	0.083	0.035	0.008
Damthang	0.024	0.063	0.033	0.069	0.104	0.149	0.160	0.171	0.128	0.092	0.037	0.004
Singlabazar	0.070	0.068	0.042	0.052	0.062	0.141	0.144	0.143	0.112	0.073	0.027	0.014
Sevoke	0.061	0.028	0.128	0.098	0.083	0.173	0.254	0.191	0.196	0.155	0.058	0.015
Domohani	0.018	0.016	0.029	0.070	0.084	0.196	0.208	0.146	0.170	0.182	0.033	0.010
Neora	0.022	0.037	0.077	0.088	0.088	0.171	0.220	0.192	0.164	0.109	0.041	0.014
Jalpaiguri	0.013	0.014	0.030	0.054	0.097	0.215	0.206	0.154	0.110	0.132	0.032	0.005
Bagrakote	0.045	0.061	0.041	0.069	0.125	0.186	0.227	0.165	0.203	0.107	0.015	0.037
Rongo	0.040	0.057	0.041	0.163	0.172	0.238	0.322	0.193	0.180	0.162	0.039	0.026
Nagrakata	0.034	0.027	0.068	0.066	0.078	0.204	0.236	0.174	0.143	0.061	0.027	0.029
Diana	0.050	0.013	0.071	0.067	0.064	0.212	0.247	0.191	0.178	0.113	0.014	0.030
Murti	0.033	0.020	0.070	0.066	0.105	0.157	0.234	0.174	0.160	0.091	0.023	0.012
NH-31	0.014	0.019	0.035	0.116	0.100	0.227	0.194	0.158	0.136	0.139	0.026	0.004
Mathabhanga	0.057	0.054	0.087	0.094	0.101	0.190	0.234	0.140	0.163	0.141	0.063	0.000
Falakata	0.030	0.018	0.087	0.100	0.124	0.202	0.228	0.189	0.156	0.110	0.029	0.007
Hasimara	0.057	0.026	0.030	0.082	0.091	0.192	0.289	0.179	0.157	0.081	0.069	0.006
Chepan	0.019	0.032	0.036	0.095	0.113	0.209	0.265	0.184	0.128	0.166	0.093	0.028
Barobhisha	0.000	0.050	0.038	0.096	0.122	0.170	0.253	0.184	0.170	0.118	0.000	0.000
Alipurduar	0.011	0.028	0.055	0.078	0.119	0.180	0.226	0.211	0.172	0.125	0.050	0.005
Buxaduar	0.014	0.044	0.122	0.091	0.124	0.203	0.307	0.232	0.190	0.121	0.074	0.027
Kumargram	0.016	0.062	0.083	0.087	0.104	0.210	0.261	0.171	0.222	0.136	0.034	0.105
Champasari	0.049	0.013	0.023	0.106	0.078	0.164	0.232	0.172	0.158	0.203	0.056	0.003

(0.0 implies monthly rainfall is 0.0 mm during considered period)

TABLE 5

Data range of  $r_t$  for calculation of month wise Mean value

S. No.	Month	Mean derived from the range
1.	January	$0.0001 < r_t \leq 0.008$
2.	February	$0.0001 < r_t \leq 0.008$
3.	March	$0.0006 < r_t \leq 0.05$
4.	April	$0.002 < r_t \leq 0.3$
5.	May	$0.005 < r_t \leq 0.3$
6.	June	$0.005 < r_t \leq 0.9$
7.	July	$0.02 < r_t \leq 1.0$
8.	August	$0.009 < r_t \leq 0.7$
9.	September	$0.009 < r_t \leq 0.7$
10.	October	$0.0004 < r_t \leq 0.4$
11.	November	$0.0001 < r_t \leq 0.02$
12.	December	$0.0001 < r_t \leq 0.008$

TABLE 6

Data range for calculation of station wise Monthly Mean value of  $r$ 

S. No.	Month	Mean derived from the range
1.	January	$0.001 < r \leq 0.4$
2.	February	$0.001 < r \leq 0.4$
3.	March	$0.001 < r \leq 0.6$
4.	April	$0.005 < r \leq 0.6$
5.	May	$0.005 < r \leq 0.8$
6.	June	$0.01 < r \leq 1.0$
7.	July	$0.01 < r \leq 1.5$
8.	August	$0.01 < r \leq 1.0$
9.	September	$0.01 < r \leq 0.8$
10.	October	$0.005 < r \leq 0.6$
11.	November	$0.001 < r \leq 0.4$
12.	December	$0.001 < r \leq 0.4$

Interestingly precipitations data are obviously inclusive of effects of all parameters exist historically over the area, like topographical effects, vegetations, positional effects etc. And as no additional criteria, even altitude, have been considered to find rain constant values ( $r$ ), therefore in this process these  $r$  values are inclusive of effects of all parameters historically available over that area.

It may be mentioned here that to calculate mean value of the rain constants trimmed mean has been considered, otherwise the result shows biasness. For example if a system stays over the area more than 24 hours without any significant movement then the rainfall amount will be much higher due to this active system but 24 hours pressure change will be nearly zero. In these cases  $r$  value becomes much higher than mean calculated and these  $r$  values have been discarded. From the frequency distribution of  $r_m$  and  $r_t$  values it is observed that for every month there is a cluster made of most frequent or nearest values. Mean has been derived from this cluster of values to avoid biasness. To find the mean of  $r_m$ , data range considered between 0.003 to 1.5 and for the mean of  $r_t$ , data range considered between 0.0001 to 1.0 and accommodated 75 to 100% data values. However, data are very scanty for January, February, November and December, *i.e.*, in dry months.

*Result : (i) Month wise mean  $r_m$  value (for maximum rain fall) over the area :* For this calculation all  $r_m$  values corresponding to daily maximum rainfall month wise, of the area for the period 2009 to 2013 have been considered and find the best fit

mean (Fig. 5, Table 1 & Table 2). From monthly mean values it is observed that there is a significant rise from March to July and just reverses from July to November. It is also observed that the graphical representation of these monthly mean values (Fig. 5) is very similar to the normal distribution curve.

Also comparing Fig. 4 and Fig. 5, it can be said that the maximum rainfall from a system is proportional to the strength as well as moisture available in the atmosphere. With these values of  $r_m$  and equation (3), one can estimate the maximum rainfall over this area associated with a passing system of known strength or vice versa.

*(ii) Month wise mean  $r_t$  value for daily total rain fall for 23 stations :* For this calculation all  $r_t$  values corresponding to daily total rainfall, month wise, of the area for the period 2009 to 2013 have been considered and find the best fit mean (Fig. 6, Table 3 & Table 5). From the monthly mean values of daily total rain constant it is observed that January, February, November and December are nearly dry months. And  $r_t$  is significantly higher in July than the other months. This implies that a system gives more rainfall in total in July than other months. Now with this value one can estimate total rainfall for these 23 numbers of stations for a known system from equation (5).

*(iii) Month wise mean daily  $r_j$  value for individual stations :* It is the mean of daily  $r$  values, month wise, of each station individually for the period 2009 to 2013 (Table 4 & Table 6). With this value one can estimate an

average amount of rainfall of any station for a passing system of known strength. But it is again to say that this  $r$  value can vary from 0 to  $r_m$  according to the pattern of the system. From this value we can find the characteristic of the station with respect to a system in terms of rainfall.

### 3. Conclusions

It is observed from rain constant values that the more moisture in the environment the less force required making rain. It implies that July is the wettest month and December is the driest month (Fig. 5 and Fig 6).

A critical value can also be derived such as the magnitude of pressure gradient force in terms of pressure deference which can produce 0.1 mm rainfall in a particular month over a particular area can be called as critical value of the system for that month over that area. It is, then, obvious that a weather system of having strength less than critical value can create clouds but no rain and higher values will indicate bad weather.

In an average climatic condition, the range bound values of rain constants as observed in section 2.2 (application of the model) of the study imply that the assumption holds well. In the study a typical characteristic

of Sub-Himalayan West Bengal and Sikkim region has been evolved in terms of the rain constants. It suggests that if we prepare standardized values of rain constants for a particular region it will be helpful to estimate extreme values of rainfall quantitatively for a system of known strength using single parameter, atmospheric pressure.

### *Acknowledgement*

The author is grateful to respected DDGM, RMC Kolkata for providing the data to carry out the study. He is also thankful to Dr. G. N. Raha, Director-in-Charge, M. C. Gangtok, for precious advice and obviously thankful to Shri D. Roy, Scientist B and colleagues, FMO, Jalpaiguri for their unconditional help extended to him.

Disclaimer : The contents and views expressed in this research paper/article are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

### References

Manual on Estimation of Probable Maximum Precipitation (PMP), WMO - No. 1045, World Meteorological Organization, 2009.

---