Indian J. Met. Geophys. (1971), 22, 541-550

551.571.7 : 551.573 : 551.577(540)

Mean precipitable water vapour and rainfall liability index for the Indian area and neighbourhood

R. Y. MOKASHI

Meteorological Office, Poona

(*Received 27 September 1969*)

ABSTRACT. Mean monthly precipitable water vapour at 19 radiosonde stations in India, based on data for all years for which upper air ascents are available upto 1965 and 15 radionsonde stations in the neighbouring countries, have been calculated. The seasonal variations of precipitable water vapour and the mean monthly rainfall over the country are discussed. It is seen that the diversity in the magnitude of rainfall is not reflected by the values of the precipitable water. There may be enough precipitable water at a place but dynamic factors like ascending currents etc may not be generally present to cause rain. As a rough indicator of the liability for rainfall at a place, the ratio of the mean monthly rainfall and the monthly mean precipitable water have been worked out for all the stations. Isopleths of this ratio—Rainfall Liability Index (RLI)—have been drawn for various months. It is felt that the maps of RLI over the country would be more meaningful and of greater practical utility for hydrological purposes than those of mean precipitable water alone.

1. Introduction

Precipitable water vapour in the atmosphere may be defined as the depth of water that would result should all water vapour in a vertical column of the atmosphere over a unit area be condensed. Since the density of water is unity, the depth in cm of the condensed water vapour is numerically equal to its mass in grams. It is a measure of the total moisture content of the atmosphere.

Mean monthly precipitable water vapour at 12 radiosonde stations in India, based on upper air data for the six-year period, 1956-1961 have been calculated and presented by Ananthakrishnan *et al.* (1965). This study has been extended to 19 radiosonde stations in India, based on data for all years for which upper air ascents are available from 1944 to 1965 and 15 stations in neighbouring countries.

2. Data used

Particulars of available data are given in Table 1.

3. Method of calculation

The method of calculation was the same as that used by Ananthakrishnan *et al.* (1965).

If r, the humidity mixing ratio is expressed in grams of water vapour per kilogram of dry air, the precipitable water vapour ($\triangle W$) in an isobaric layer of 100 mb thickness ($P_\circ - P$, *i.e.,* pressure at bottom layer *minus* pressure at top layer) whose mean mixing ratio is r gm/kg can be expressed, approximately as —

$$\triangle W = \frac{r}{1000}(P_\circ - P) = \frac{r}{10}$$

Thus, if a column in the atmosphere is divided into layers each of 100 mb thickness with mixing ratios r_1, r_2, r_3 ...., then the total precipitable water in the column is given by—

$$W = \frac{1}{10}(r_1 + r_2 + r_3 + \ldots\ldots)$$

The mean of the values of r of the bottom and top of an isobaric layer can be taken as the mean mixing ratio for the year.

The values of the humidity mixing ratio were evaluated for the isobaric layers 900, 800, 700, 600 and 500 mb from the mean monthly radiosonde data, separately for morning and afternoon ascents.

Above the freezing level, the readings of the wet-bulb element of the Indian radiosondes are not reliable and hence have not been taken into account. Also, the major contributions to the precipitable water comes from the layers below the freezing level, hence in the present work, contributions to the total precipitable water have been taken only from these layers. In the case of freezing level occurring below the 500-mb level the values of r for 500-mb level were obtained by extrapolation.

TABLE 1

Data used

	Co-ordinates		Altitude (m)	Radiosonde ascent data	
	Lat. (°N)	Long. (°E)		Morning*	Afternoon†
Ahmadabad	23°04′	72°38′	55	Jul 61—Dec 65	Jul 61—Dec 65
Allahabad	25°27′	81°44′	98	Nov 55—Dec 65	Oct 44—Dec 65
Amritsar	31°38′	74°52′	234	Jul 57—May 60	Jul 57—May 60
Bangalore	12°58′	77°35′	921	Mar 61—Dec 65	Jun 61—Dec 65
Bombay	19°07′	72°51′	14	Mar 55—Dec 65	Sep 54—Dec 65
Calcutta	22°39′	88°27′	6	Mar 55—Dec 65	Mar 44—Dec 65
Gauhati	26°06′	91°35′	54	Aug 55—Dec 65	Jul 55—Dec 65
Jodhpur	26°18′	73°01′	224	Apr 56—Sep 65	Apr 46—Sep 65
Madras	13°00′	80°11′	16	Jun 55—Dec 65	Jul 46—Dec 65
Minicoy	08°18′	73°00′	2	—	May 63—Dec 65
Nagpur	21°06′	79°03′	310	Mar 55—Dec 65	Oct 46—Dec 65
New Delhi	28°35′	77°12′	216	Mar 55—Dec 65	Jan 44—Dec 65
Poona	18°32′	73°51′	559	—	Jun 44—Jul 56
Port Blair	11°40′	92°43′	79	Mar 57—Dec 65	Dec 49—Dec 65
Shillong	25°34′	91°53′	1598	—	May 53—Jul 55
Srinagar	34°05′	74°50′	1587	Aug 62—Dec 65	Aug 62—Dec 65
Trivandrum	08°29′	76°57′	64	Oct 56—Dec 65	Jul 47—Dec 65
Veraval	20°54′	70°22′	8	Dec 56—Jul 61	Oct 44—Jul 61
Visakhapatnam	17°43′	83°14′	3	Oct 56—Dec 65	Nov 44—Dec 65

*0300 GMT prior to April 1957, 0000 GMT later
†1100 to 1530 GMT prior to 1949; 1500 GMT, 1949 to March 1957 and 1200 GMT thereafter

TABLE 2

Monthly mean precipitable water (grams) — ½(00+12) GMT

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ahmadabad	1·64	1·65	1·92	2·36	2·93	4·31	*5·53*	5·52	4·71	2·99	2·31	1·93	37·80
Allahabad	1·64	1·49	1·73	1·98	2·67	4·42	5·98	*6·01*	5·25	3·15	1·78	1·59	37·69
Amritsar	1·24	1·35	1·40	1·80	1·87	2·78	4·98	*4·99*	4·19	2·30	1·43	1·33	29·66
Bangalore	1 85	1·94	2·13	2·77	3·31	3·61	*3·69*	3·68	3·52	3·34	2·59	2·32	34·75
Bombay	2·46	2·32	2·72	3·28	4·11	5·13	*5·65*	5·55	5·01	4·03	3·16	2·64	46·06
Calcutta	2·10	2·16	2·79	3·63	4·55	5·74	6·04	*6·09*	5·75	4·52	2·60	2·07	47·95
Gauhati	2·29	2·54	2·98	3·87	4·85	5·99	*6·31*	6·31	5·84	4·61	3·05	2·47	51·11
Jodhpur	1·31	1·33	1·46	1·79	2·49	3·76	*4·99*	4·88	4·05	2·12	1·54	1·27	30·99
Madras	2·99	2·78	2·88	3·64	4·40	5·07	5·06	*5·22*	4·98	4·77	4·03	3·37	49·19
Minicoy*	3·65	3·62	3·75	4·43	*5·03*	4·84	4·87	4·73	4·83	4·63	4·59	4·12	53·09
Nagpur	1·95	1·85	2·06	2·58	3·08	4·50	5·10	*5·11*	4·64	3·29	2·23	1·88	38·27
New Delhi	1·36	1·41	1·84	1·95	2·46	3·83	5·58	*5·63*	4·44	2·48	1·53	1·32	33·83
Poona*	1·81	1·75	2·07	2·69	3·14	3·93	*4·29*	4·12	4·06	3·23	2·19	1·93	35·21
Port Blair	3·96	3·80	3·96	4·49	5·14	*5·20*	5·14	5·17	5·19	5·18	4·72	4·17	56·12
Shillong*	1·25	1·48	1·99	1·97	2·71	3·68	*3·79*	3·77	3·47	2·34	1·63	1·53	29·61
Srinagar	0·86	0·86	1·31	1·60	1·54	2·07	*2·69*	2·66	2·03	1·32	0·85	0·93	18·72
Trivandrum	3·55	3·61	3·80	4·46	*4·78*	4·63	4·60	4·54	4·59	4·58	4·49	3·91	51·54
Veraval	2·28	2·13	2·35	2·83	3·37	4·65	*5·23*	5·09	4·61	3·40	2·79	2·44	41·17
Visakhapatnam	2·71	2·89	3·19	3·97	4·65	5·36	*5·54*	5·51	5·39	4·70	3·29	2·71	49·91

*Based on 12 GMT data only

Highest values in *italics*

4. Presentation of results

The mean monthly values of precipitable water in gm for isobaric layers, separately for the morning and afternoon ascents for the 19 Indian stations were calculated (not given here).*

Table 2 gives the mean monthly precipitable water vapour taken as the average of the values of morning and afternoon ascents. Table 3 gives the mean monthly rainfall for the 19 stations.

Table 4 gives the ratio between the mean monthly rainfall and the monthly mean precipitable water for the 19 stations.

The seasonal variations of precipitable water vapour over the country are diagrammatically represented in Fig. 1. The mean monthly values, taken as the average of the values of morning and afternoon ascents (Table 2), are utilised for drawing the isopleths.

The seasonal variations of the ratio between the mean monthly rainfall and the monthly mean precipitable water (Table 4) over the country are diagrammatically represented in Fig. 2.

Values of the monthly mean precipitable water, the mean monthly rainfall and the ratio between the mean monthly rainfall and the monthly mean precipitable water in respect of 15 extra Indian stations are given in Table 5, 6 and 7 respectively. The values in Table 3, 5 and 7 are also utilized for drawing the isopleths in Figs. 1 and 2.

5. Discussion

5.1. *Distribution of precipitable water*

The following general features are shown by all the stations —

(*i*) The values of precipitable water in the atmosphere show a gradual variation over the year with a maximum in the monsoon months (July—August) and a decrease towards the earlier and later parts of the year. The lowest values are encountered in the winter months (January and February).

(*ii*) The amplitude of the seasonal variation is much more at the northern stations than at the southern stations.

(*iii*) The values of precipitable water for the monsoon months is more or less uniform at all stations.

Trivandrum, Minicoy and Port Blair — There is a remarkable similarity in the maximum/minimum values of the precipitable water vapour and the amplitude of the seasonal variation in the case of these 3 stations (Fig. 3). Also, the magnitude of W fluctuates around 4·8 gm from May to November for these stations. There are 2 rainfall peaks in the case of these stations in June and September/October, however, the precipitable water changes very little during the months May to November. The amplitude of the seasonal variation for Trivandrum is the lowest among all the 19 stations studied.

Visakhapatnam and Madras — The precipitable water vapour which is less than 3 gm in the winter months, gradually increases from March and attains the maximum value between 5·2 and 5·4 gm in July/August in the case of these stations (Fig. 3). The moisture content of the atmosphere remains nearly constant upto September and decreases thereafter. October and November are the months of maximum rainfall at these stations, although the months of maximum precipitable water are July/August.

Poona and Bangalore — In general, there is similarity in the magnitude of the monthly values of the precipitable water vapour for these 2 stations (Fig. 3). The values of W and monthly rainfall throughout the year, except for the monsoon months (June—September) are higher in the case of Bangalore (September rainfall nearly the same). The highest monthly rainfall for Poona is in July and that for Bangalore in October, the magnitude of the highest rainfall being nearly the same for the 2 stations.

Bombay, Ahmadabad and Veraval — A sudden increase of W in May/June and corresponding decrease in October/November are shown by these stations (Fig. 3) at the beginning and end of the monsoon season. The monthly mean precipitable water vapour and the mean monthly rainfall reach their peak in the month of July. The values of W for July are 5·7, 5·5 and 5·2 gm, respectively. The rainfall amount for this month for Bombay, however, is nearly 3 times that of Ahmadabad and Veraval.

Nagpur — After the extreme dryness in winter, there is steady increase in the moisture content of the atmosphere over this station from March, reaching a peak in July/August (Fig. 3). This coincides with the highest monthly rainfall over this station in July. The monthly rainfall in August is reduced by about 20 per cent from the maximum fall in July, although the moisture content for July and August nearly remains the same.

Gauhati, Calcutta and Allahabad — The maximum values of precipitable water for these stations (Fig. 3) are 6·3, 6·1 and 6·0 gm, respectively and as such are higher than the maximum values of the remaining stations. Gauhati shows the

* *See* India Met. Dep. Pre-published sci. Rep. No. 75

TABLE 3

Mean monthly rainfall (cm)

(Based on observations from 1931 to 1960)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ahmadabad	0·39	0·03	0·09	0·19	0·45	10·00	*31·63*	21·33	16·28	1·31	0·54	0·07	82·31
Allahabad	2·02	2·22	1·43	0·48	0·82	10·17	27·48	*33·31*	19·51	3·97	0·69	0·63	102·73
Amritsar	3·80	1·06	2·56	0·95	1·07	3·21	*16·94*	16·82	10·58	5·43	0·96	1·53	64·91
Bangalore	0·38	1·41	0·59	3·69	11·92	6·53	9·31	9·48	12·85	*19·51*	4·61	1·64	81·92
Bombay	0·01	0·09	0·01	0·04	2·00	64·75	*94·54*	66·04	30·92	11·70	0·72	0·09	270·91
Calcutta	1·38	2·42	2·65	4·27	12·06	25·91	30·06	*30·63*	28·97	16·02	3·49	0·32	158·18
Gauhati	1·14	1·83	5·34	12·59	27·36	29·34	*30·15*	26·30	19·01	9·01	1·15	0·50	163·72
Jodhpur	0·73	0·51	0·19	0·22	0·64	3·09	12·18	*14·55*	4·74	0·68	0·33	0·15	38·01
Madras	2·38	0·68	1·51	2·47	5·17	5·26	8·35	12·43	11·80	26·70	*30·87*	13·91	121·53
Minicoy	3·50	2·54	1·70	5·35	19·98	*29·36*	21·76	19·98	14·41	18·51	14·14	7·57	158·80
Nagpur	1·54	0·19	2·45	2·02	0·99	17·43	*35·15*	27·71	18·05	6·16	0·87	0·17	112·73
New Delhi	2·49	2·18	1·65	0·68	0·79	6·50	*21·11*	17·29	14·97	3·12	0·12	0·52	71·42
Poona	0·19	0·03	0·31	1·76	3·47	10·28	*18·68*	10·64	12·73	9·19	3·70	0·49	71·47
Port Blair	2·89	2·63	2·25	7·12	36·25	*58·95*	43·55	43·59	51·62	32·92	20·54	15·74	318·05
Shillong	1·52	2·85	5·94	13·64	32·54	*54·46*	39·49	33·46	31·49	22·02	3·49	0·63	241·53
Srinagar	7·28	7·23	*10·41*	7·81	6·34	3·56	6·10	6·28	3·18	2·87	1·75	3·59	66·40
Trivandrum	2·01	2·03	4·35	12·21	24·86	*33·12*	21·54	16·40	12·29	27·12	20·69	7·31	183·93
Veraval	0·07	0·13	0·02	0·46	0·53	13·53	*30·48*	14·58	6·69	2·91	0·73	0·11	70·24
Visakhapatnam	0·72	1·49	0·87	1·27	5·35	8·78	12·19	13·22	16·73	*25·93*	9·06	1·75	97·36

Highest values in *Italics*

TABLE 4

Rainfall Liability Index (RLI)=Mean monthly rainfall (cm)/Monthly mean precipitable water (cm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ahmadabad	0·24	0·02	0·05	0·08	0·15	2·32	*5·72*	3·86	3·46	0·44	0·23	0·04
Allahabad	1·23	1·49	0·83	0·24	0·31	2·30	4·59	*5·54*	3·72	1·26	0·39	0·40
Amritsar	3·06	0·79	1·83	0·53	0·57	1·15	*3·40*	3·37	2·53	2·36	0·67	1·15
Bangalore	0·21	0·73	0·28	1·33	3·60	1·81	2·52	2·58	3·65	*5·84*	1·78	0·71
Bombay	0·00	0·04	0·00	0·01	0·49	12·62	*16·73*	11·90	6·17	2·90	0·23	0·03
Calcutta	0·69	1·12	0·95	1·18	2·65	4·51	4·98	5·03	*5·04*	3·54	1·34	0·15
Gauhati	0·50	0·72	1·79	3·25	*5·64*	4·90	4·78	4·17	3·25	1·95	0·38	0·20
Jodhpur	0·56	0·38	0·13	0·12	0·26	0·82	2·44	2·98	1·17	0·32	0·21	0·12
Madras	0·80	0·25	0·52	0·68	1·17	1·04	1·65	2·38	2·37	5·60	*7·66*	4·13
Minicoy	0·96	0·70	0·45	1·21	3·97	*6·07*	4·47	4·22	2·98	4·00	3·08	1·84
Nagpur	0·79	1·03	1·19	0·78	0·32	3·87	*6·89*	5·42	3·89	1·87	0·39	0·09
New Delhi	1·83	1·55	0·90	0·35	0·32	1·70	*3·78*	3·07	3·37	1·26	0·08	0·39
Poona	0·11	0·02	0·15	0·65	1·11	2·61	*4·35*	2·58	3·13	2·85	1·69	0·25
Port Blair	0·73	0·69	0·57	1·59	7·05	*11·34*	8·47	8·43	9·95	6·35	4·35	3·77
Shillong	1·22	1·93	2·98	6·92	12·01	*14·80*	10·42	8·87	9·07	9·41	2·14	0·41
Srinagar	*8·47*	8·41	7·95	4·88	4·12	1·72	2·27	2·36	1·57	2·17	2·06	3·86
Trivandrum	0·57	0·56	1·14	2·74	5·20	*7·15*	4·68	3·61	2·68	5·92	4·61	1·87
Veraval	0·03	0·06	0·01	0·16	0·16	2·91	*5·83*	2·86	1·45	0·86	0·26	0·05
Visakhapatnam	0·27	0·52	0·27	0·32	1·15	1·64	2·20	2·40	3·10	*5·52*	2·75	0·65

Highest values in *Italics*

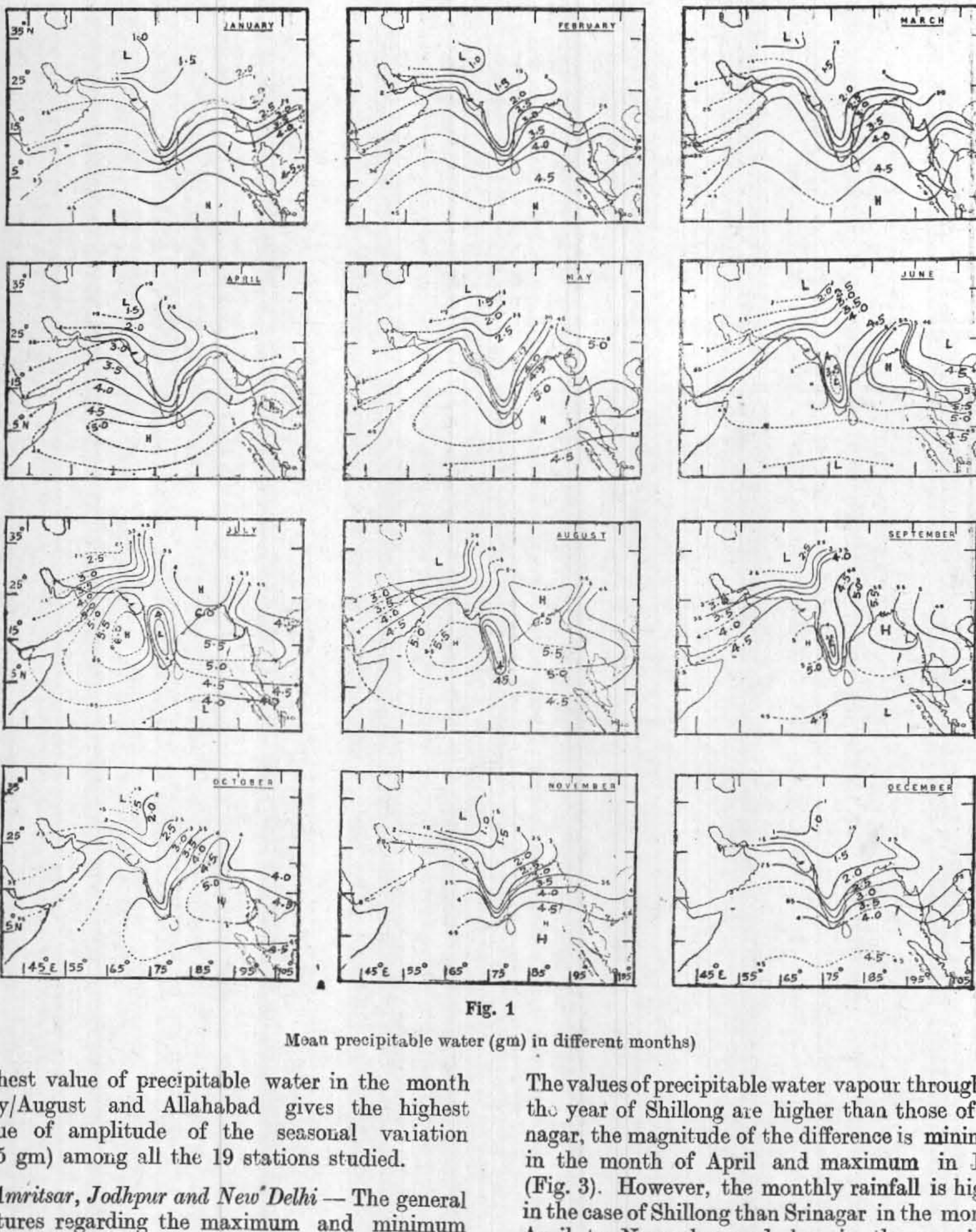

Fig. 1

Mean precipitable water (gm) in different months)

highest value of precipitable water in the month July/August and Allahabad gives the highest value of amplitude of the seasonal variation (4·5 gm) among all the 19 stations studied.

Amritsar, Jodhpur and New Delhi — The general features regarding the maximum and minimum values of the precipitable water and their amplitude are the same for Amritsar and Jodhpur. These values for Delhi are comparatively higher (Fig. 3). The precipitable water increases from May and reaches the peak value in the month July/August which coincides with the highest monthly rainfall at these stations in July/August.

Shillong and Srinagar — These are high level stations with an altitude of about 1·6 km a. s. l.

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The values of precipitable water vapour throughout the year of Shillong are higher than those of Srinagar, the magnitude of the difference is minimum in the month of April and maximum in June (Fig. 3). However, the monthly rainfall is higher in the case of Shillong than Srinagar in the months April to November and less in the remaining four months of the year. The highest rainfall in the case of Shillong is in June and that for Srinagar in March. In April, the rainfall at Shillong is nearly twice that of Srinagar and in June it is 11 times.

In general, the moisture content of the atmosphere over the Peninsula remains higher than that of the other parts of India, throughout the year, except for the period June to September.

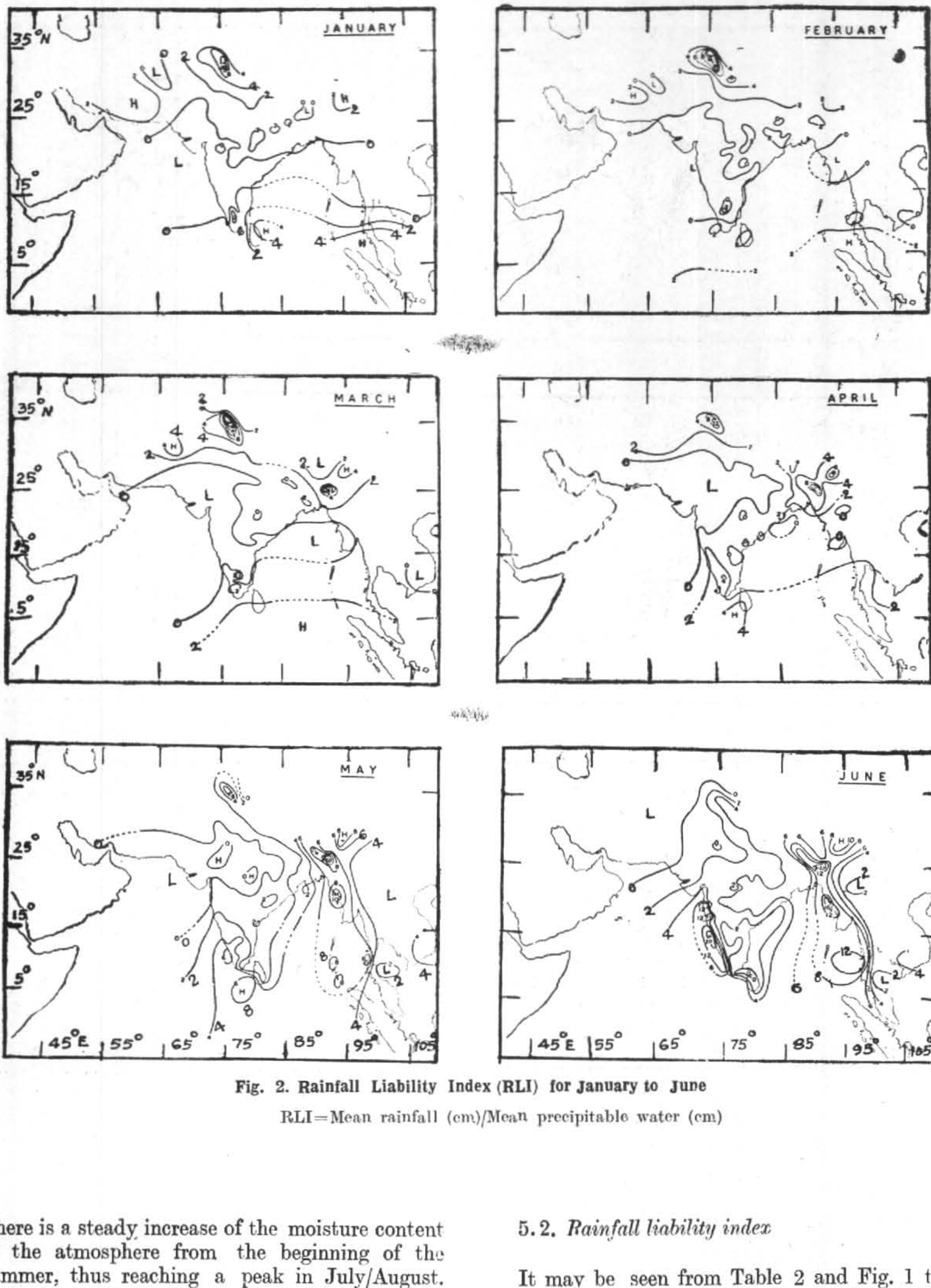

Fig. 2. Rainfall Liability Index (RLI) for January to June

RLI=Mean rainfall (cm)/Mean precipitable water (cm)

There is a steady increase of the moisture content of the atmosphere from the beginning of the summer, thus reaching a peak in July/August. The lowest values of the moisture content over the extreme south of India are in July/August. These features are diagrammatically depicted in Fig. 1.

5.2. *Rainfall liability index*

It may be seen from Table 2 and Fig. 1 that the diversity in the magnitude of rainfall is not reflected by the values of monthly mean precipitable water. This clearly shows that although there may be enough precipitable water at a place,

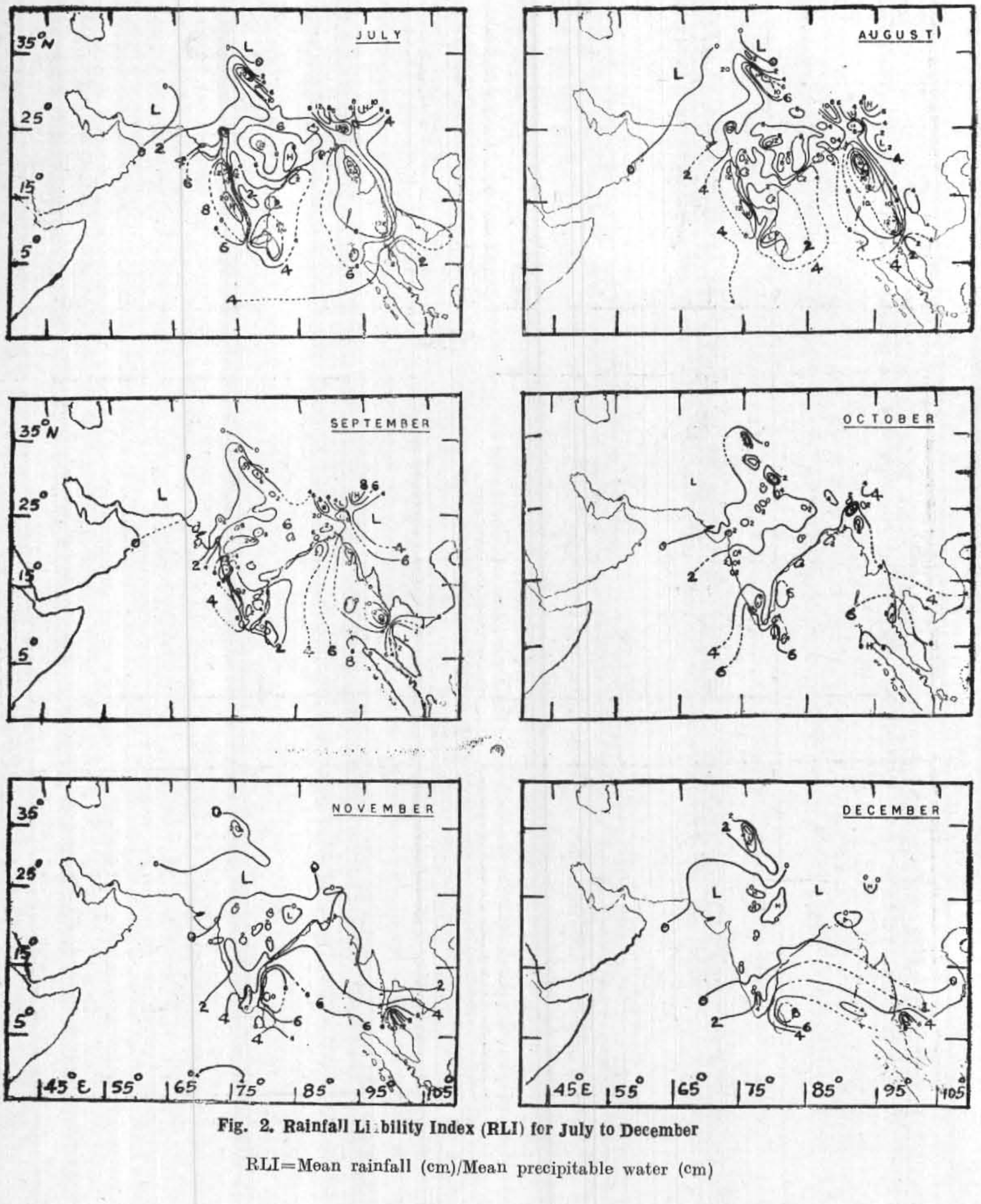

Fig. 2. Rainfall Liability Index (RLI) for July to December

RLI=Mean rainfall (cm)/Mean precipitable water (cm)

dynamic factors like ascending currents etc., may not be generally present in order to cause rain. As an illustration, the values of mean precipitable water and the rainfall for the month of July for Bombay, Jodhpur and Madras are given below—

	Bombay	*Jodhpur*	*Madras*
Mean precipitable water (gm)	5·7	5·0	5·1
Mean rainfall (cm)	94·5	12·2	8·3

TABLE 5

Monthly mean precipitable water (gm)

	Period of data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Aden	*1951-60	2·925	2·889	3·257	3·628	3·782	4·016	4·415	*4·623*	4·312	3·237	2·997	3·033	43·114
Akyab	1945	—	—	—	3·464	3·858	4·972	*5·420*	5·199	5·094	4·012	3·739	3·958	39·716
Bahrain	*1951-60	1·873	1·854	2·115	2·404	2·723	2·810	3·077	*3·206*	2·931	2·621	2·516	2·307	30·167
Bangkok	*1954-60	3·576	4·044	4·198	4·703	5·169	5·129	5·215	5·332	*5·349*	4·757	4·218	3·484	55·173
Chiangmai	*1954-60	2·342	2·481	2·765	3·444	4·671	4·767	4·839	*4·854*	4·593	4·122	3·435	2·970	45·277
Chittagong	1944-46	1·826	2·259	2·715	3·446	4·410	5·628	5·753	*5·889*	5·330	4·866	3·066	2·225	47·413
Colombo	*1958-62	4·171	4·229	4·099	*5·041*	5·030	4·445	4·538	4·625	4·756	4·639	4·743	4·259	54·575
Gan Island	†1960-65	4·452	4·418	4·418	*4·757*	4·620	4·224	4·258	4·451	4·451	4·521	4·634	4·452	53·656
Hong Kong	*1956-60	2·017	2·420	3·039	3·744	4·377	*4·931*	4·903	*4·931*	4·470	3·467	2·581	2·193	43·073
Karachi	*1951-60	2·169	2·451	3·007	3·324	3·975	4·744	*5·510*	5·097	4·655	3·458	2·631	2·298	43·319
Peshawar	1944-46	1·047	0·931	1·431	1·765	1·740	2·003	4·047	*4·359*	2·863	1·839	1·216	0·998	24·239
Quetta	1946-47	—	—	1·251	0·828	0·782	1·049	1·248	*2·236*	0·930	0·751	1·024	—	10·099
Rangoon	*1960-63	2·773	2·714	2·631	3·581	4·886	5·532	5·486	*5·715*	5·596	5·199	4·061	2·841	51·015
Saigon	*1952-58	4·194	3·873	4·563	4·827	5·165	*5·425*	4·936	4·696	4·936	4·748	4·425	4·337	56·125
Songkhla	*1954-60	4·140	3·698	4·124	4·318	4·865	4·655	4·742	4·689	4·675	*4·900*	4·669	4·264	53·739

*Radiosonde data taken from the short-period averages for 1951-1960 for CLIMAT TEMP (WMO Publ., No. 170. TP. 84)

†Radiosonde data taken from the *Daily Weather Report*, Overseas Supplement of London Meteorological Office

Highest values in *Italics*

TABLE 6

Mean monthly rainfall (cm)

	Period of data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Aden	*1941-60	*0·70*	0·30	0·60	0·00	0·01	0·00	0·30	0·20	*0·70*	0·10	0·30	0·60	3·81
Akyab	1881-1940	0·15	0·41	1·04	5·03	39·12	115·14	*139·93*	113·39	57·68	28·65	12·95	1·91	515·40
Bahrain	*1931-60	1·60	1·50	1·10	0·60	0·10	0·00	0·00	0·00	0·00	0·00	0·90	*1·80*	7·60
Bangkok	*1931-60	0·90	2·90	3·40	8·90	16·60	17·10	17·80	19·10	*30·60*	25·50	5·70	0·70	149·20
Chiangmai	*1931-60	0·70	1·20	1·50	4·90	14·40	14·60	18·80	23·10	*28·90*	12·60	3·90	1·00	125·60
Chittagong	1881-1940	0·61	2·79	6·25	15·06	26·47	53·31	*59·77*	51·87	32·11	18·01	5·51	1·63	273·39
Colombo	*1931-60	8·80	9·60	11·80	26·00	35·30	21·20	14·00	12·40	15·30	*35·40*	32·40	17·50	239·70
Gan Island	†1960-67	22·24	12·87	9·15	21·17	22·18	23·34	18·34	19·03	19·10	*31·12*	21·39	23·10	243·03
Hong Kong	*1951-60	3·00	6·00	7·00	13·30	33·20	*47·90*	28·60	41·50	36·40	3·30	4·60	1·70	226·50
Karachi	*1931-60	0·70	1·10	0·60	0·20	0·00	0·70	*9·60*	5·00	1·50	0·20	0·20	0·60	20·40
Peshawar	1881-1940	3·66	3·89	*6·20*	4·47	1·96	0·79	3·20	5·16	2·06	0·58	0·79	1·70	34·46
Quetta	1881-1940	4·93	*5·03*	4·42	2·49	0·99	0·43	1·17	0·84	0·10	0·31	0·71	2·57	23·99
Rangoon	*1951-60	0·80	0·50	0·60	1·70	26·00	52·40	49·20	*57·40*	39·80	20·80	3·40	0·30	252·90
Saigon	*1951-60	0·60	1·30	1·20	6·50	19·60	28·50	24·20	27·70	*29·20*	25·90	12·20	3·70	180·60
Songkhla	*1931-60	15·70	5·90	5·80	9·10	11·90	10·10	9·40	9·50	10·50	31·60	*57·60*	43·90	221·00

*Data taken from the Climatological Normals (CLINO) for CLIMAT for the period 1931-1960 (WMO Publ. No. 117 TP. 52)

†Data taken from the *Daily Weather Report*, Overseas Supplement of London Meteorological Office

Highest values in *Italics*

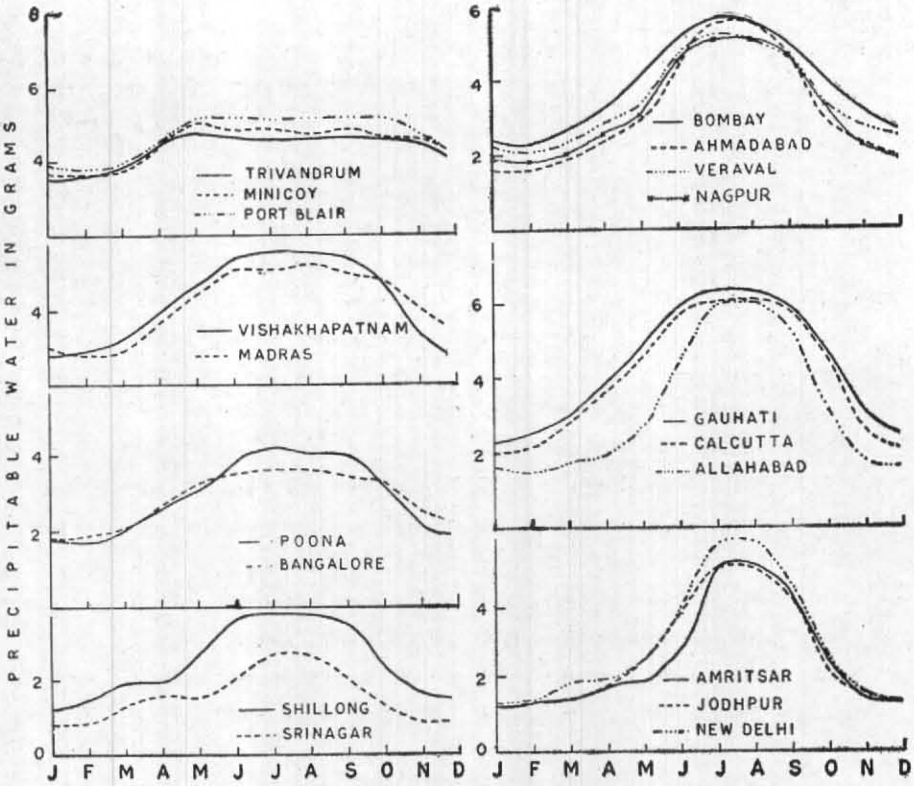

Fig. 3

The ratio of the mean monthly rainfall to the monthly mean precipitable water can be used as a rough indicator of the liability for rainfall at a place. Isopleths of this ratio, which may be called Rainfall Liability Index (RLI) drawn for various months will be found very useful. The spatial variation of the monthly rainfall in India is much more than the spatial variation of the precipitable water. Therefore, the map (Fig. 1) showing the precipitable water based on 19 stations in India and 15 stations in neighbouring countries will be adequately representative. However, for preparing fairly representative map showing the RLI (Fig. 2), the rainfall normals of about 250 departmental stations distributed over the country (including some hill stations) and 29 stations in neighbouring countries were utilized and the corresponding values of precipitable water were read off from Fig. 1.

The availability of moisture and favourable dynamic factors for its utilisation as precipitation are well brought out in the maps of RLI. These maps clearly bring out the difference in rainfall liability between different regions of the country. For example, the RLI for July is 16·7 at Bombay, 2·4 at Jodhpur and 1·7 at Madras. High values of RLI are obviously linked with favourable ascent conditions and corresponding frequent rainfall and low values of RLI with the lack of such conditions.

It is felt that the maps of RLI over the country would be more meaningful and may be of greater practical utility for hydrometeorological purposes than those of mean precipitable water alone.

The main climatological features connected with RLI are given below—

Broadly the year can be divided into four seasons, *viz.*, January and February (Winter Season), March to May (Hot Weather Season), June to September (Southwest Monsoon Season) and October to December (Post Monsoon Season). More than 75 per cent of the annual rainfall is received during the season, June to September, over almost the entire country with a few exceptions (Assam, Jammu & Kashmir and the south Peninsula). Correspondingly, the values of RLI are high over the country during this season. There is also a similarity between the large variation of the seasonal distribution of rainfall in various parts of the country and the variation in the values of RLI.

January and February — The influence of western disturbances is seen during this season over Jammu & Kashmir and the Punjab and even over the lower latitudes upto Vidarbha (and sometimes

TABLE 7

Rainfall Liability Index (RLI) = Mean monthly rainfall (cm)/Monthly mean precipitable water (cm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Aden	*0·239*	0·104	0·184	0·000	0·026	0·000	0·068	0·043	0·162	0·031	0·100	0·198
Akyab	0·000	0·000	0·000	1·452	10·139	23·157	*25·817*	21·809	11·324	7·141	3·465	0·481
Bahrain	0·856	0·811	0·521	0·250	0·037	0·000	0·000	0·000	0·000	0·000	0·357	*0·882*
Bangkok	0·251	0·718	0·810	1·894	3·211	3·333	3·417	3·583	*5·720*	5·357	1·351	0·201
Chiangmai	0·299	0·484	0·542	1·424	3·084	3·067	3·884	4·763	*6·296*	3·058	1·137	0·377
Chittagong	0·334	1·237	2·301	4·371	6·002	9·473	*10·389*	8·807	6·024	3·701	1·798	0·731
Colombo	2·110	2·269	2·878	5·159	7·018	4·764	3·084	2·678	3·214	*7·629*	6·835	4·108
Gan Island	4·996	2·913	2·071	4·450	4·801	5·526	4·307	4·275	4·291	*6·883*	4·616	5·189
Hong Kong	1·485	2·479	2·303	3·556	7·580	*9·716*	5·837	8·418	8·143	0·951	1·783	0·776
Karachi	0·323	0·449	0·199	0·060	0·000	0·148	*1·742*	90·98	0·323	0·058	0·076	0·261
Peshawar	3·494	4·174	*4·331*	2·533	1·124	0·393	0·791	1·183	0·718	0·381	0·647	1·705
Quetta	0·000	0·000	*3·533*	3·006	1·267	0·412	0·936	0·375	0·110	0·406	0·694	0·000
Rangoon	0·289	0·185	0·228	0·475	5·317	9·476	8·962	*10:053*	7·107	4·000	0·837	0·106
Saigon	0·143	0·336	0·263	1·346	3·791	5·249	4·899	5·894	*5·911*	5·453	2·754	0·853
Songkhla	3·792	1·595	1·408	2·106	2·444	2·172	1·983	2·062	2·248	6·449	*12·334*	10·305

Highest values in *Italics*

further lower latitudes). They give rise to high values of RLI over this region. Nilgiri hills, the southeast Peninsula and Ceylon also show high RLI values.

March to May — During this season Jammu & Kashmir the Punjab, eastern Assam, the extreme south Peninsula and the head Bay show higher values of RLI. In the later part of the season, the values of RLI are seen penetrating further into the interior of the country from the south. This can be attributed to the effects of insolation resulting in the occurrence of inland thunderstorms.

June to September — High values of RLI over Konkan, Andaman, Kumaon hills, Bihar Plateau, Uttar Pradesh and the Punjab are noticed. The moisture tongue which appears in May, goes upto Bombay (Konkan); the moisture tongue has two currents — Arabian current and the Bay current. July and August months were regarded uptill now to be nearly similar in the moisture content but it is revealed that it is not so, as can be seen from the maps. In August the west coast, Madhya Pradesh, sub-Himalayan West Bengal and Assam show lower RLI values than those in July.

October to December — In October, over Assam, the east coast as well as over the south Peninsula, the RLI is more; while in November the high liability value retreats further towards the south. There is a general decrease in RLI in December over the country, except over the extreme north-west parts where higher RLI values caused by movement of western disturbances are noticed.

Acknowledgements — The author would like to express his sincere thanks to Dr. P. Koteswaram, Director General of Observatories, for his guidance in the study of this problem. Thanks are also due to members of staff of the Upper Air Section, who helped in the computations involved in the study and in the preparation of the diagrams.

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