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Relationship between evaporation and other meteorological factors

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ABSTRACT. Using correlation techniques, an assessment is made of the influence exerted by basic meteorological factors in controlling the evoporative power of air. Linear regression equations are developed for twentyfive stations linking pan evaporation with saturation vapour pressure deficit, maximum temperature and mean daily wind speed. Evaporation computed with formulation thus developed compares favourably with actual data.

1. Introduction

Observations of evaporation from class A type pan were introduced at about 30 stations in India more than a decade ago. All these evaporimeters are covered with meshes to prevent birds and animals from drinking water which would otherwise affect the observations. In view of the limited network of stations it was felt that it would be useful to examine the contribution to pan evaporation values from various meteorological factors and build up regression equations between evaporation and these factors. Such a study would also help in getting an idea of evaporation in neighbouring areas which are homologous in character. Studies of similar nature were made in South Africa (Louw and Kurger 1967) and in East Germany (Richter *et al.* 1970).

2. Data and factors

(a) *Data*

The monthly mean evaporation data of 25 stations for about 9 to 10 years (which number about 100 to 120 values for each station) have been taken up for examination and study. The stations are shown in Fig. 1. Available monthly data of evaporation for all the years have been published recently (India met. Dep. 1970).

(b) *Factors*

Eight factors mentioned below were examined —

(*i*) *Saturation vapour pressure deficit* — This is taken as the difference between the saturation vapour pressure (mb) corresponding to monthly mean air temperature and the monthly average of the mean daily vapour pressure (mb) at 0830 and 1730 hours IST.

(*ii*) *Mean monthly maximum temperature* — Monthly values in °C have been used.

(*iii*) *Mean monthly relative humidity* — The average of the mean monthly values at 0830 and 1730 hours IST has been used.

(*iv*) *Mean monthly air temperature* — This is defined arithmetic mean of monthly mean daily maximum temperature and monthly mean daily minimum temperature.

(*v*) *Monthly mean daily wind speed* (*kmph*) — The wind speed data used are those recorded by the observatory anemometers which are generally at heights of about 10 to 15 metres above ground.

(*vi*) *Mean duration of bright sunshine* (*per day per month*) — Sunshine data are available for 14 stations; for other stations the diurnal range of temperature has been considered.

(*vii*) *Cloudiness* — The average monthly values at 0830 and 1730 hours IST have been used.

(*viii*) *Number of rainy days* — The monthly number of rainy days of 2·5 mm or more have been used.

3. Method

In order to find the degree of association between pan evaporation values and the meteorological factors correlation approach has been tried. Using three factors which are found to be highly significant, regression equations have been obtained. In view of the small number of years for which data are available all months have been combined to obtain a sample of about 100 to 120 values. For n equal to 100, significant

TABLE 1

Correlation coefficients (CCs) between evaporation (Pan) and other meteorological factors

Station	Wind speed	Sunshine	Saturation vapour pressure deficit	Maximum temperature	Relative humidity	Mean temp.	Cloudiness	No. of rainy days	Inter Correlation Coefficients: Saturation vapour pressure deficit and max. temp.	Inter Correlation Coefficients: Vapour pressure deficit and wind	Inter Correlation Coefficients: Maximum temp. and wind
					Western Region						
Ahmadabad (S)	·46	·48	·85	·83	—·43	·75	—·09	—·09	·83	·19	·37
Okha	·66	·09	·08	·66	·10	·55	—·01	—·12	—·47	—·40	—·45
Surat	·40	—·09	—·36	·60	—·20	·63	·03	—·09	·77	—·49	—·22
Bombay (S)	—·17	·62	·87	·71	—·52	·69	—·11	—·27	·60	—·42	—·36
Poona (S)	·34	·41	·97	·77	—·73	·69	—·17	—·25	·68	·14	·36
					Eastern Region						
Calcutta (S)	·82	·05	·81	·89	—·05	·79	—·09	—·14	·60	·46	·75
Gaya	·61	·28	·96	·87	—·72	·71	·02	—·41	·84	·49	·72
Imphal	·83	—·23	·85	·76	—·51	·68	·21	—·17	·61	·71	·50
Sabour	·78	—·10	·82	·89	—·45	·75	·02	—·28	·76	·53	·72
Shillong	·70	·06	·86	·73	—·46	·60	·03	—·47	·22	·42	·41
					Southern Region						
Bangalore (S)	—·01	·77	·93	·78	—·29	·69	·33	—·43	·74	—·09	·31
Hyderabad (S)	·08	·32	·82	·85	—·67	·74	—·16	—·12	·95	—·07	·08
Kodaikanal (S)	·12	·73	·83	·59	—·83	·28	·02	—·37	·31	·00	·19
Madras	·73	·11	·81	·73	—·71	·72	—·24	—·17	·40	·37	·73
Palayamkottai (S)	·64	—·07	·80	·74	—·82	·74	—·14	—·20	·26	·54	·55
Trivandrum (S)	—·06	·63	·80	·79	—·77	·70	—·27	—·47	·86	—·41	—·31
Visakhapatnam	·53	·29	·80	·76	—.23	·70	·01	·47	·66	·34	·62
Minicoy	·01	—·19	·31	·60	—.45	·48	·03	—·11	·16	·23	—·54
					Central and Northern Region						
Nagpur (S)	·31	·37	·93	·95	—·75	·80	—·16	—·26	·67	·14	·35
Allahabad	·65	·14	·76	·90	—·75	·74	·04	—·39	·72	·40	·69
Bikaner	·83	·10	·90	·86	—·21	·91	·05	·01	·81	·69	·76
Chambal Dam	·39	·09	·92	·85	—·63	·68	·03	—·37	·84	·33	·54
Jodhpur	·79	·09	·89	·83	—·24	·85	·06	·03	·81	·58	·77
Lucknow (S)	·63	—·04	·91	·88	—·71	·75	·31	·23	·79	·47	·60
New Delhi (S)	·61	·03	·89	·78	—·63	·71	—·08	—·04	·82	·66	·46

NOTE : Data used—Available monthly values of 1959-68 (S)—Stations equipped with sunshine recorders

Level of significance	5 per cent	1 per cent
Correlation coefficient : (n = 100)	·1946	·2540

CCs are (i) 0·1946 at 5 per cent level of significance, (ii) 0·2540 at 1 per cent level of significance. The relevant statistical information is given in Tables 1 to 5.

Table 1 gives the correlation coefficients (CCs) between pan evaporation values and each of the above mentioned meteorological factors. Table 1 also contains inter CCs among the following — (i) Saturation vapour pressure deficit, (ii) Maximum temperature and (iii) Mean daily wind speed.

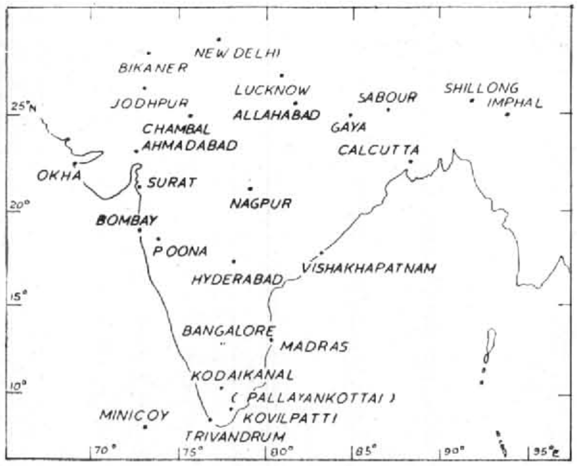

Fig. 1
Location of (Pan) evaporimeter stations.

TABLE 2

Regression Equations

Station	Equation	Multiple CCs ($\times 10^{-2}$) R_{123}	Multiple CCs ($\times 10^{-2}$) R_{1234}
Ahmadabad	$y = \cdot 234x_1 + \cdot 156x_2 + \cdot 410x_3 - 5\cdot 150$	92	93
Okha	$y = \cdot 232x_1 + \cdot 320x_2 + \cdot 176x_3 - 7\cdot 865$	79	81
Surat	$y = \cdot 103x_1 + \cdot 486x_2 + \cdot 478x_3 - 15\cdot 551$	82	83
Bombay	$y = \cdot 298x_1 + \cdot 122x_2 + \cdot 089x_3 - 3\cdot 457$	91	96
Poona	$y = \cdot 306x_1 + \cdot 149x_2 + \cdot 099x_3 - 1\cdot 316$	99	99
Calcutta	$y = \cdot 245x_1 + \cdot 021x_2 + \cdot 272x_3 - 0\cdot 700$	97	97
Gaya	$y = \cdot 307x_1 + \cdot 043x_2 + \cdot 182x_3 - 0\cdot 298$	99	99
Imphal	$y = \cdot 197x_1 + \cdot 140x_2 + \cdot 291x_3 - 2\cdot 638$	97	98
Sabour	$y = \cdot 122x_1 + \cdot 179x_2 + \cdot 219x_3 - 4\cdot 227$	94	96
Shillong	$y = \cdot 234x_1 + \cdot 065x_2 + \cdot 107x_3 - 0\cdot 490$	98	98
Bangalore	$y = \cdot 301x_1 + \cdot 118x_2 + \cdot 001x_3 - 1\cdot 769$	95	99
Hyderabad	$y = \cdot 065x_1 + \cdot 456x_2 + \cdot 016x_3 - 8\cdot 676$	85	94
Kodaikanal	$y = \cdot 362x_1 + \cdot 017x_2 + \cdot 045x_3 - 0\cdot 458$	84	87
Madras	$y = \cdot 183x_1 + \cdot 129x_2 + \cdot 085x_3 - 2\cdot 844$	95	99
Palayamkottai	$y = \cdot 577x_1 + \cdot 034x_2 + \cdot 182x_3 - 14\cdot 504$	97	98
Trivandrum	$y = \cdot 022x_1 + \cdot 220x_2 + \cdot 110x_3 - 2\cdot 662$	84	91
Visakhapatnam	$y = \cdot 318x_1 + \cdot 178x_2 + \cdot 069x_3 - 3\cdot 635$	87	97
Minicoy	$y = \cdot 144x_1 + \cdot 114x_2 - \cdot 073x_3 + 0\cdot 000$	70	77
Nagpur	$y = \cdot 252x_1 + \cdot 052x_2 + \cdot 235x_3 - 1\cdot 597$	92	96
Allahabad	$y = \cdot 055x_1 + \cdot 230x_2 + \cdot 425x_3 - 5\cdot 650$	93	95
Bikaner	$y = \cdot 167x_1 + \cdot 117x_2 + \cdot 311x_3 - 2\cdot 553$	95	97
Chambal Dam	$y = \cdot 249x_1 + \cdot 167x_2 + \cdot 039x_3 - 7\cdot 353$	93	96
Jodhpur	$y = \cdot 261x_1 + \cdot 077x_2 + \cdot 197x_3 - 1\cdot 912$	93	95
Lucknow	$y = \cdot 188x_1 + \cdot 179x_2 + \cdot 179x_3 - 4\cdot 102$	95	99
New Delhi	$y = \cdot 121x_1 + \cdot 102x_2 + \cdot 074x_3 + 0\cdot 836$	90	99

y = Mean monthly evaporation (mm/day),

x_1 = Mean monthly saturation vapour pressure deficit (mb)

x_2 = Mean monthly maximum temperature (°C)

x_3 = Mean monthly wind speed (kmph)

x_4 = Mean air temperature (°C)

R_{1234} = Multiple CC with factors x_1, x_2, x_3, x_4

R_{123} = Multiple CC with factors x_1, x_2, x_3

TABLE 3

Pecentage conribution tc total variance due to factors x_1, x_2 and x_3 and when combined in the crder x_1, x_2, x_3

Station	Combined contribution			Percentage individual contribution		
	x_1	x_1+x_2	$x_1+x_2+x_3$	x_1	x_2	x_3
Ahmadabad	73	77	84	73	4	7
Okha	1	46	63	1	45	17
Surat	13	38	68	13	25	30
Bombay	76	77	83	76	1	6
Poona	95	96	97	95	1	2
Calcutta	65	90	95	65	25	5
Gaya	92	82	95	72	10	13
Imphal	72	84	89	67	17	5
Sabour	67	91	97	73	18	6
Shillong	73	93	96	92	1	3
Bangalore	87	89	89	87	2	0
Hyderabad	67	73	73	67	6	0
Kodaikanal	69	69	70	69	0	1
Madras	65	85	90	65	20	5
Palayamkottai	71	90	95	71	19	5
Trivandrum	65	68	71	65	3	3
Visakhapatnam	64	74	75	64	10	1
Minicoy	9	41	48	9	32	7
Nagpur	87	89	92	87	2	3
Allahabad	82	89	91	82	7	2
Bikaner	81	83	90	81	2	7
Chambal Dam	84	86	87	84	2	1
Jodhpur	80	83	87	80	3	4
Lucknow	82	89	91	82	7	2
New Delhi	79	80	80	79	1	0

Table 2 gives the regression equation connecting evaporation with (*i*) saturation vapour pressure deficit, (*ii*) maximum temperature, (*iii*) mean daily wind speed and the multiple correlation coefficients. The last column gives the multiple CC with one more factor, mean air temperature.

Table 3 gives percentage contribution of each of the factors, *viz.*, (*i*) Saturation vapour pressure deficit, (*ii*) Maximum temperature, (*iii*) Mean daily wind speed and (*iv*) all the three factors combined taken in this order.

Table 4 gives the standard deviation for each station for the period 1959 to 1968.

Table 5 gives the comparison between actual and calculated values of evaporation for the year 1969.

TABLE 4

Standard deviation

Station	Evaporation (mm/day)	Saturation vapour pressure deficit (mb)	Maximum temperature (°C)	Mean wind speed (kmph)
Ahmadabad	2·970	7·965	3.952	1·950
Okha	1·597	2·514	2·609	4·195
Surat	2·159	5·620	2·386	2·925
Bombay	1·018	2·989	1·447	2·990
Poona	2·401	4·623	3·751	2·908
Calcutta	1·407	3·525	3·259	3·208
Gaya	3·593	9·668	5·478	3·066
Imphal	1·250	2·271	3·001	1·760
Sabour	1·943	5·403	4·564	2·651
Shillong	0·813	2·332	3·238	2·349
Bangalore	1·596	4·191	2·619	3·256
Hyderabad	2·446	7·710	3·504	6·174
Kodaikanal	0·831	1·859	3·170	2·183
Madras	1·583	5·025	3·157	6·116
Palayamkottai	2·330	2·403	2·419	3·766
Trivandrum	0·875	2·403	1·247	2·751
Visakhapatnam	1·606	2·965	2·571	3·810
Minicoy	0·539	1·583	0·749	4·654
Nagpur	3·030	10·287	4·407	2·633
Allahabad	2·769	14·608	5·824	1·980
Bikaner	3·464	10·628	6·150	3·530
Chambal Dam	3·492	10·018	4·826	3·145
Jodhpur	3·387	8·728	5·018	3·799
Lucknow	3·165	9·738	5·612	2·961
New Delhi	3·599	9·340	5·971	3·285

4. Analysis and discussion

The importance of each of the meteorological factors in controlling evaporation is now discussed.

(i) Wind

(a) *Northeastern region* — Correlation coefficient between wind and evaporation is highly significant at stations in northeast India. Of the four stations Calcutta, Imphal and Sabour show CCs of 0·8 and Shillong 0·7. As the total number of values used in calculating CC is about 100, these CCs should be regarded as clearly demonstrating the high degree of association between wind and evaporation.

(b) *Western region* — Of the five stations tried, 4 show significance and only Bombay has a low negative CC (—0·17). The significant CCs are also not high. Only Okha CC is 0·66. Surat is 0·40 and Ahmadabad is 0·46.

(c) *Southern region* — Of the eight stations whose data were correlated, only three stations Madras, Palayamkottai and Visakhapatnam have CCs of 0·5 to 0·7 with wind. At all the other stations the CCs are low, generally less than 0·1. Hyderabad has a CC of 0·08 and Bangalore —0·01.

(d) *Central and Northern region* — 6 of the 8 stations are highly correlated with CC more than 0·6 and Nagpur and Chambal Dam show 0·3 and 0·4 CC respectively.

(e) The above examination brings out the significant association in general between mean daily wind speed and evaporation. Low CCs have been noted at a number of stations in the southern region. The location and exposure of wind instrument could not be the main cause of the low CCs as otherwise, similar results should have been noted at the other stations and this may be partly responsible for some of the low CCs.

(ii) Sunshine

Bangalore, Bombay, Kodaikanal and Trivandrum show high CCs. Good correlation has been noted in western India. Bombay CC is 0·62. Poona and Ahmadabad have 0·4 to 0·5 CC. In the northern and eastern regions, low degree of association with some of the CCs being even negative, has been noted. Of the 14 CCs, six are not significant.

While some stations have shown good degree of association between sunshine and evaporation, there is no clear relationship suggested by this table.

Where sunshine data were not available, diurnal temperature range was used and the CCs with evaporation are low being mostly less than 0·2. Range seems to be poorly correlated with evaporation.

(*iii*) Saturation vapour pressure deficit shows generally the highest degree of association from among the various factors examined. 22 out of the 25 stations have CCs of 0·8 or higher, with evaporation. The exceptions are Surat (0·37), Minicoy (0·31) and Okha (0·08). Surat and Minicoy CCs are significant. The contribution as single factors in a linear regression equation with evaporation is small (—10 to 14 per cent). Six of the CCs are 0·9 or more. Poona and Gaya have CCs of 0·97 and 0·96 respectively. As saturation vapour pressure deficit has been computed as the difference between the saturation vapour pressure corresponding to the mean temperature of the month and the mean of actual daily vapour pressure values corresponding to screen temperature over humidity, the results might have further improved had the values recorded over the pan been also examined.

(iv) Maximum temperature

Next to vapour pressure deficit, monthly values of mean daily maximum temperature are very highly correlated with evaporation. Almost all the CCs are greater than 0·60. Two third of the stations give CCs greater than 0·80, the maximum being 0·95. Interestingly the three exceptions of low CCs noted in the case of vapour pressure deficit are much improved.

(v) Mean temperature

Excepting three, all the other CCs are 0·6 or higher. 21 of the 25 CCs are lower than CCs with maximum temperature. As mean temperature is the average of maximum and minimum, the influence of minimum temperature on evaporation does not appear to be significant.

(vi) Relative humidity

Two third of the number of stations show significant negative CCs with evaporation but the consistency is not of the same order as CCs with maximum temperature or vapour pressure deficit. In the southern, central and northern regions several negative CCs are numerically 0·7 or higher. Trivandrum and Allahabad CCs are —0·77 and Palayamkottai —0·82.

(vii) Cloudiness

Only 5 CCs are above 0·2. Two exceed 0·3. Cloudiness does not appear to be a significant factor in influencing evaporation.

(viii) Rainy days

About three fourth of the 25 CCs are negative. Some stations mostly in the northern areas show significant relationship with evaporation. There is no consistent relationship.

5. Inter-correlation among the factors — Saturation vapour pressure deficit, maximum temperature and wind speed

Except for Shillong and Minicoy all the stations gave significant CCs between maximum temperature and saturation vapour pressure deficit. More than two third of the stations have CCs greater than 0·6.

Stations in northern region show significant CC between vapour pressure deficit and

TABLE 5

Comparison between actual and calculated values of evaporation

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ahmadabad	A	5·1	6·4	8·7	11·1	13·0	10·2	8·4	3·6	5·4	5·9	6·1	5·0
	C	4·9	6·5	10·0	12·3	11·9	10·7	7·9	4·1	5·5	6·0	6·3	5·1
	D	3·9	1·6	14·9	10·8	8·5	5·0	5·9	13·9	1·8	1·7	3·3	2·0
Bombay	A	3·0	3·7	4·1	4·9	5·7	4·1	2·7	2·7	2·9	3·9	3·7	3·0
	C	3·3	4·1	3·9	4·5	6·3	3·9	3·1	2·9	3·3	4·0	3·5	3·3
	D	10·0	10·8	4·9	8·2	10·5	4·9	14·8	7·4	13·8	2·6	5·4	10·0
Okha	A	5·8	5·8	5·8	7·2	9·1	9·4	7·5	5·5	6·7	5·1	6·9	6·5
	C	5·9	6·5	6·1	8·7	10·5	10·8	8·8	6·0	7·7	5·6	7·5	7·2
	D	1·7	12·1	5·2	6·9	15·3	14·8	9·3	9·1	14·9	9·8	8·7	10·8
Nagpur	A	3·8	5·9	8·2	11·8	8·8	9·3	4·4	3·3	4·6	5·2	4·9	3·9
	C	4·2	6·1	9·1	12·3	12·0	10·7	5·1	3·7	5·0	5·6	4·2	4·4
	D	10·5	3·4	10·9	4·2	13·6	15·1	15·9	12·1	8·7	7·7	14·3	12·9
Bangalore	A	6·3	6·7	8·6	6·8	5·5	5·0	4·1	4·2	3·7	3·4	4·0	3·2
	C	*	6·5	8·3	*	6·1	5·0	4·7	4·1	4·2	3·9	3·7	3·1
	D	*	3·0	3·5	*	10·9	0·0	14·6	2·4	13·5	14·7	7·5	3·1
Madras	A	5·0	5·4	6·8	7·6	7·2	8·8	6·4	6·4	6·9	4·4	3·7	3·1
	C	4·3	4·9	5·9	6·7	6·9	7·8	5·9	5·9	5·9	3·9	3·2	2·7
	D	14·0	9·3	13·2	11·8	9·7	11·3	7·8	7·8	14·4	11·4	13·5	12·9
Hyderabad	A	7·9	10·3	13·2	12·5	12·2	10·8	6·7	6·9	5·4	7·6	5·8	5·1
	C	6·7	8·9	10·7	11·7	10·9	9·5	6·4	6·4	5·7	6·5	5·2	4·5
	D	15·2	13·6	11·4	6·4	10·7	12·0	4·5	7·2	5·6	14·5	10·3	11·8
Visakhapatnam	A	6·9	7·1	8·9	9·8	6·9	7·6	5·5	5·4	5·1	5·2	5·3	5·9
	C	6·1	6·8	7·7	8·3	6·9	7·7	6·1	6·2	5·9	5·4	5·2	5·7
	D	11·6	4·2	13·5	15·3	0·0	1·3	10·9	14·8	15·6	3·8	1·9	3·4
Kodaikanal	A	3·3	3·8	4·4	3·7	3·1	2·8	2·4	2·1	2·9	1·7	2·1	1·7
	C	2·9	3·2	*	3·2	2·9	2·7	2·1	1·9	2·6	1·5	1·8	1·5
	D	12·1	15·8	*	13·6	6·5	3·5	12·5	9·5	10·3	11·8	14·3	11·8
Minicoy	A	3·4	3·9	4·5	4·0	4·3	4·9	4·3	4·6	4·7	3·8	3·2	2·9
	C	*	4·4	4·6	4·4	3·7	4·3	4·0	4·3	4·5	4·0	3·6	3·1
	D	*	12·8	2·2	10·0	13·9	12·2	7·0	6·5	4·3	5·3	12·5	6·9
Lucknow	A	2·9	4·6	7·2	10·9	9·7	9·9	4·3	3·5	3·3	3·7	2·9	2·3
	C	3·3	4·4	8·0	10·7	9·8	9·9	4·1	3·8	3·4	3·5	3·2	2·6
	D	13·8	4·3	11·1	1·8	1·0	0·0	4·6	8·6	3·0	5·4	10·3	13·0
Allahabad	A	2·8	4·0	13·2	9·1	8·4	9·2	4·7	3·5	3·8	3·9	2·8	1·9
	C	2·4	3·7	11·1	7·9	7·9	8·1	5·0	3·7	3·7	3·6	3·3	1·7
	D	14·3	7·5	15·9	13·2	6·0	11·9	6·4	5·7	2·6	7·7	14·2	10·5
New Delhi	A	3·7	5·1	8·0	7·3	9·6	10·9	6·4	5·6	5·5	6·1	4·8	3·4
	C	4·2	*	7·4	8·2	10·3	11·4	6·9	6·0	5·7	5·5	5·2	3·9
	D	13·5	*	7·5	12·3	7·3	4·6	9·4	7·1	3·6	9·8	8·3	14·7
Bikaner	A	3·2	2·9	6·3	9·8	11·9	14·2	10·0	8·9	8·6	7·3	4·3	2·8
	C	*	*	7·8	9·9	12·4	13·7	11·1	10·1	9·9	7·7	4·0	2·5
	D	*	*	7·9	1·0	4·2	3·5	11·0	13·0	15·1	5·5	7·0	10·7
Chambal Dam	A	4·3	5·8	8·6	11·4	13·4	11·8	5·0	2·7	4·5	5·4	4·6	3·4
	C	3·7	5·6	7·6	9·9	12·2	11·0	4·9	3·0	4·2	5·0	4·1	3·0
	D	13·9	3·4	11·6	13·2	9·0	6·8	2·0	11·1	6·7	7·4	10·9	11·8

TABLE 5 *(contd)*

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Imphal	A	2·1	4·0	4·9	5·6	6·6	4·1	4·3	4·1	4·1	3·5	2·2	1·8
	C	2·4	4·1	5·0	6·0	6·4	4·6	4·9	4·4	4·3	3·7	2·5	2·0
	D	14·3	2·5	2·0	7·1	3·0	12·1	13·9	7·3	4·9	5·7	13·6	9·1
Calcutta	A	2·8	3·4	5·1	6·2	6·5	4·6	3·2	3·0	3·5	3·8	3·4	2·7
	C	2·9	3·7	5·3	6·4	6·5	4·9	3·3	3·4	3·6	4·1	3·7	2·8
	D	3·6	8·8	3·9	3·2	0·0	6·5	3·1	13·3	2·8	5·3	8·8	3·7
Sabour	A	1·4	2·7	5·8	6·7	5·3	*	*	*	*	*	3·2	1·3
	C	1·2	2·5	5·5	6·4	5·5	*	*	*	*	*	3·0	1·2
	D	14·3	7·4	5·2	4·5	3·8	*	*	*	*	*	6·3	7·7
Gaya	A	3·5	3·1	8·7	10·6	9·0	7·2	4·1	3·7	3·8	3·5	3·1	2·3
	C	3·9	3·5	8·3	10·1	9·4	7·5	4·7	4·1	4·1	3·7	3·4	2·6
	D	11·4	12·9	4·6	4·7	4·4	4·2	14·6	10·8	7·9	5·7	9·7	13·0
Shillong	A	1·7	3·0	3·5	4·1	2·5	2·2	2·0	*	1·9	1·8	1·6	1·4
	C	1·9	3·0	3·6	4·3	3·0	2·5	2·3	*	1·8	1·8	1·7	1·5
	D	11·8	0·0	2·9	4·9	11·1	13·6	15·0	*	5·3	0·0	6·3	7·1
Trivandrum	A	5·3	5·3	6·0	5·2	4·3	3·7	3·4	4·1	4·5	3·6	3·4	3·4
	C	5·0	5·1	5·7	5·5	4·6	4·0	3·8	4·2	4·4	3·2	3·2	3·3
	D	5·7	3·8	5·0	5·8	7·0	8·1	11·8	2·4	2·2	11·1	5·9	2·9
Poona	A	4·7	6·9	10·0	12·0	12·5	9·2	5·7	4·2	4·8	5·8	4·9	5·0
	C	4·9	7·1	10·4	11·7	12·0	9·5	6·0	4·8	5·2	5·7	5·2	5·4
	D	4·3	2·9	4·0	2·4	4·0	3·3	5·3	14·3	8·3	1·7	6·1	8·0
Palayamkottai	A	6·3	7·3	7·4	*	11·4	14·9	13·2	8·8	10·6	5·1	4·6	5·3
	C	6·6	7·8	8·0	*	11·9	14·1	13·6	9·3	10·4	5·3	4·9	5·5
	D	4·8	6·8	8·1	*	4·3	5·4	3·0	5·7	1·9	3·9	6·5	3·8

Note: Data of Jodhpur and Surat are not available for 1969 *—Data not available
A—Actual, C—Calculated, D—Percentage departure

wind. Interestingly maximum temperature and wind show good CCs. All except two of them are significant at 5 per cent. Stations in the northern areas show significance with vapour pressure deficit. In the southern and western regions also, a number of them are significant.

The CCs between maximum temperature and wind speed show a better association than those between saturation vapour pressure deficit and wind speed. But for Surat and Kodaikanal all the CCs between maximum temperature and wind speed are significant. More than one third of the stations have CCs greater than 0·60.

6. Regression equations

(*a*) The above analysis shows that the most significant factors with evaporation are (*i*) Saturation vapour pressure deficit, (*ii*) Maximum temperature, (*iii*) Relative humidity, (*iv*) Mean temperature and (*v*) Wind.

(*b*) Saturation vapour pressure deficit has very high individual CCs consistently. This may be taken as the first factor. The next factor chosen is mean daily maximum temperature which has better CCs than mean temperature. The third factor is wind.

(*c*) Table 2 gives the multiple CCs of the regression equations with the factors saturation vapour pressure deficit, maximum temperature and wind for each of the 25 stations. The multiple CCs obtained by adding another factor, mean temperature, is also shown in the table.

In view of the high inter CCs among the factors vapour pressure deficit, maximum temperature and wind, marked increase in the multiple CCs by combining one or more factors with vapour pressure deficit should not be expected. Other factors were not included as the high CCs of vapour pressure deficit and maximum temperature with evaporation appear sufficient to evolve linear regression equations with high multiple CCs.

Only 7 of the regression equations have less than 0·9 multiple CCs (*i.e.*, less than 80 per cent contribution to total variance). About half of the stations have multiple CCs of the order of 0·95. By using these regression equations it should be possible to evaluate pan evaporation values, reliable enough for most purposes.

7. Contribution due to different factors

Table 3 shows the contribution of the different factors to total variance when taken in order of vapour pressure deficit, maximum temperature and wind. The small contribution due to the wind when it is the third factor is to be noted. The table suggests that two factors may be enough to get dependable regression equations. Even the addition of second factor has not often materially improved the regression.

8. Verification of regression equations

The regression equations developed were tested by computing evaporation and comparing with actually recorded data for available stations for 1969. The results (Table 5) are encouraging, the maximum deviation of the computed values in a few cases being only 12 per cent from the actual. It is further seen that the deviation from the actual evaporation invariably lies within $\pm \cdot 1\ \sigma$, where σ is the standard deviation for the respective stations given in Table 4.

9. Concluding Remarks

(*i*) Despite limitations of use of monthly mean values in correlating evaporation with meteorological factors, this study has demonstrated, that linear regression equations can be derived and used with advantage for estimation of pan evaporation.

(*ii*) Saturation vapour pressure deficit and maximum temperature (mutually highly intercorrelated) are the two principal factors exerting maximum influence on evaporation.

(*iii*) Relatively less consistent CCs in respect of wind might be due to lack of total linearity in the relationship between wind and evaporation.

(*iv*) Cloudiness, rainy days and temperature range have negligible influence on evaporation.

(*v*) In view of the foregoing this study lends support to the mass transfer method of computing evaporation.

(*vi*) Although the verification of the formulae with actual evaporation during 1969 has been encouraging, their performance in other years requires to be watched.

(*vii*) Further investigation should be directed to the development of a set of constants applicable to broad climatic/geographic regions.

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