

Sunshine and sky cloudiness over Iran

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ABSTRACT. Using data provided by the Iranian Meteorological Organization (IMO) obtained from 36 stations for a period of 11 years (1965-1975), spatial distribution of the averaged monthly relative duration of sunshine over country is studied; also, averaged annual variations of the relative sunshine and sky clearness are investigated for every station, and assuming linear correlation between the two quantities, the regression and correlation coefficients are computed for each of the stations.

It is clearly seen that a major part of the country has relative duration of sunshine less than 60 per cent during half a year (December to May), and more than that in the second half. It is also shown that the country is actually divided into four different regions from sunshine and cloudiness point of view; the southern region is under substantial influence of the monsoon, remaining parts, but the northern area, being only fairly affected. Moreover, the percentage of sky free from cloud is more or less higher than the percentage of the duration of sunshine in summer, and generally, either lower or identical in winter.

1. Introduction

Having a clear picture of the distribution of sunshine in time and space is important for climatological purposes and solar energy utilization.

The relationship between duration of sunshine and amount of cloud is also of great interest, for this can be used in estimating hours of sunshine from observations of the cloud amount in regions where the former is lacking.

Such studies have a long history in the literature, and the present work is mainly indebted to the followings: Rao and Rao (1965), Jagannathan and Ganesan (1967), Rao and Ganesan (1971), Ganesan (1972).

Measurements of sunshine duration were available for a period of 11 years (1965-1975), recorded in 39 stations using Campbell-Stokes recorder : 3 stations are rejected due to obvious unreliability of the data; measurements of the remaining 36 stations are, therefore, taken into consideration, and, where the set of data is incomplete, it is statistically adjusted. Observation of the amount of cloud has been carried out three times daily during 1965 through 1970

and twice a day since then. The names and geographic coordinates of the stations are given in Table 1 (see also Fig. 4).

In the case of Tehran station, where actual daily duration of sunshine is available, percentage of *monthly mean* of daily relative duration of sunshine averaged for each calendar month over the period (Hadjebi 1978) is computed using the formula:

$$100(\overline{n/N}) = \frac{100}{k} \sum_{j=1}^k \left[\frac{1}{m} \sum_{j=1}^m (n/N)_j \right] \quad (1)$$

where,

n = actual daily duration of sunshine,

N = maximum possible daily duration of sunshine,

k = 11, number of years in the period,

m = number of days in a month.

For the rest of the stations, the following formula is utilized :

$$100(\overline{n/N}) = \frac{100}{k} \sum_{j=1}^k \left(\frac{\sum_{j=1}^m n_i}{\sum_{j=1}^m N_i} \right) \quad (2)$$

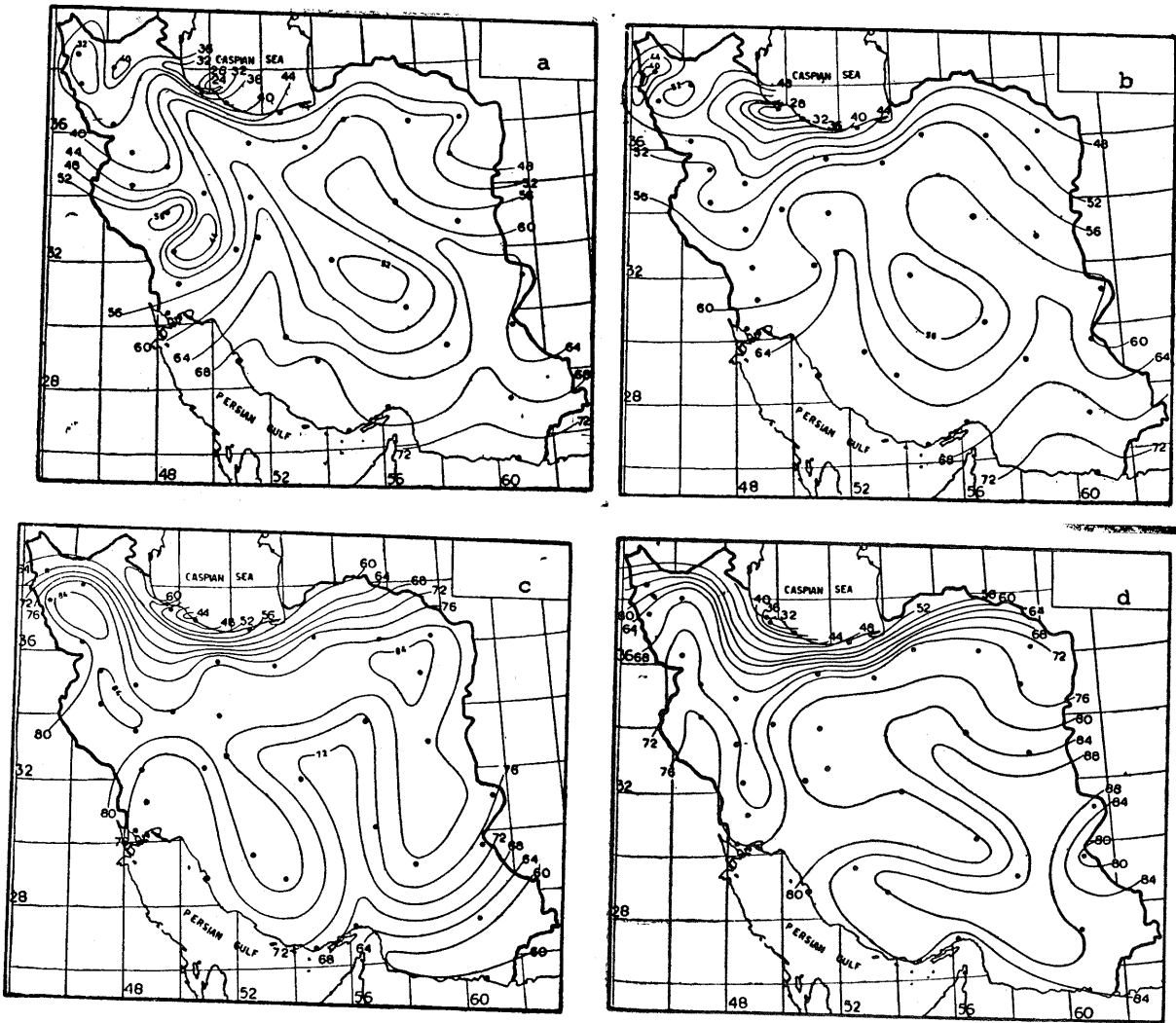


Fig. 1. Isopleth of $100(\bar{n}/\bar{N})$, monthly mean of percentage of sunshine averaged over the period 1965-1975 : (a) January, (b) April, (c) July, (d) October

where,

$$\bar{n} = \frac{1}{m} \sum_{i=1}^m n_i, \text{ monthly mean of } n,$$

$$\bar{N} = \frac{1}{m} \sum_{i=1}^m N_i, \text{ monthly mean of } N.$$

Eqn. (2) gives the percentage of *monthly* relative duration of sunshine averaged for each calendar month over the period.

However, according to an analytical justification (Bani-Hashem 1980), daily n/N averaged over month is approximately equal to \bar{n}/\bar{N} , the difference being of the order of 3 per cent or less. Thus,

$$100(\bar{n}/\bar{N}) \approx 100(\bar{n}/\bar{N}), \quad (3)$$

and, therefore, the term $100(\bar{n}/\bar{N})$ is used in the text and no distinction is made with

$100(\bar{n}/\bar{N})$. Furthermore, monthly mean of daily sky cloudiness averaged for each calendar month over the period is computed using the equation :

$$\bar{C} = \frac{1}{k} \sum_{j=1}^k \left(\frac{1}{m} \sum_{i=1}^m C_i \right) j, \quad (4)$$

where, C is the averaged daily amount of cloud.

2. Distribution of the sunshine and sky cloudiness

The distribution of sunshine over the country during each calendar month has been illustrated by plotting isolines of the averaged percentage of monthly mean of the daily values, $100(\bar{n}/\bar{N})$, superimposed on a simple map of Iran including, in addition, only the reporting synoptic stations; Fig. 1 presents those of January, April, July and October as the *seasonal representatives*.

TABLE 1

Linear regression and correlation coefficients between relative duration of sunshine and sky clearness in every station, arranged in groups, and in each group in decreasing latitudes

No.	Station	<i>a</i>	<i>b</i>	<i>r</i>	No.	Station	<i>a</i>	<i>b</i>	<i>r</i>
<i>Group I</i>									
1	Khoy	0.86	-0.02	0.95	7	Babolsar	0.75	0.11	0.90
2	Tabriz	0.83	0.02	0.96	8	Shahroud	0.59	0.32	0.96
3	Rezaieh (Urmieh)	0.95	0.01	0.95	9	Mashhad	0.76	0.15	0.98
4	Anzali	0.94	0.04	0.96	10	Sabzevar	0.58	0.30	0.96
5	Rasht	0.98	-0.02	0.93	11	Saghez	0.79	0.09	0.95
6	Ramsar	0.85	0.03	0.94	12	Torbat- Heydarieh	0.72	0.16	0.97
<i>Group II</i>									
13	Tehran	0.69	0.23	0.97	19	Khorramabad	0.56	0.25	0.98
14	Semnan	0.76	0.15	0.97	20	Esfahan	0.52	0.36	0.94
15	Sanandadj	0.74	0.17	0.96	21	Dəzful	0.67	0.14	0.94
16	Hamadan	0.79	0.11	0.97	22	Shahr-Kord	0.67	0.22	0.95
17	Kermanshah	0.72	0.17	0.98	23	Abadan	0.52	0.28	0.94
18	Arak	0.71	0.19	0.95	24	Kerman	0.54	0.31	0.87
<i>Group III</i>									
25	Shiraz	0.65	0.27	0.97	28	Bandar-Abbas	0.52	0.30	0.82
26	Fassa	0.56	0.34	0.93	29	Lengeh	0.58	0.27	0.72
27	Iranshahr	0.41	0.40	0.52	30	Chahbahar	0.58	0.28	0.70
<i>Group IV</i>									
31	Tabas	0.49	0.36	0.89	*	Kerman	0.54	0.31	0.87
32	Birjand	0.64	0.22	0.95	35	Zahedan	0.49	0.35	0.95
33	Yazd	0.63	0.21	0.85	36	Bam	0.70	0.20	0.93
34	Zabol	0.66	0.17	0.94					

* : Repeated in G. II.

The percentage of sunshine in *January* (Fig. 1a) is very low (24-40 per cent) on most part of the Caspian coast and in the northwest; it gradually increases southward and reaches the highest value of the month (72 per cent) in the southeast corner, three-fold as high as the lowest in the north. Also, a particular feature of this map is the formation of several ovals produced by the wavy nature of the isopleths in the northwest, west and the large, central desert areas.

The general pattern of the map of *April* (Fig. 1b) resembles that of January to a great extent, and besides vanishing a pair of ovals in the west, the only notable departure from is more or less increase in the amount of sunshine throughout the country, except the south.

The trend of percentage of sunshine in *July* (Fig. 1c) is quite different from those of January

and April. A major part of the country around central latitudes, almost from east to west is mainly enclosed with an isopleth of 80 per cent, including three very high value ovals (84 per cent). Outside this isopleth, excluding a very narrow region around the Caspian Sea and a small area in the southeast corner, the percentage of sunshine is higher than 60 per cent, increasing from both directions, north and south, towards the central latitudes.

It is important to mention that, despite the fact that the level of the percentage of sunshine is, as expected, increased in July, in the southeast corner, however, below the isoline reading 68 (Fig. 1c), it is surprisingly decreased compared to the maps of January and April [Figs. 1(a) and (b)]; that is, the percentage of sunshine in this region in July is even less than that in January. There is more to come on this matter later.

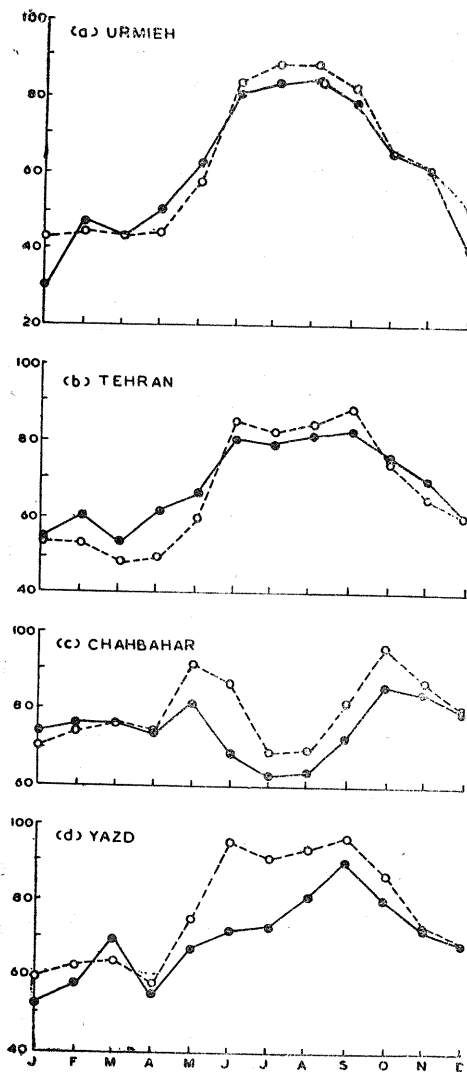


Fig. 2. Annual variation of $100(n/N)$, ●—● and that of $100(1-C)$, ○---○ in the representative stations: (a) Rezaieh; (b) Kermanshah; (c) Chahbahar; (d) Yazd

Although there seems to be quite a similarity in appearance between the maps of October (Fig. 1d) and July, detailed comparison reveals rather pronounced differences. One of these is the existence of a small trough to the west of the Tehran station on the map of July and its development into a much larger one, covering almost the whole western areas in Fig. 1(d). This trough in its latter state, or strictly speaking, the isoline of 76 per cent on the map of October divides the country into two regions, above and below this line. The region above it, which nearly includes the entire northern and western areas, has sunshine less than that in July, (less than 76 per cent), where the region below it, that is, the rest of the country, has a percentage of sunshine higher than 76 per cent, including the observed absolute maximum of the year (88 per cent) on an 8-shaped isopleth in the southwest.

3. Annual variation of the percentage of sunshine and sky clearness

The annual variations of $100(n/N)$ and $100(1-C)$ are studied and classified in four distinct groups. Fig. 2 illustrates sample graphs of these groups, which are briefly described in what follows, where filled circles are the percentage of sunshine and open circles the percentage of clear sky; Roman numerals in brackets immediately following the station names in Table 1 refer to the corresponding groups.

Group I—As representative of Group I, the graphs of the Rezaieh (Urmieh) station are shown in Fig. 2(a); both graphs in this group are approximately normal curves, nearly coincided.

Group II—This group is best represented by the graphs of the Tehran station, shown in Fig. 2(b) with roughly flattened maximum in both graphs in summer. Sky clearness in this group exceeds the percentage of sunshine by, approximately, 10-22 per cent.

Group III—The graphs of the Chahbahar station are given in Fig. 2(c) as representative of this group, where a dip is produced in both graphs in summer which, in some cases, reaches the absolute minimum of the year. The difference between the percentage of sky clearness and sunshine is about 8-23 per cent.

Group IV—There are given in Fig. 2(d) the graphs of the Yazd station, a typical sample of the group. As shown in this figure, the percentage of sunshine has a low gradient and reaches maximum late summer; the percentage of clear sky, however, shows a flattened maximum in this season similar to Group II, and it is higher than the sunshine percentage, particularly, in early summer (10-23 per cent, different stations).

As a result of this classification, the country has been divided into four different regions from sunshine and sky cloudiness point of view (Fig. 4). This is also in good general agreement with the patterns seen on Figs. 1 and 3.

4. Month of maximum and minimum

Fig. 3 illustrates for each of n/N and C and the month(s) of both maximum and minimum in different parts of the country, where the chief points are briefly as follows:

As seen in Fig. 3(a), in general, the averaged monthly mean of daily relative duration of sunshine is maximum during June/July/August in the north and west; it is shifted to September in the central regions, including some parts of the east and southwest, and to October in a major part of the south and southeast, except for the far south along the coast where it is mainly occurred in either May or October and May.

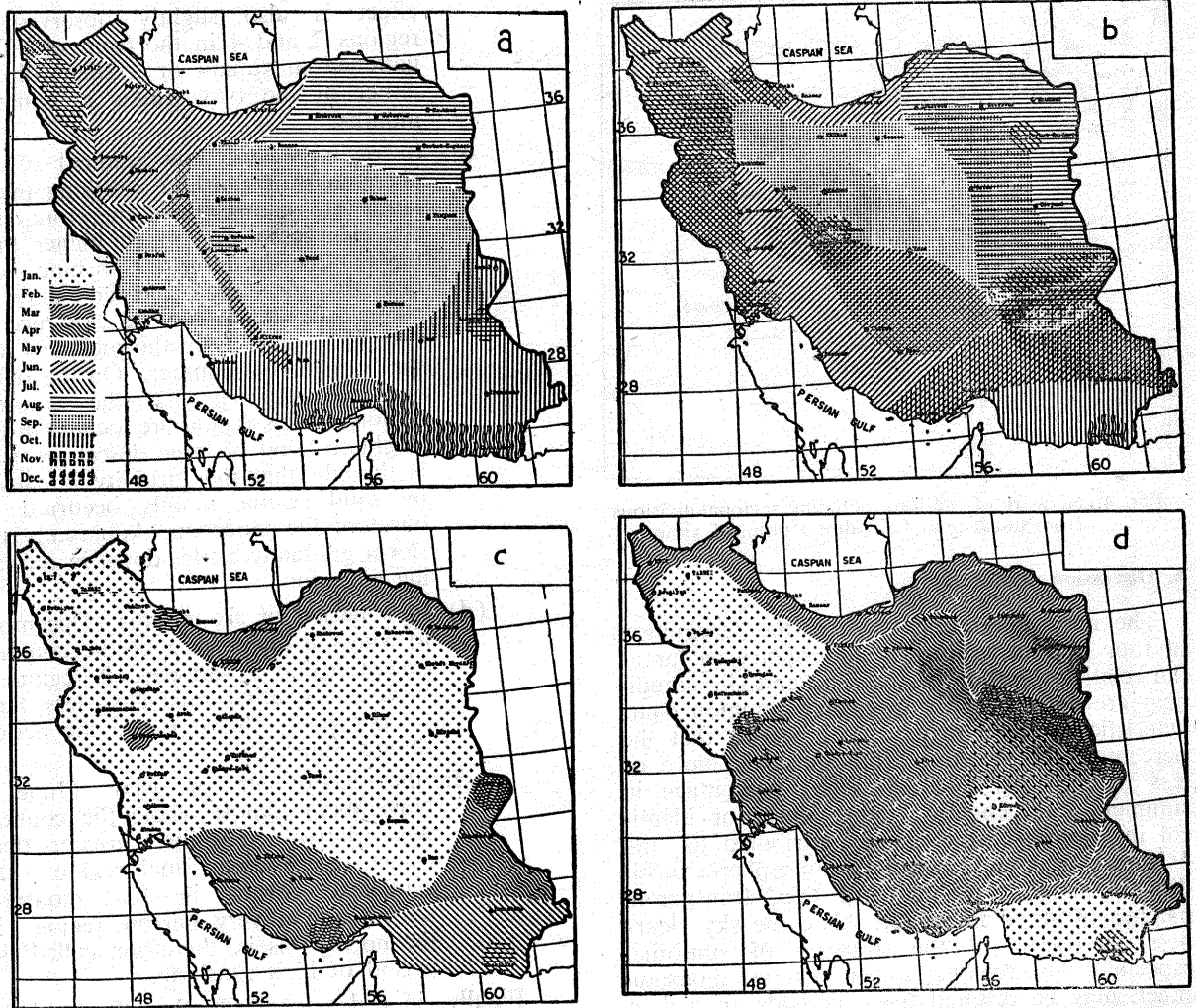


Fig. 3. Month(s) of (a) max. & (c) min. $100 \overline{n/N}$ monthly mean percentage of sunshine and (b) min. & (d) max. \overline{C} monthly mean of cloud amount averaged over the period 1965-1975

Comparing the maps of maximum $\overline{n/N}$ and minimum \overline{C} (Fig. 3b), a close relationship is evident except for, mainly, the southwest where \overline{C} is minimum in June rather than September, a part of the southern regions where \overline{C} is minimum either in October, as is $\overline{n/N}$, or in June and finally, September which is the month of maximum $\overline{n/N}$ in the central regions, on the map of minimum \overline{C} also includes a narrow neck extended towards the northwest and a tail to the southeast.

Fig. 3(c) shows that, in general, minimum $\overline{n/N}$ occurs in January, except for a narrow region in the north which is minimum in March, a region in the south in April, and surprisingly, the southeast corner in the summer month of July. Comparing this to the map of maximum \overline{C} (Fig. 3d), the narrow region in the north where maximum $\overline{n/N}$ occurs in March is extended on the latter map to the northwest

and to the lower latitudes in the northeast; a large area in the central regions shows maximum \overline{C} mainly in April rather than January, and finally, the southeast corner generally reaches maximum \overline{C} in January, recalling that this area has minimum $\overline{n/N}$ mainly six months later, in July.

5. Correlation of the relative duration of sunshine and sky clearness

The relationship between $\overline{n/N}$ and $1-\overline{C}$ has been considered to be of the linear form of:

$$\overline{n/N} = b + a(1-\overline{C})$$

which is previously suggested by Ganesan (1972). The regression coefficients a and b , and the correlation coefficient r are computed for every station and given in Table 1. It is seen that the correlation is high except for the southeast corner stations of region 4 (Fig. 4) where r varies from 0.52 to 0.83,

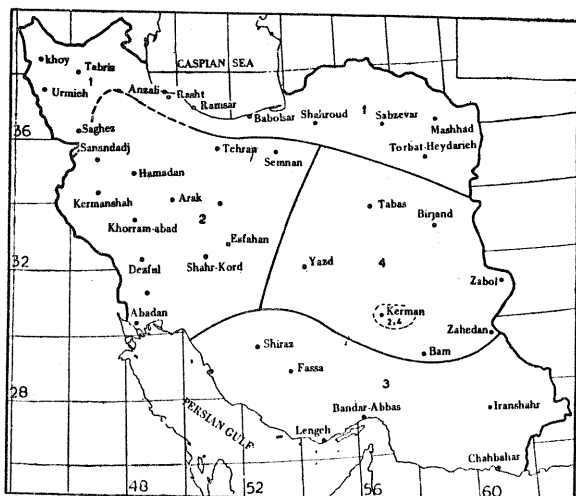


Fig. 4. Network of stations including regional divisions from sunshine and cloudiness point of view

6. Discussion and conclusion

The most interesting result is the recognition of four distinct regions in the country as far as the relative duration of sunshine and sky cloudiness are concerned. A particular common characteristic of these regions is, however, that the percentage of sky free from cloud is more or less higher than the sunshine percentage in summer, and generally, either lower or identical in winter. This is mainly attributed to the existence of some amount of atmospheric turbidity in summer months and thin, transparent patches of cloud in winter. Also, the sky clearness in excess of the duration of sunshine, especially in regions under strong monsoon effect, may be resulted from methods applied in sunshine measurement and cloud observation. The latter is observed only twice a day which may give rise to missing of some clouds possibly existing during a short period of the day, where the same clouds may cause obstruction in receiving sunshine which is measured continuously throughout the day.

Further results of this investigation are briefly stated as follows:

- (a) The nearly coinciding normal curves of the annual variations in region I are accounted for low atmospheric turbidity and for the annual variation of the physical processes responsible for the development of convective clouds.
- (b) Considering that the dip or the V-shaped pattern seen on the graphs of region 3 is also a prevailing climatic feature in India (*see, e.g., Ganesan 1972*), it is concluded that this region is under substantial influence of easterly currents from India, particularly, during the monsoon. Such an

effect is also slightly observed in regions 2 and 4 in the form of either flattened maximum or a slight dip in either of the two graphs in summer months.

- (c) In region 4, the low gradient of the percentage of sunshine reaching maximum late summer, and therefore, the sky clearness being much higher than the relative duration of sunshine, particularly, in early summer, may be taken as evidence for the existence of very high turbidity in the region in late spring to early summer. On the other hand, considering that the synoptic stations in this region are located in the neighbourhood of large desert areas, it is thought that the turbidity is caused by sand storms mainly occurred by onset of the monsoon. Apparently the storm gradually settles down in retreating monsoon.
- (d) In a period of six months (December to May) a major part of the country, except region 3 and part of region 4, receives relative sunshine less than 60 per cent: this is called the period of low sunshine.

In the second half of year (June to November) almost whole the country has relative sunshine greater than 60 per cent except a small region in the southeast corner in the monsoon season and a very narrow region in the north; this is, therefore, called the period of high sunshine.

Finally, in order to clarify the effects of the monsoon, atmospheric turbidity and sand storms, direct investigations are suggested.

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References

- Bani-Hashem, T., 1980, In preparation.
- Ganesan, H. R., 1972, *Indian J. Met. Geophys.*, **23**, 3, p. 395.
- Hadjebi, B., 1978, *Earth & Space Phys.*, **7**, 1, 25.
- Jagannathan, P. and Ganesan, H. R., 1967, *India met. Dep. Sci. Rep.*, **13**, 1.
- Omumi, H., 1978, Thesis (in Persian), Inst. Geophys., Tehran Univ.
- Rao, K. N. and Ganesan, H. R., 1971, *India met. Dep. Sci. Rep.*, **172**, 1.
- Rao K. N. and Rao, D. R. K., 1966, *Indian J. Met. Geophys.*, **17**, 1, p. 17.