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Letters to the Editor

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FOG IN RELATION TO ELEVATION AND TOPOGRAPHICAL FEATURES AT TWO STATIONS IN SIKKIM

1. In plains of India, radiation fog which belongs to the group of cooling fog, is the main type of fog reported by various authors (Rangarajan 1952, Basu 1952, Kundu 1957, Chandiramani 1958, Venkateswara Rao and Mukherjee 1958, Das 1985, Haldar 1986, Haldar and Sreenivasan 1989 and Verma 1989). In hilly regions situated at an average altitude of 1500-2000 m, occurrence of fog is mostly due to influx of moist air and cooling due to ascent along the mountain slope. Unlike winter fog over plains, fog due to low cloud in pre-monsoon and southwest monsoon season is one of the most important weather phenomena over the high ridges in Sikkim. The advection fog is produced by the advection of moist air from the plains of West Bengal over the ridges of Sikkim. The drifting of relatively moist air from the ocean inland over the high ridges produces fog even in the pre-monsoon season. On some occasions low stratus cloud may produce fog only on the ridges and clear air in the valleys. The frequency of occurrence of fog is so high that hardly some days remain free from fog especially during southwest monsoon season.

In hilly region formation of fog is greatly influenced by the altitude of the place. Occurrence of fog over stations situated very close by and even on the same slope of a ridge, differs considerably because of elevation and topographical features.Studies of fog formation in relation to altitudinal variation at stations situated in the eastern Himalayas and Sub-Himalayas have not been done so far. An attempt has been made to study the effect of altitude and topography on variation of fog formation at two stations, *viz.*, Tadong and Gangtok situated on Chola ridge.

2. *Data* — Systematic weather records both for Tadong and Gangtok are available from May 1983. Thus, data for the period from May 1983 to December 1989 have been considered for the study. Minimum temperature, dew point temperature and relative humidity for 0830 IST for some of the no fog and foggy days chosen randomly have been taken.

3. *Geographical position and physical aspects* — Tadong (27° 20′N and 88° 38′E) and Gangtok (27° 20′N and 88° 37′E) are situated in the southern slope of Chola ridge at elevations of 1322 and 1765 m respectively. The Chola range, which forms the eastern boundary of Sikkim is pierced by several passes. It is only in the south that it is not separated by any mountainous feature from West Bengal. Otherwise Sikkim is separated from Nepal, Tibet and Bhutan by way of mountainous walls ranging in height from 3600 to over 9100 m amsl. It is a land of varied elevation ranging from 244 m amsl at the southern foothills to over 9100 m along its northern and northwestern boundaries. It may be viewed as a stupendous stairway hewn out of the western border of the Tibet plateau by glaciers and great rivers and leading down to the Indian plains (Grover 1974).

Meteorological Observatory (M.O.), Gangtok is at an aerial distance of about 4 km and at a vertical height of 443 m from that of M.O., Tadong which is located almost at the bottom of the V-shaped valley whereas M.O., Gangtok is located almost at the top of the same side of the valley. The average distance between the ridges which form the valley is about 5-6 km. The important geographical feature which causes wide variation in the weather phenomena between Gangtok and Tadong is that these ridges join together to form a mountainous wall at a distance of about 3 km from M.O., Gangtok. Another important geographical feature is the Mount Kunchenjunga, the third highest peak in the world which is situated only at an aerial distance of about 50-60 km northwest of Gangtok. The river *Teesta* flows at a distance of about 15 km from these observatories. Being situated in the catchment area of the Teesta, these observatories come under direct influence of southwest monsoon current which penetrates quite far north of Sikkim through the Teesta valley. Being immediately opposite top of the Bay of Bengal, and not screened by intervening hills, Gangtok and Tadong receive the full force of monsoon current from the south.

4. *Fog season* — Unlike plains where fog is mostly experienced in winter months, fog season of Tadong and Gangtok situated in a hilly region is spread

TABLE 1

Monthly frequency of fog over Tadong and Gangtok

	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average number per year	Tadong	1.8	3.5	2.3	2.7	6.4	11.4	20.0	15.4	16.1	5.0	1.6	2.9
	Gangtok	5.5	4.6	4.5	3.5	10.3	17.5	26.8	21.5	21.3	7.9	0.85	3.43

throughout the year. It is more frequently reported during early morning and late afternoon hours of southwest monsoon season. It also occurs in the early morning hours of winter and early morning and late afternoon hours of pre-monsoon months, however, with lesser frequencies.

5. *Frequency of occurrence* — For the period May 1983 to December 1989, Tadong had 614 cases of fog whereas Gangtok had 877 cases for the corresponding period. The average frequency of occurrence of fog varied widely from month to month for both the stations (Table 1). There were only 11 and 6 days (in 7 years) of fog in the month of November whereas July, August and September had 140 & 188, 108 & 151, and 113 & 149 days of fog for the same period respectively at Tadong and Gangtok. Tadong and Gangtok had experienced 71.8 and 69.7% of fog during the southwest monsoon season.

In the coldest months (*i.e.*, December, January, and February) though Gangtok had more cases of fog than that of Tadong, yet at both the places percentage frequency lies between 2 & 4.

After the withdrawal of monsoon from the region there is a sudden decrease in frequency of fog occurrence both at Gangtok and Tadong in October. This can be attributed due to the change in wind pattern from moist southerly to dry northerly wind.

The larger frequency of fog at Gangtok in all the months except in November is presumably due to favourable meteorological conditions as induced by its elevation and topographical features. The monsoon current gets entrapped within the mountain wall near Gangtok. Because of lower temperature and higher relative humidity as induced by higher elevation, occurrence of fog becomes more frequent at Gangtok.

6. *Time of commencement and dispersal of fog* — On maximum percentage (around 70-80%) of occasions fog sets in by 0730 IST. Thus, early morning to 0730 IST can be considered to be the most favourable time for the onset of fog. Both at Tadong and Gangtok, cases of occurrence of fog are also considerably high between 1431 and 1730 IST during pre-monsoon and southwest monsoon months. Except in July and September, Gangtok had more foggy afternoon than at Tadong. In winter months, fog generally forms in the early morning hours. On rare occasions fog forms in the afternoon hours of pre-monsoon and winter months.

The general dissipation time of fog is between 0731 to 1030 and from 1531 to 1730 IST for both the stations. About 60-75% cases of fog dissipated between 0730 and 1030 IST except in January and November when 36 and 90% of cases dissipated by 1030 IST at Tadong. Whereas much lesser percentage (30-47% in southwest monsoon months and 42-70% in the months of other seasons) of fog dissipated between 0730 and 1030 IST at Gangtok. On maximum number of occasions, fog dissipated by 0930 IST at Tadong whereas it was one hour later at Gangtok. It is interesting to note that time period between 1031 and 1530 IST is neither favourable for setting in nor for dissipation of fog at both the stations.

7. *Duration of fog* — The duration of fog is lowest in the month of November whereas it is highest in the southwest monsoon months. The fog lifts sooner at Tadong than at Gangtok. On an average the duration of fog is greater at Gangtok. The maximum frequency lies in the interval 2-4 hours at Gangtok and 2-5 hours at Tadong. The number of occasions when fog lifts within ½ hour is considerably higher at Tadong than at Gangtok. It is also interesting to note that on 25% of occasions fog dissipated in the time interval of ½-2 hours at Tadong whereas for the corresponding time interval it was only 17% at Gangtok. An examination of data shows that on 294 cases out of 614 and on 70 cases out of 877 fog started before 0530 IST at Tadong and Gangtok respectively. Number of occasions, when fog lasted after 1730 IST, is quite high at Gangtok than at Tadong. This may be due to the bowl shaped topographic feature of the upper portion of the ridge which prevents free passage of the air.

8. *Relation between fog and humidity figures and dew point temperature* — Irrespective of seasons on days of fog occurrence, the humidity figures range between 90-95% and 90-98% in winter, 83-96% and 87-98% in pre-monsoon and 90-96% and 94-98% in southwest monsoon season respectively at Tadong and Gangtok. Dew point temperatures, in general, were higher by about 0.5-4°C than minimum temperatures except in some cases when dew point temperature was either same (in southwest monsoon) or lower than that of minimum temperature (in winter and pre-monsoon seasons). Fog became thickest and lasted for about 10 hours when the humidity figure on all those days of fog was very high with values about 95-98%. This clearly indicates that the thickest and longest duration of fog required very high humidity in the atmosphere.

There is a gradual rise in humidity and dew point temperature in pre-monsoon and southwest monsoon seasons than that in winter. Consequent upon the rise in the values of humidity and dew point temperature, occurrence of fog during pre-monsoon and southwest monsoon seasons was comparatively much higher. Because of lower elevation, Tadong had lower humidity and higher values of minimum and dew point temperatures than that of Gangtok. An analysis of the data shows that Gangtok had longer duration and higher frequency of fog compared to that of Tadong. This is attributed due to higher values of humidity and lower values of minimum and dew point temperatures.

For all foggy days the dew point temperature was higher by about 0.0-3.5°C and 0.4-5.0°C respectively at Tadong and Gangtok. Relative humidity was very high due to influx of moisture. Higher values of humidity and dew point temperatures than that of minimum temperature confirm that higher elevation of a place up to certain height (1500-3000 m approx.) plays important role in fog occurrence. Altitudinal effect is expected to be noticed up to a certain height.

9. *Conclusions* — The following conclusions are drawn from the study :

(i) Gangtok had experienced higher frequency, longer duration and thickest fog due to its higher elevation and typical topographical feature.

(ii) For formation of fog of longer duration and thickest nature humidity in the range of 95-98% is favourable.

(iii) Although fog occurs at Gangtok and Tadong in all the months, frequency is highest in southwest monsoon months and least in November.

(iv) For both the stations, morning hours up to 0730 IST are found to be the most favourable for formation of fog whereas fog dissipates mostly by 0930 and 1030 IST at Tadong and Gangtok respectively.

(v) Duration of fog of more than 10 hours duration is more frequent in southwest monsoon months at Gangtok.

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