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# Forecasting of minimum temperature over Gangtok

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**सार** — गंगतोक के न्यूनतम तापमान में दिन-प्रतिदिन के परिवर्तन, अंतर व स्थिरता और वहां शीत लहर एवं प्रचण्ड शीत लहर के आने की अवधि का निर्धारण करने के लिए, 1969 से 1992 के वर्षों के दौरान, नवंबर से मार्च तक पांच माह की शीत ऋतु का अध्ययन किया गया। ओसांक, मेघ मात्रा और एक दिन पूर्व रिकार्ड किए गए अधिकतम व न्यूनतम तापमान के आंकड़ों सहित न्यूनतम तापमान का पूर्वानुमान जारी करने के लिए समाश्रयण मॉडल विकसित किए गए हैं। तापमान के कुल परिवर्तनों का 4/5 भाग ''अल्प परिवर्तन'' और ''कोई परिवर्तन नहीं'' की श्रेणी में आता है। ''लगभग सामान्य'' तापमान बहुतायत में पाया गया जब न्यूनतम तापमान में सामान्य से कुछ अधिक परिवर्तन हुआ। जनवरी और फरवरी में क्रमश: शीत लहर तथा प्रचण्ड शीत लहर की घटनाएं अधिक हुई। यह देखा गया कि तापमान में अधिक परिवर्तन होने से शीत लहरों की प्रतिशत बारम्बारता धीरे-धीरे कम होती जाती है। समाश्रयण मॉडल से नवम्बर से फरवरी तक अच्छे परिणाम मिलते हैं।

**ABSTRACT.** A study has been conducted to assess day-to-day changes, departure and persistence of minimum temperature and the frequency of cold wave and severe cold wave over Gangtok for five winter months, *i.e.*, November-March for the years 1969 to 1992. Regression models have also been formulated to forecast minimum temperature with the knowledge of dew point, cloud amount, maximum temperature and minimum temperature recorded on previous day. In case of changes, 'little change' and 'no change' constitute about four-fifth of total changes. The cases of 'nearly normal' were found maximum when departure of minimum temperature from normal was considered. Frequency of cold wave and severe cold wave has been recorded more in January and February respectively. It has been observed that there is a gradual fall in the percentage frequency with the increase in the magnitude of variation. Regression model gives good results from November to February.

**Key words** — Minimum temperature, Persistence, Forecasting, Regression, Parameters.

## 1. Introduction

Gangtok is the main hill station of Sikkim which has become a major centre of tourist activities in recent years. Hazards of low temperature, like, frost and cold wave are a recurring problem during winter season. Hence, forecasting of minimum temperature during winter months will be of immense benefit to the public, farming community and tourism industry, in particular. When the departure of minimum temperature is 3°C to 4°C below normal, situation is described as cold wave and when departure is 5°C or more below normal, it becomes a severe cold wave as normal minimum temperature of station remains almost below 10°C.

Narasimhan and Ramdas (1937) investigated the possibility of predicting minimum temperature by statistical methods using maximum temperature and vapour pressure recorded on the previous afternoon. Raghavan (1967). Subbaramayya and Surya Rao (1976) studied in detail the occurrence of heat and cold wave that prevailed over Indian subcontinent.

The best way to improve the accuracy of local forecast is to study the behaviour of changes in minimum temperature over the station. Further, an attempt has been made to forecast minimum temperature over Gangtok with the knowledge of dew point, cloud amount, minimum temperature and maximum temperature recorded on previous day using statistical technique.

## 2. Material and methods

Daily minimum temperature data of Gangtok from 1969 to 1992 for the months of November, December, January, February and March have been considered for the present study. Changes in the minimum temperature were calculated with respect to previous day's value and classified

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TABLE 1

**Percentage variation of changes of minimum temperature under different magnitude scales**

| Month | No change (0) | Little change (−1) | Fall (−2) | Appreciable fall (−3 to −4) | Marked fall (−5 to −6) | Rise (+2) | Appreciable rise (+3 to +4) | Marked rise (+5 to +6) |
|---|---|---|---|---|---|---|---|---|
| November | 38.8 | 48.5 | 5.4 | 2.0 | 0.0 | 4.9 | 0.4 | 0.0 |
| December | 36.1 | 51.6 | 4.6 | 1.5 | 0.3 | 5.0 | 0.7 | 0.2 |
| January | 32.9 | 49.4 | 6.3 | 2.1 | 0.0 | 7.9 | 1.4 | 0.0 |
| February | 33.5 | 44.9 | 8.7 | 2.0 | 0.3 | 8.1 | 2.5 | 0.0 |
| March | 28.6 | 47.3 | 5.1 | 4.5 | 0.0 | 9.7 | 4.5 | 0.3 |

TABLE 2

**Percentage number of cases of departure of minimum temperature of varying steps over Gangtok**

| Month | No change (0) | Nearly normal (−1) | Below Normal (−2) | Appreciably below normal (−3 to −4) | Markedly below normal (−5 to −6) | Above normal (+2) | Appreciably above normal (+3 to +4) | Markedly above normal (+5 to +6) |
|---|---|---|---|---|---|---|---|---|
| November | 21.3 | 41.8 | 9.0 | 14.5 | 3.4 | 6.2 | 3.8 | 0.0 |
| December | 20.9 | 41.7 | 11.2 | 15.2 | 3.3 | 5.4 | 2.3 | 0.0 |
| January | 20.7 | 37.3 | 9.7 | 18.3 | 1.9 | 7.0 | 4.1 | 1.0 |
| February | 16.7 | 35.1 | 13.9 | 13.3 | 3.5 | 8.9 | 8.1 | 0.5 |
| March | 18.4 | 36.8 | 9.3 | 8.8 | 2.8 | 13.3 | 10.0 | 0.6 |

according to their magnitude based on the standard meteorological convention. Daily departure of minimum temperature from normal was also computed as per meteorological convention for all the winter months of 24 years and the values for individual months were tabulated in percentage.

The persistence of a particular phenomenon for a number of days is another parameter which is important from forecasting point of view. The change in the trend of this parameter has been classified into three categories. *viz*.. no change. fall or rise. Fall includes the cases where next day's value is lower than previous day by 1°C or more. The number of days for which one type of change occurred is counted as unit. The whole data were analysed for individual days on this principle and results were classified as percentage number of continuous days on which minimum temperature either does not change or falls or rises continuously.

The daily data were also analysed to find out total number of cold wave and severe cold wave cases in each month as per criteria given by India Meteorological Department.

Minimum temperature reveals some kind of persistence. so it can be forecast by statistical techniques. Linear multiple regression model of the form has been developed using previous day's meteorological parameters from 1981 to 1992 as given below :

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 \qquad (1)$$

The different parameters of the model could be denoted as.

TABLE 3

**Percentage number of cases of no change, fall and rise that last for one day or more**

| Month | Number of days | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | | | | **No change** | | | |
| November | 17.6 | 8.3 | 3.5 | 2.3 | 0.6 | 0.2 | — |
| December | 21.4 | 6.2 | 2.9 | 0.8 | — | — | 0.2 |
| January | 20.8 | 6.6 | 2.0 | 0.4 | 0.2 | 0.2 | — |
| February | 20.6 | 7.4 | 1.5 | 1.3 | 0.7 | — | — |
| March | 20.4 | 5.4 | 1.3 | 0.4 | — | 0.2 | — |
| | | | | **Fall** | | | |
| November | 28.3 | 6.4 | 1.4 | 0.6 | — | — | — |
| December | 30.1 | 6.4 | 1.3 | 1.0 | — | — | — |
| January | 27.5 | 5.4 | 0.7 | 0.5 | — | — | — |
| February | 23.8 | 7.6 | 0.9 | 0.2 | — | — | — |
| March | 25.8 | 5.4 | 1.5 | 0.4 | — | — | — |
| | | | | **Rise** | | | |
| November | 26.5 | 3.7 | 0.6 | — | — | — | — |
| December | 24.9 | 5.4 | 0.4 | — | — | — | — |
| January | 26.8 | 7.8 | 1.1 | — | — | — | — |
| February | 25.3 | 8.2 | 1.9 | 0.4 | 0.2 | — | — |
| March | 24.7 | 12.0 | 1.3 | 1.0 | 0.2 | — | — |

$Y$ — Forecast minimum temperature.

$X_1$ — Dew point.

$X_2$ — Maximum temperature.

$X_3$ — Minimum temperature.

$X_4$ — Cloud amount.

$a$ — Intercept.

$b_1, b_2, b_3, b_4$ — Regression coefficients.

Keeping in view the need of sufficient time for protective agricultural operations, general regression model and regression models for individual months from November to March have been developed to forecast next day's minimum temperature at 0300 UTC of today with the knowledge of dew point (0300 UTC), cloud amount (0300 UTC), minimum temperature (0300 UTC) and maximum temperature (1200 UTC) of previous day. Each parameter has been given equal weightage. As wind remains calm most of the times, this parameter has been omitted from the model. The accuracy of forecast minimum temperature was tested for all the months of twelve years.

### 3. Geographical position and physical aspects

Severe winter in the hilly terrain of Sikkim, which is surrounded by high mountainous ranges all around except in south, is not directly linked with the eastward passage of western disturbances. Even the flow of cold winds from mid-latitudes during the passage of these disturbances is not experienced in the State because of high mountains along its northern and western periphery. Gangtok (27°20'N, 88°37'E and 1765 m asl) is situated on the Chola ridge in the southeastern part of a narrow oblong tract in the southeastern Himalayas and sub-Himalayas. Because of its peculiar and isolated geographical position, winter over Gangtok under similar weather condition is somewhat unique and different from that reported in other hilly terrains of the Himalayan ranges (Grover 1974). The departure of minimum temperature from normal is mostly due to local weather condition prevailing over the station and due to nocturnal cooling under clear sky (Samui and Gupta 1992).

### 4. Results and discussion

#### 4.1. *Day-to-day changes of minimum temperature*

The percentage of changes of minimum temperature over Gangtok for different months averaged over twenty four years, from 1969 to 1992 are depicted in Table 1. The cases of little change were found maximum in all the months representing approximately one-half of total changes. The highest value was recorded in December (51.6%) and the lowest one in February (44.9%). On an average, the cases of no change were found one-third of total changes in all months representing maximum value in November (38.8%) and minimum in March (28.6%). The cases of little change and no change together constituted about four-fifth of total changes in each month reporting the highest value in December (87.7%) and the lowest in March (75.9%). The third place has been occupied by rise in December, January and March and by fall in November and February. Fall was found maximum in February and minimum in December. Rise gradually increased from November to March. Appreciable rise also followed the same pattern as that of rise. Appreciable fall was recorded more in March (4.5%) and less in December (1.5%). Marked fall and marked rise were found either nil or negligible in different months.

TABLE 4

Frequency of cold wave and severe cold wave at Gangtok (1969-1992)

| Month | Cold wave | Severe cold wave |
|---|---|---|
| November | 84 | 21 |
| December | 103 | 22 |
| January | 134 | 15 |
| February | 96 | 29 |
| March | 61 | 16 |

#### 4.2. *Departure of minimum temperature*

The percentage number of cases of departure of minimum temperature from normal for different months are given in Table 2. The cases of nearly normal were found maximum in all the months varying from 35.1% to 41.8%. The second place was occupied by no change in all the months representing the highest value in November (21.3%) and the lowest in February (16.7%). Both nearly normal and no change decreased from November to February and increased in March. On an average, appreciable below normal and below normal occupied third and fourth place respectively. There was no pattern in below normal case but appreciable below normal increased from November to January and then started decreasing. Both above normal and appreciable above normal showed increasing trend from December to March. The cases of markedly below normal were found maximum in February (3.5%) and minimum in January (1.9%). Markedly above normal was recorded nil in November & December and negligible in other months. There were only three instances in 24 years when departure of minimum temperature was recorded more than 6°C (−6.5°C, −6.6°C, −6.7°C).

#### 4.3. *Continuous trend of same type of variation*

Table 3 shows percentage number of continuous days by which minimum temperature either does not change or fall or rise continuously. For all the three types of changes and for all the five months, the value gradually decreases with increase in number of days. Changes that persisted for one day were found in about 72% of the cases, *i.e.*, about 20% in case of no change and about 26% each in fall and rise categories. On an average, about 20% of the cases were recorded for the changes lasting for two days. The value was about

TABLE 5

**Models for forecasting minimum temperature**

| Month | Model | SD of forecast minimum temperature | | | | |
|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Nov | Dec |
| All five months | $Y = 1.116 + 0.078X_1 - 0.027X_2 + 0.901X_3 - 0.159X_4$ | 1.06 | 1.15 | 1.34 | 0.86 | 0.93 |
| January | $Y = 1.267 + 0.149X_1 - 0.044X_2 + 0.871X_3 - 0.199X_4$ | 1.05 | | | | |
| February | $Y = 1.645 - 0.027X_1 - 0.043X_2 + 0.938X_3 - 0.145X_4$ | | 1.13 | | | |
| March | $Y = 2.263 + 0.081X_1 + 0.034X_2 + 0.824X_3 - 0.174X_4$ | | | 1.33 | | |
| November | $Y = 1.435 + 0.069X_1 - 0.056X_2 + 0.905X_3 - 0.146X_4$ | | | | 0.85 | |
| December | $Y = 1.250 + 0.075X_1 - 0.046X_2 + 0.908X_3 - 0.178X_4$ | | | | | 0.93 |

$Y$ — Forecast minimum temperature, $X_1$ — Dew point (0300 UTC), $X_2$—Maximum temperature (1200 UTC of previous day), $X_3$ — Minimum temperature (0300 UTC), $X_4$ — Cloud amount (0300 UTC), SD — Standard deviation.

92% when changes lasting for one or two days for all the months were taken together. The changes persisting for one and two days were found more in fall and rise respectively. The changes that last for three and four days showed a higher no change as compared to rise and fall. Changes persisting for five days were recorded a few for no change and rise and nil for fall. There were no cases of rise and fall for the changes lasting for more than five days. Hence, the continuous fall of temperature not lasting for more than four days may be considered beneficial for forecasting the changes in minimum temperature.

4.4. *Cold wave and severe cold wave*

Frequency of cold wave and severe cold wave from 1969 to 1992 over Gangtok for November, December, January, February and March is given in Table 4. Maximum number of cold wave cases were recorded in January (134) and minimum in March (61). However, severe cold wave cases were found highest in February and lowest in January.

4.5. *Models for forecasting minimum temperature*

General regression model and regression models for individual months from November to March and verification of forecast minimum temperature have been reported in Table 5. In all the regression models formulated, parameter $X_3$, *i.e.,* the minimum temperature recorded at 0300UTC shows maximum influence on the forecast value expressed by its high regression coefficient of the order of 0.9. The relationship appears quite obvious due to persistence effect of local weather condition and especially in the absence of wind at the station. The other important parameter is the cloud amount which contributes negatively. The effect of this factor (recorded at 0300 UTC) is quite clear as more the clouds during day time, lesser the solar radiation and consequently lower the next day's minimum temperature. Dew point and maximum temperature have small effect as compared to above two parameters which is evident by the smaller magnitude of their respective coefficients. Verification of forecast minimum temperature shows that the model is suitable for forecasting minimum temperature for November [Standard deviation (SD) : 0.86], December (SD : 0.93), January (SD : 1.06) and February (SD : 1.15). However, the model does not give satisfactory results for March which may be due to influence of other meteorological factors during transition period.

There is no significant improvement in the accuracy of forecast minimum temperature when separate regression models for individual months are used and verified (Table 5).

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