Letters to the Editor

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AN OBJECTIVE METHOD OF FORECASTING THUNDERSTORM OVER SANTACRUZ (BOMBAY)

1. The meteorologist has to forecast the anticipated occurrence of thunderstorm to issue TREND forecast and air-field warning in advance to caution the pilots. This forecast has to be issued at a very short notice with the available data and sometimes he cannot wait for the charts to be plotted and analysed in view of the urgency to issue forecast. Under this situation, an objective method will help the forecaster to issue the forecast. Freeman (1962) defined the objective method of forecasting as the one which calls for no judgement on the part of the forecaster. This forecast will remain the same if the same data is given to two different forecasters who may not be knowing the topography of a place. In other words, the question of subjectivity is ruled out in this method. The objective method of forecast depends on the production of diagrams or formulae. In the case of the production of diagram, the line of best fit has to be rigidly defined and which in turn involves the subjectivity of the analyst. As such, substituting the value of the variables in the formula (prediction equation) is considered as the quick and easy method of forecast. The present study has been made to find out a "discriminant function" to forecast thunderstorm over Santacruz (Bombay). The forecast was tested with an independent data set and the results are discussed.

2. The thunderstorm (TS) frequency as per climogram of Santacruz (1931-60) is as under :

May — 1, June — 5, July — 1, August — 0, September — 3, October — 3 and November — 1.

The RS/RW (TEMP) data of Santacruz, for the period May to November (barring August) from 1984 to 1992, is used as the developmental data and that pertaining to 1993 is reserved as the independent/test data. The radar reports for the same period have also been used. For this purpose. the thunderstorm frequency is defined as follows :

(*i*) recording of lightning/thunder by the current weather observation at the Meteorological Office, Santacruz and/or

(*ii*) sudden increase in wind speed by more than 10 knots for a considerable duration (other than gusts) and/or

(*iii*) radar report showing cumulonimbus (Cb) cloud top 6 km and above within 50 km radial distance of Santacruz.

3. A critical analysis is done on the frequency of thunderstorm as defined above and the average frequency of thunderdays has been worked out and shown in Table 1. The high incidence of thunderstorm days occurs during the month of June followed by October. It is also noticed that evening thunderstorm frequency predominates over the other periods. During June, the weak westerly winds prevail upto 600 hPa and easterlies set beyond 500 hPa. During July, August and September, strong westerlies prevail in the lower levels of the atmosphere. During the month of October, light or variable wind of speed less than 3 kt prevailed upto 500 hPa and easterlies aloft. On all the thunderstorm days, it is found that strong windshear exceeding 200×10^{-4} per second exists upto 300 m height from the ground level and the shear gets diminished rapidly with height and becomes negative beyond 1500 m height.

3.1. The existing methods of forecasting thunderstorm from the computation of Total Total Index (TTI), George's stability index, Showalter's lifted index and SWEAT index (1992) could correctly forecast the occurrence of thunderstorm over Santacruz upto a maximum of 60% of the cases with over and under warning in more than 40% of cases. As such, the above methods are not found

TABLE 1

Average frequency of thunderstorm days (1987-93)

Month	Time (UTC)			
	00-06	06-12	12-18	18-24
June	1.0	3.0	4.0	2.0
July	1.0	2.0	1.0	1.0
August	1.0	0.5	1.0	0.0
September	1.25	1.25	2.0	0.0
October	1.50	1.75	2.0	1.0

TABLE 2

Verification of objective method (1993)

Forecast / Observed	TS	No TS	Total
TS	70	19	89
No TS	6	16	22
Total	76	35	111

TS — Thunderstorm   Skill score = 0.42

suitable for forecasting TS over Santacruz. The thermodynamical parameters, such as, dry bulb temperature, dew point temperature, dewpoint depression, lifting condensation level (LCL) at various pressure levels, level of free convection (LFC), freezing level (FL) and height of FL over LFC and the lapse rate (LR) were analysed critically to find out the correlation/association between those parameters and the possibility of TS over Santacruz by employing statistical techniques, like probability analysis, association of attributes and correlation analysis.

3.2. A diagnostic analysis of TS days over Santacruz suggests that there is a strong positive association between 850 hPa dewpoint depression (DD) of less than 3°C and TS in 80% of the cases. Also, in about 70% of the TS days the LFC was seen in the range 850 ± 50 hPa. These facts suggest that 850 hPa DD may be a predictor for the occurrence of TS. Based on the association of FL (on an average 560 hPa during the period of study), moisture confinement, reversal of winds into easterlies aloft 500 hPa and very weak divergence between 600 and 550 hPa with the formation of TS, 600 hPa dry bulb temperature is taken into consideration and the LR between 850 hPa and 600 hPa is selected as another predictor to forecast TS as it has relatively high correlation coefficient.

3.3. The technique of determining a "discriminant function" as suggested by Panofsky and Brier (1958) is used to predict the occurrence of TS. The method is detailed below:

The discriminant function is defined as:

$$L = b_0 + b_1 X_1 + b_2 X_2 \qquad (1)$$

The data set is grouped into two units in such a way that group 1 contains the data of predictors $\{X_1, X_2\}$ when the predictand has occurred and group 2 contains the data of the same predictors denoted by primes $\{X'_1, X'_2\}$ when the event did not occur. Denoting the average values of group 1 and group 2 as $\overline{L(1)}$ and $\overline{L(2)}$ respectively, the coefficients of b_1, b_2 are to be obtained by maximizing the quantity,

$$\left\{ \frac{\overline{L(1)} - \overline{L(2)}}{S_L} \right\}^2$$

where, S_L is the standard deviation of L estimated from pooling the sum of squares computed within each group. The constant b_0 is determined so that the relation $L = 0$ defines the point of separation between group 1 and group 2. The positive value of L indicates group 1 (the predictand is sure to occur) and the negative value of L indicates group 2 (the predictand will not occur).

On simplifying b_1, b_2 can be obtained by solving the equations,

$$b_1 \overline{x_1^2} = b_2 \overline{x_1 x_2} = (N_1 N_2 d_1)/(N_1 + N_2)^2 \qquad (2)$$

$$b_1 \overline{x_1 x_2} + b_2 \overline{x_2^2} = (N_1 N_2 d_2)/(N_1 + N_2)^2 \qquad (3)$$

where, small case letters x_1, x_2 are departures from respective means, i.e., $\{x_1\} = \{X_1\} - \overline{X}_1$; $\{x_2\} = \{X_2\} - \overline{X}_2$.

N_1 and N_2 are the number of cases in group 1 and 2 respectively.

$d_1 = \overline{X}_1 - \overline{X}'_1$; $d_2 = \overline{X}_2 - \overline{X}'_2$ (bar denotes mean).

$\overline{x_1 x_2}$ is computed for the entire $(N_1 + N_2)$ number of cases.

Considering X_1 as 850 hPa DD and X_2 as the lapse rate between 850 and 600 hPa and taking group 1 as those events when lightning/thunder were observed or Cb cloud top of 6 km height and above as reported by radar report. Group 2 lists all other cases. The discriminant function thus obtained is:

$$L = 1.27 - 0.982 \ (DD_{850}) + 0.419 \ (LR_{850-600}) \qquad (4)$$

where, DD_{850} is the dew point temperature at 850 hPa and $LR_{850-600}$ is the LR between 850 and 600 hPa. This function is said to have the property that the straight line in the (X_1, X_2) plane given by $L = 0$ best discriminates between the two alternatives, viz., group 1 (TS is sure to occur) and group 2 (TS will not occur). The equation was tested with an independant data set and the results are tabulated (Table 2). This method could correctly predict the occurrence of TS in 79% of cases and has a skill score of 0.42. This method is quite simple and the forecast can be issued within 10 minutes from the receipt of the TEMP data and hence suitable for issuing the local/TREND forecast in respect of Santacruz airport.

References

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