A few values of K which do not fit in may be due to the absence of favourable conditions of instability in the atmosphere at that time.

Examination of Table 3 shows the relationship between the millibaric height difference of convective condensation level (CCL) and freezing level (FL) to the frequency of occurrence of thunderstorm. This method was developed by Legg (1948) and Tillotson (1951). The present study corroborates their findings that when the difference between CCL and FL is greater, the chances of occurrence of thunderstorms are more.

The values of the compound probabilities have been shown in Table 4 after computing them by taking the values of S. I. and K simultaneously. The values of these two parameters have been plotted in the base and five times the compound-probability percentage depicted in three dimensional diagram in Fig. 2.

5. It is very clear from the Tables 1, 2 and 3 that the occurrence of thunderstorms mostly takes place in the afternoon or in the early part of night at Srinagar and its neighbourhood.

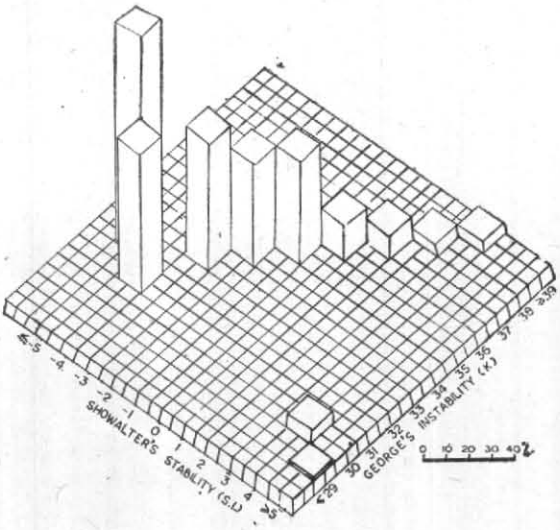

Fig. 2. Three dimensional diagram giving compound probability percentage of thunderstorms at Srinagar. Vertical axes : the heights of the parallelopiped are the functions of heights.

6. The authors wish to express their sincere thanks to Shri Ranjit Singh for his valuable guidance. They are also very much thankful to the staff of Meteorological Centre, Srinagar for their valuable help in preparing the diagrams and going through the manuscript.

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13 May 1975

REFERENCES

George, J. J.	1960	*Weather Forecasting for Aeronautics.*
Legg. E. M.	1948	*Monuscript, W.B.O., Denver.*
Showalter, A. K.	1953	*Bull. Am. met. Soc.*, **34**, 6, p. 250.
Tellotson, Kenneth C.	1951	*Mon. weath. Rev.*, **79**, 2, pp. 27-34.

551.508.21 ; 551.521

A COMPARATIVE STUDY OF THERMISTOR RESPONSE BETWEEN GROUND AND 80 KM

1. While investigating the suitability of an indigeneous microbead thermistor as a temperature sensor for meteorological rocket payload, comparative study of the time constants of the microbead thermistor*, a bead thermistor used in laboratory tests and a rod thermistor used in the IMD radiosonde, was conducted.

2. The time constant of the thermistor can be defined as the time taken by the thermistor to come to an equilibrium with 63.2 per cent of the change in the ambient temperature.

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*Developed by M/S Tempo Industrial Corporation, Bombay

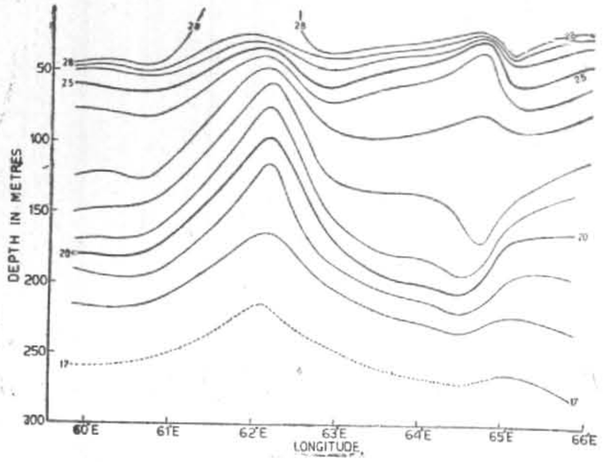

Fig. 1. Vertical distribution of temperature (°C) along the 10°N zonal section in May 1973

The time constant T is given by

$$T = \frac{M_t\, C_t}{S} \tag{1}$$

where, M_t is the weight of the thermistor, C_t is the specific heat at constant temperature and S is the dissipation factor of the thermistor. M_tC_t is called the heat capacity of the thermistor.

From Eq. (1) it is seen that by keeping the heat capacity of the thermistor constant, one can increase S and achieve a smaller time constant. S is expressed as :

$$S = 4\, \sigma\, A_t\, T_e^3 + \frac{2K\beta}{X} + h_t\, A_t \tag{2}$$

where, σ— Stefan Boltzmann constant ($=1\cdot38\times10^{-12}$ cal cm^{-2} sec^{-1} K^{-1}), A_t—surface area of thermistor, K—thermal conductivity of lead wires ($=\cdot074$ cal cm^{-1} sec^{-1} K^{-1}), β—cross sectional area of lead wires$=1\times10^{-5}$ cm^2 (for bead thermistor), X—length of lead wires, h_t—convective heat transfer coefficient and T_e— environmental temperature.

The first term of R.H.S. in Eq. (2) gives the rate of energy transfer per degree Kelvin by long wave radiation. It depends upon the area of the thermistor and the environmental temperature. The second term gives the heat transfer rate per degree Kelvin due to conduction along the thermistor leads. This term will contribute more if X, the lead length, is decreased, but minimum length of lead has to be allowed so as to connect the thermistor to binding posts. Thermal conductivity remaining constant, β the cross-section of the wire, can be made thinner. But again this is limited by the fact that it has to withstand the vibration of the rocket to the order of 100 to 2000 c/s. Third term gives the rate of heat transfer per degree Kelvin by forced convection.

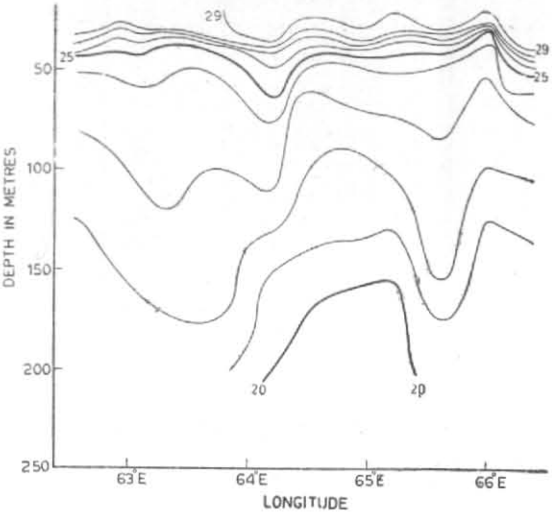

Fig. 2. Vertical distribution of temperature (°C) along the 20°N zonal section in June 1973

3. All calculations are carried out assuming atmosphere as continuum upto 80 km, instead of dividing it into three regions, namely, continuous region, slip region and molecular region. By such an assumption, a maximum difference of only 10 per cent on the positive side, is likely in the value of the time constants. Hence, for a simplified calculation, atmosphere is considered as a continuum.

In Eq. (2) all quantities except h_t are known. They are either physical constant of thermistor or atmosphere. Thus, h_t is computed for various levels and dissipation factor is calculated . All atmospheric constants are taken from 1962 ARDC model of U.S.A.

$$R_e = \frac{\rho\, d\, v}{\mu}$$

where, d=diameter of thermistor; v=fall velocity of thermistor, *i.e.*, of parachute which the thermistor along with payload descends; μ=viscosity and ρ=atmospheric density.

Fall rate of the parachute was observed in the field. The parachute was taken 200 metres up by a balloon and detached to have a free fall along with a dummy payload. Fall rate was found out knowing the height accurately with the help of theodolites. This fall rate was extrapolated upto 80 km. The fall rate is compared (Fig. 1) to that of Wagner (1961).

The parachute has the following parameters : Radius = 200 cm; area = $1\cdot46\times10^4$ cm^2; C_d (drag coefficient) = $1\cdot5$ and weight = 600 gm.

In the calculation of rod thermistor the ascent rate of a balloon was considered with free lift of $2\cdot5$ kg.

Then, using Reynold's number, Prandtl number is calculated by

$$P_r = \frac{C_p \mu}{R_e}$$

This in turn, is used in the calculation of the Nusselt number given by

$$N_u = 2 + 0{\cdot}37 \, (R_e)^{0.6} \, (P_r)^{1/3}$$

Finally the convective heat transfer coefficient is given by

$$h_t = \frac{N_u \, K}{d}$$

where d=diameter of thermistor and K=thermal conductivity of air.

It is logical to assume that there does not exist any temperature gradient in the thermistor itself. Knowing the convective heat transfer coefficient h_t and the dissipation factor, the time constants are calculated from Eq. (1).

Physical parameters of the thermistors are as follows :

Type	*Weight*	*Area*
Microbead	·3 milligram	$2{\cdot}8\times10^{-3}$ cm^2
Bead	2·2 milligram	$1{\cdot}5\times10^{-2}$ cm^2
Rod	196 milligram	$1{\cdot}367$ cm^2

Fig. 2 gives time constants in the form of a graph. A slight decrease in the value of time constants between 40 and 60 km is due to the sudden increase in the thermal conductivity values. Thus the microbead thermistor is far superior to the bead thermistor. The time constant of the thermistor can be still reduced by mounting the thermistor on a mylar film, thus increasing its heat capacity. This way, the time constant can be reduced to 50 per cent. Knowing time constant, other atmospheric corrections can be easily calculated.

5. Thanks are due to Mr. H. Mitra who encouraged this work and under whose guidance payload work is being carried out.

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REFERENCE

Wagner, N. K. 1961 *J. Met.*, **18**, pp. 606-614.