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# Will it be duststorm or thunderstorm today ?

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**सार** — इस अध्ययन में ग्वालियर में मानसून-पूर्व ऋतु के दौरान अंधड़ या अंधड़ के बाद गर्ज के साथ बौछारों के प्रागनुमान के लिए एक सुस्पष्ट तकनीक विकसित करने का प्रयास किया गया है। ऐसे दिनों का जब अंधड़ आया और ऐसे दिनों का जब गर्ज के साथ तूफान आया, दो माध्य 0000 यू० टी० सी० टीफाइग्राम्स प्रस्तुत किए गए। अंधड़/अंधड़ के बाद गर्ज के साथ बौछारों वाले दिनों का गर्ज के साथ तूफान वाले दिनों से, 0000 यू० टी० सी० सतह और टैम्प आंकड़ों में अंतर पर प्रकाश डाला गया। ग्वालियर में अंधड़ के आंकड़ों का, दिशा, समय, पाक्षिक और घटना की आवृत्ति के महीने के संबंध में, सांख्यिकीय विश्लेषण भी किया गया। अंधड़ के कारण चंडवात की अधिकतम झोंका गति (पी० जी० एस०) के प्रागनुमान के लिए एक समाश्रयण समीकरण बनाया गया।

**ABSTRACT.** Attempt to develop a distinct technique for the prediction of duststorm or duststorm followed by thundershower during pre-monsoon season over Gwalior, has been made. Two mean 0000 UTC tephigrams have been produced for the days when the duststorms and thunderstorms occurred. Difference is highlighted in the 0000 UTC surface and TEMP data on the days of duststorm/duststorm followed by thundershower with those on the days of thunderstorm. Statistical analysis of the duststorm data over Gwalior has also been carried out with respect to direction, time, fortnight and month of occurrence of the event. For prediction of peak gust speed (PGS) of squall due to duststorm a single regression equation has been developed.

**Key words** — Duststorm, Thunderstorm, Peak Gust Speed.

## 1. Introduction

At present there is no distinct method for forecasting only duststorm or duststorm followed by thundershowers. Bhalotra (1954) first attempted to differentiate the duststorm and thunderstorm based on the humidity contents. But he did not find any difference in the atmospheric humidity content on the days of occurrence of the two phenomena.

At Gwalior during pre-monsoon season all the three weather phenomena, *e.g.,* thunderstorm, duststorm or duststorm followed by thundershower are observed. Present study is a maiden attempt to distinctly identify the atmospheric characteristics which lead to duststorm or thunderstorm over Gwalior. For the purpose of our study we have included duststorm followed by thundershower under the category of duststorm only. Since the phenomena mostly occur towards afternoon hours hence the study is based on the analysis of 0000 UTC Tephigram of Gwalior and 0000 UTC surface chart. Results thus obtained could be, therefore, used in aid of prognosis of these phenomena.

## 2. Data used

Seventeen years of duststorm and thunderstorm data, between 1976 to 1992, were extracted from the current weather register of Gwalior for the months of March, April, May and June. 35 tephigrams (0000 UTC) for the days of duststorms and 35 for the days of thunderstorms were selected for the months of April, May and June with complete information on following parameters :—

(a) gpm values upto 150 hPa

(b) Temperature upto 150 hPa

(c) Wind upto 150 hPa

(d) Dew point upto 400 hPa.

Tephigram were obtained from Gwalior Met. Office. For all the 70 days for which Tephigrams were selected, following parameters for 0000 UTC for the day of occurrence were plotted on surface chart from Air Force Administrative College, Coimbatore, data bank :—

(a) Dew point

(b) Dew point change in 24 hrs

(c) Dew point departure ($TT-T_dT_d$)

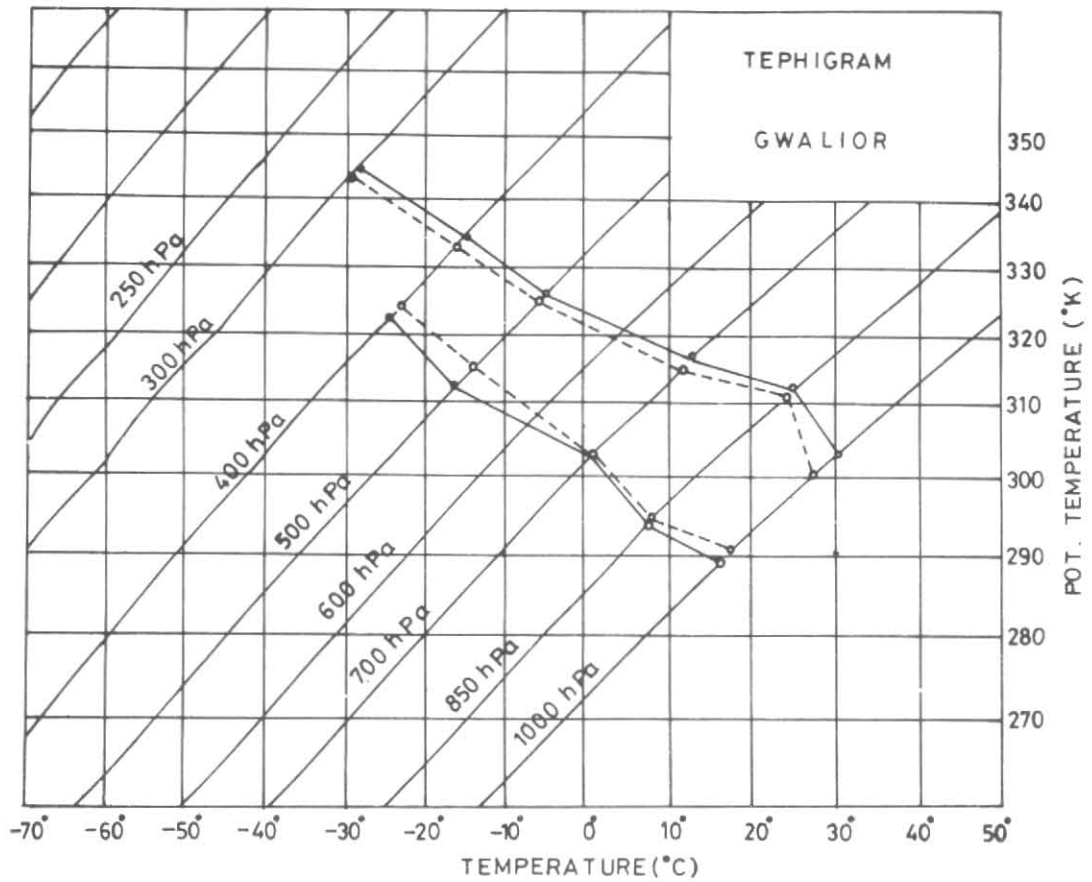



Fig. 1. Mean April, May and June 0000 UTC tephigram of Gwalior for days when duststorm (continuous lines) and thunderstorm (dashed lines) occurred. Set of lines on the right hand side of the figure are ELR curves and that on the left hand side of the figures are dew point curves

## 3. Methodology

3.1. To assess the critical humidity values on the surface over Gwalior and in its neighbourhood, following parameters were plotted and analysed over area bounded by Lat. 20°N to Lat. 34°N and Long. 60°E to Long. 85°E :—

(a) Dew point

(b) Dew point change in 24 hrs

(c) Dew point departure ($TT-T_dT_d$).

The analysis was done for all the days of occurrence of either thunderstorm or duststorm from 1976 to 1992.

3.2. *Tephigram*

(a) For distinctly marking the parameters which are unique to duststorm as against thunderstorm, mean 0000 UTC tephigrams, for 35 cases of duststorm and another 35 cases of only thunderstorm was prepared. Arithmetic mean of all the parameters was taken for each standard level. Following parameters were studied :—

(*i*) Geopotential height

(*ii*) Temperature

(*iii*) Dew point

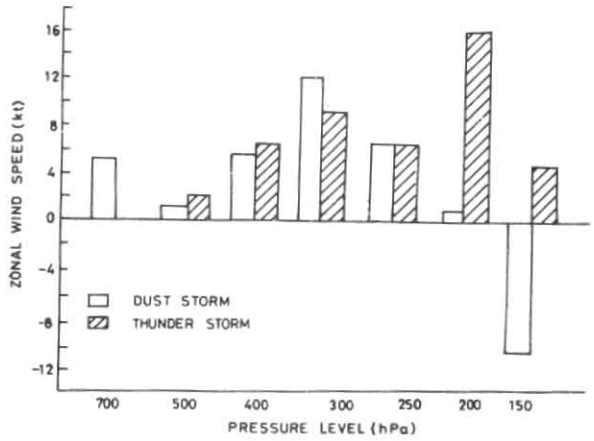



Fig. 2. Bars indicate the shear in kt (indicated by Y-axis) obtained after subtracting the U-component of wind of the lower level from the immediate higher level, as mentioned at X-axis

(*iv*) U-component of wind at each level.

(b) Total precipitable water content (TPW) was also worked out for each level for all the cases of duststorms and thunderstorms. And a mean was taken for TPW of each level. Since dew point values are not available above 400 hPa, TPW values were computed only upto this level.

## 4. Statistical analysis of duststorm and thunderstorm data of Gwalior

4.1. A total of 369 duststorms, duststorms followed by thundershower and only thunderstorms occurred between 1976 to 1992 during pre-monsoon season of Gwalior between April to June. A statistical analysis of following parameters was carried out :—

(a) Frequency of occurrence

(*i*) Monthwise frequency.

(*ii*) Frequency with respect to direction.

(b) Monthly distribution and diurnal variation.

(c) Direction of approach in each month and diurnal variation.

TABLE 1

**Mean gpm values in 0000 UTC for duststorm and thunderstorm over Gwalior**

| Pressure (hPa) | Duststorm (gpm) | Thunderstorm (gpm) | Difference (gpm) |
|---|---|---|---|
| 850 | 1445.79 | 1458.42 | −12.63 |
| 700 | 3127.58 | 3122.85 | + 4.73 |
| 500 | 5850.36 | 5827.96 | +22.4 |
| 400 | 7577.08 | 7627.5 | −50.42 |
| 300 | 9672.86 | 9672.28 | + .58 |
| 250 | 10940.11 | 10908.0 | +32.11 |
| 200 | 12475.00 | 12471.88 | + 3.12 |
| 150 | 14356.25 | 14273.75 | +82.5 |

(d) Frequency distribution of peak gust speed (PGS).

(e) Average PGS in various fortnights.

(f) Probability of exceeding specified limits of PGS.

## 5. Regression equation for PGS

5.1. Most suitable parameter which accounts for the low level relative dryness of duststorm as compared to thunderstorm is parameter '*X*' which was earlier used by Singh (1983) to develop regression equation for Hindon in pre-monsoon, due to thundersquall. '*X*' is defined as follows :—

$$X = T_2 - T_1$$

where,

$T_2$ = The temperature obtained by descending dry adiabatically from 600 hPa to surface,

$T_1$ = Surface temperature (0000 UTC).

Inherent advantages of using parameter '*X*' is that it has got least approximation errors, which is not the case when parameter is based on forecast surface maximum temperature. Secondly it is in conformity with the observed fact that on the day of duststorm upto 600 hPa and below total precipitable water content (TPW) is much lower than thunderstorm. Hence assumption that the parcel descends from 600 hPa along DALR will be better approximation than assuming it to follow SALR.

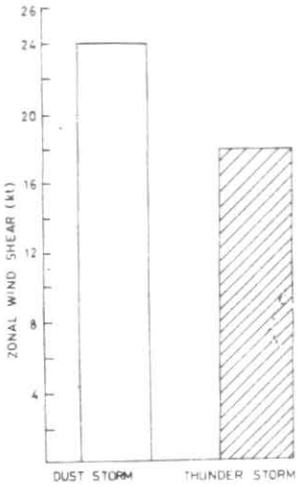



Fig. 3. Y-axis indicates the wind speed shear in kt between 850-300 hPa. Note the prominently stronger shear for duststorm days

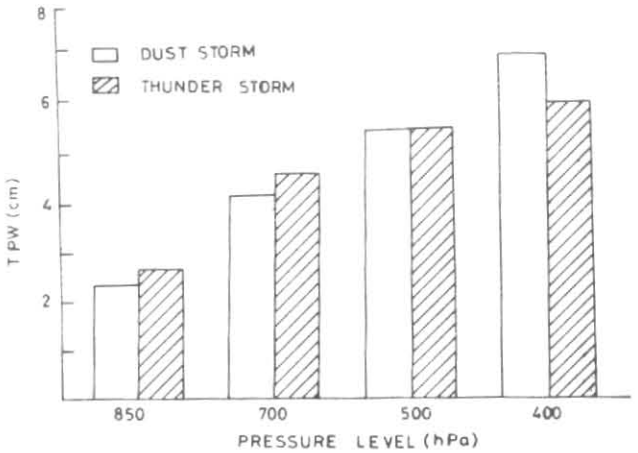



Fig. 4 Y-axis indicates total precipitable water (TPW) content in cm upto the levels indicated at X-axis. Note higher accumulation of moisture on duststorm days at 400 hPa

## 6. Results and discussion

6.1. *Surface chart analysis (0000 UTC) of 'D' Day*

(a) *Dew Point Temperature (DP)* — Analysis of DP shows that within preferred area bounded by Lat. 24° N to Lat. 28° N and Long. 76° E to Long. 80° E. DP values less than or equal to 21° C are favourable for occurrence of duststorm. Cut off values of 21° C, however, do not conclusively exclude non-occurrence of thunderstorm.

(b) *Dew Point Departure (DPD)* — When DPD (*i.e.* $TT-T_dT_d$) is more than 11° C, then it is favourable for the occurrence of duststorm. This parameter also does not exclusively indicate the non-occurence of thunderstorm when DPD > 11° in the region.

(c) *Dew Point Change (24 hourly)* — This does not give any indication which may distinguish duststorm and thunderstorm days.

6.2. *Mean tephigram (0000 UTC) of duststorm and thunderstorm days*

Mean tephigram for duststorm cases and thunderstorm cases is shown in Fig. 1. A categorial analysis of various elements are presented hereunder :—

(a) *Changes in gpm at various levels* — A comparison of the mean gpm values in case of Tephigram for duststorm days and thunderstorm days is presented in Table 1. It is observed that rise of the order of 4 m to 22 m at 700 hPa and 500 hPa levels respectively are noticed and fall of the order of 12 m and 50 m at 850 hPa and 400 hPa levels respectively are indicated for duststorm days. At 300 hPa the difference was negligible. But at higher levels gpm values in duststorm were higher by 32.11, 13.12 and 82.5 m at 250, 200 and 150 hPa levels respectively. The consistent high gpm values in upper troposphere at 250, 200 and 150 hPa levels may be taken as favourable condition for the occurrence of duststorm. Hence if the gpm values of 500, 200 and 150 hPa are higher than 10940 gpm, 12475 gpm and 14356 gpm respectively, it is favourable condition for duststorm.

(b) *Temperature* — Table 2 shows the average temperature for the cases of duststorm and thunderstorm. Columns 4 and 5 of the table show the lapse rate in the process curve. It may be observed that lapse rate of the order of 4.5° C/km existed in case of duststorm between surface and 850 hPa as compared to only 3.0° C/km in case of thunderstorm. High lapse rate in duststorm is attributable to low moisture content in 0000 UTC tephigram of Gwalior within gradient level. Hence if lapse rate between surface and 850 hPa is more than 4.5° C/km then it is favourable for duststorm At higher levels there is no significant difference in the lapse rate. Difference in the ELR at the lower levels may be noticed in Fig. 1.

TABLE 2

**Temperature and lapse rate (Γ)**

| Pressure (hPa) | Dust-storm (°C) | Thunder-storm (°C) | Lapse rate (°C/km) | | Layers for Γ-calculation (hPa) |
|---|---|---|---|---|---|
| | | | Ds | Ts | |
| Surface (183 m) | 30.88 | 28.6[illegible] | — | — | — |
| 850 | 25.2 | 24.71 | 4.5 | 3.0 | sur-850 |
| 700 | 13.23 | 11.6 | 7.12 | 7.89 | 850-700 |
| 500 | − 4.46 | − 5.88 | 6.5 | 6.5 | 700-500 |
| 400 | −14.21 | −15.96 | 5.6 | 5.6 | 500-400 |
| 300 | −27.91 | −29.02 | 6.5 | 6.4 | 400-300 |
| 250 | −37.49 | −37.64 | 7.5 | 7.0 | 300-250 |
| 200 | −47.76 | −48.08 | 6.7 | 6.7 | 250-200 |

(c) *Dew Point (DP)* — Analysis shows that surface dew point value less than 16° C is favourable for occurrence of duststorm. Whereas. DP > 16° C is favourable for the occurrence of thunderstorm. It was also observed in surface data study that dew point temperature < 21° C in the preferred region is favourable for the occurrence of duststorm. But this does not exclude the possibility of thunderstorm below this value. DP > 21° C is not favourable for duststorm. It is favourable for thunderstorm only.

(d) *U-Component of wind shear* — Fig. 2 shows the layer-to-layer wind shear and Fig. 3 shows the wind shear between 850 and 300 hPa. It is more in case of duststorm (24.32 kt) as compared to thunderstorm (17.95 kt). Hence if wind shear between 850 to 300 hPa is more than 24 kt it is favourable for duststorm. Wind shear becomes same for both thunderstorm and duststorm between 300 and 200 hPa layer. And it reverses in higher layer *i.e.*, between 250 and 200 hPa. It is 0.33 kt for the day of duststorm and 16.24 kt for the day of thunderstorm. Hence if wind shear is negligible between 250 and 200 hPa it is favourable of duststorm: or/and if it is negative between 200 and 150 hPa it is also favourable for duststorm. Below 250 hPa. wind shear between any two immediate levels does not give any distinct picture.

TABLE 3

**Total precipitable water content (TPW)**

| Pressure (hPa) | Dust-storm (cm) | Thunder-storm (cm) | Difference (cm) |
|---|---|---|---|
| 850 | 2.29 | 2.65 | −0.26 |
| 700 | 4.13 | 4.53 | −0.4 |
| 500 | 5.55 | 5.55 | ±0.0 |
| 400 | 7.07 | 6.03 | +1.04 |

(e) *Total Precipitable Water Content (TPW)* — TPW values are shown in Table 3. A graphical representation is given in Fig. 4. Total precipitable water content for duststorm days and thunderstorm days in the mean 0000 UTC Tephigram are more or less same. Below 500 hPa mean TPW or duststorm days is comparatively less than that for thunderstorm days. TPW is same at 500 hPa for both the cases. TPW is higher between 500 and 400 hPa for duststorm days than for thunderstorm days. It implies that in case of duststorm moisture or TPW is accumulated at higher level of the cumulonimbus cloud than in case of thunderstorm. At 700 hPa there is maximum difference between the TPW of thunderstorm and duststorm. Hence it may be inferred that TPW < 4 cm at 700 hPa and TPW > 7 cm at 400 hPa is favourable for the occurrence of duststorm.

## 7. Duststorm statistics at Gwalior

7.1. *Monthly frequency* — Table 4 shows monthly percentage frequency of duststorm/duststorm followed by thundershower and thunderstorm over Gwalior between 1976 and 1992. It may be noticed that maximum duststorm or duststorm followed by thundershower activity had taken place in May only. Purely duststorm activity was highest in June (13.9%) and purely duststorm followed by thundershower was highest in May (29.9%). During the month of June, duststorm continues to occur till the onset of monsoon by last week of June. During delayed onset of monsoon—sometimes as late as by 12th July—duststorm may be recorded throughout the month of June.

7.2. *Direction of approach in each month and diurnal variation* — Figs. 5 (a & b) show the mean/minimum/maximum peak gust speed (PGS) in the months of May and June respectively. Due to only 6 duststorm occurrences recorded in the month of

TABLE 4

**Monthly frequency/percentage frequency of thunderstorm, duststorm followed by thundershowers and duststorm only**

| Months | | Thunder-storm | Dust-storm followed by thunder-shower | Dust-storm |
|---|---|---|---|---|
| March | Total number | 44 | — | — |
| | % | 100 | — | — |
| April | Total number | 43 | 5 | 1 |
| | % | 87.7 | 10.2 | 2.1 |
| May | Total number | 68 | 35 | 14 |
| | % | 58.1 | 29.9 | 12.0 |
| June | Total number | 107 | 23 | 21 |
| | % | 70.9 | 15.2 | 13.9 |

April directionwise mean PGS figure could not be drawn. Thick line in the centre of Figs. 5 (a & b) is the 10° moving average. Following monthwise inferences could be drawn :

(a) *April*

Out of total 6 duststorms recorded within 17 years. period (1976-1992). 5 of them occurred between 1200 to 1800 hrs. Only once it affected the airfield during the early night between 2100 to 2400 hrs.

Maximum PGS reached 55 kt and its direction of approach was from westnorthwest. PGS decreases sharply to 25-35 kt from this direction towards northeast or southwest.

(b) *May*

Fig. 5 (a) shows that there was one modal direction of PGS during May, *i.e.*. northnorthwest. PGS affecting the airfield from westnorthwest/west/ southwest of northwest/east are comparatively less in strength. Most probable direction of occurrence was northwest quadrant from 270° to 360°, although 22% occasions they have affected the airfield from westsouthwest and from eastnortheast direction. too.

(c) *June*

Fig. 5 (b) shows that there are three modal directions as indicated by the moving average line from where the maximum speed is recorded. They are northnorthwest. northeast and westnorthwest in order of strength of the PGS.

7.3. *Regression equation of peak gust speed*

With April. May and June data combined. following equation was derived.

$$Y = 76.70171 - 31.0696 \sqrt{X} + 5.24167 X$$

It can be used with reasonable accuracy, since its standard error is only ± 5 kt.

## 8. Conclusions

8.1. Following parameters are found to favour the occurrence of duststorm only on the day which is favourable for convective activity :

(a) Surface Chart (0000 UTC)

(*i*) Dew point

Within preferred area bounded by Long. 76° E to 80° E and Lat. 24° N to Lat. 28° N. it is less than or equal to 21° C.

(*ii*) Dew point departure ($TT-T_dT_d$)

It is more than 11° C in the preferred area.

(b) Tephigram (0000 UTC) Gwalior.

(*i*) gpm at 250 hPa > 10940 m

(*ii*) gpm at 200 hPa > 12475 m

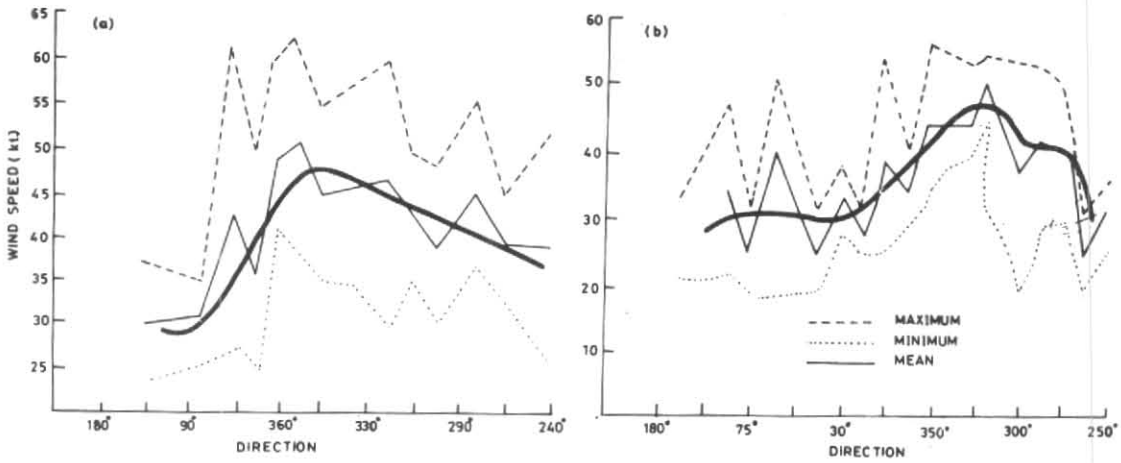
(*iii*) gpm at 150 hPa > 14356 m

(*iv*) Lapse rate between surface and 850 hPa

$(T-T_{850})/(\text{gpm}\ \ 850\text{-}189) >$ 4.5° C. where 189 is airfield elevation in metres.

(*v*) Surface Dew point < 16° C

(*vi*) U-Component




Figs. 5 (a & b). Thick line in the centre is 10° moving average of mean PGS curve, bottom (chain) curve is the minimum PGS and top (dashed) curve is the maximum PGS for (a) May and (b) June

(aa) Wind shear between 850-300 hPa > 24 kt.

(bb) Wind shear between 250-200 hPa is negative.

(c) Total precipitable water content

(*i*) TPW at 700 hPa < 4 cm

(*ii*) TPW at 400 hPa < 7 cm

8.2. For prediction of PGS following regression equation may be used for April, May and June months :

$$Y = 76.70171 - 31.0696 \sqrt{X} + 5.24167 X$$

where, $X = T_2 - T_1$

$T_2$ = Temperature of air parcel brought along DALR from 600 hPa to surface in 0000 UTC tephigram

$T_1$ = Surface temperature at 0000 UTC.

$Y$ = Forecast speed in kt.

8.3. Statistical conclusions are as follows :

(a) May is the month with highest duststorm activity over Gwalior.

(b) Directionwise occurrence is observed as follows :

(*i*) In April they may occur from 270° to 45°.

(*ii*) In May and June they occur mostly in northnorthwest direction.

(c) Time of occurrence is observed as follows :

(*i*) In April they occur mostly between 1500 to 1800 IST. In May they may occur any time during morning, afternoon, evening and night hours. But in June they are mostly occurring between 1500 to 2100 IST, *i.e.*, during afternoon or early night.

(*ii*) Activity of duststorm is lowest between 0000 to 1200 IST in all months.

(*iii*) High relative humidity and high temperature jointly affect the high frequency of occurrence in any hour of the day.

(d) In April highest peak gust speed is recorded from westnorthwest direction. In May it is from northnorthwest direction and in June it is highest from northnorthwest direction, but second highest speed is also recorded from northeast and westnorthwest directions.

(e) First fortnight of May has the highest mean PGS of 45.5 kt. Mean PGS for

second fortnight of May is 42 kt. First and second fortnight of June has PGS values 38 kt and 41 kt respectively. In the month of April it is 35 kt in the first fortnight and 43 kt in second.

(f) PGS is, in general, higher in May than in June.

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