

# On the gustiness of wind and occurrence of gusts at Vishakhapatnam

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**ABSTRACT.** The paper summarises the results of a study of the gustiness of wind and of the occurrence of gusts at Vishakhapatnam, based on the analysis of 3 years' records of the Dines Pressure Tube Anemograph with its head 56½ ft above ground. Tables showing the diurnal variation of gustiness for the twelve months of the year are given and briefly discussed. Frequencies of the time of occurrence, speeds and directions of the gusts are also given and their chief features are described. The highest gusts recorded in each one of the three years are also discussed.

## 1. Introduction

Vishakhapatnam (height above mean sea level 138 ft) is a coastal station situated on the east coast of the Indian Peninsula in Lat. 17° 42' N, Long. 83° 20' E and has an important situation both from the point of view of shipping as well as aviation. A study of the gustiness of wind and of the occurrence of gusts at the station has been made in this paper. The data used have been derived from the records of the Dines Pressure Tube Anemograph at the Vishakhapatnam Observatory for the period January 1939 to December 1941 (3 years).

## 2. Exposure of the anemograph

The Dines P.T. Anemograph is installed on the roof of a building at the Vishakhapatnam harbour with its head 56½ ft above ground level and 19 ft above the building and the recorder is placed in a room imme-

diately below. The exposure of the Dines head is good in all directions and the instrument was functioning satisfactorily during the period of observations made use of in this paper.

## 3. Method of tabulation of data

The definition of gustiness factor of wind as adopted in this paper is width of the speed ribbon in a short interval of time divided by the mean speed of wind during the same interval. For each hourly value, an interval of 10 minutes ending at each exact hour was considered. For example, for the hourly value of gustiness at 1100 IST, an interval of time from 1050 to 1100 IST only was used for determining the gustiness at that hour. If the mean speed of wind in mph during the 10-minute interval is  $b$  and the width of the speed ribbon during the same interval, *i.e.*, average

TABLE

Diurnal Variation of gustiness

Month/	Hour 1	2	3	4	5	6	7	8	9	10	11	12
Jan	0.10	0.10	0.10	0.10	0.13	0.13	0.13	0.17	0.23	0.40	0.53	0.50
Feb	0.10	0.10	0.03	0.03	0.10	0.07	0.10	0.17	0.30	0.47	0.53	0.57
Mar	0.23	0.27	0.23	0.20	0.17	0.20	0.27	0.37	0.40	0.53	0.63	0.67
Apr	0.37	0.37	0.33	0.33	0.27	0.27	0.37	0.50	0.57	0.63	0.73	0.73
May	0.30	0.30	0.23	0.27	0.27	0.27	0.37	0.43	0.47	0.53	0.60	0.67
Jun	0.40	0.37	0.40	0.40	0.40	0.33	0.40	0.47	0.50	0.50	0.53	0.60
Jul	0.53	0.53	0.53	0.50	0.53	0.57	0.57	0.57	0.60	0.67	0.63	0.67
Aug	0.40	0.40	0.40	0.43	0.47	0.50	0.50	0.57	0.57	0.57	0.60	0.60
Sep	0.27	0.30	0.23	0.23	0.23	0.23	0.33	0.40	0.53	0.60	0.60	0.63
Oct	0.23	0.27	0.30	0.20	0.30	0.30	0.37	0.40	0.47	0.47	0.50	0.50
Nov	0.40	0.37	0.37	0.37	0.37	0.37	0.43	0.50	0.57	0.60	0.53	0.53
Dec	0.30	0.30	0.33	0.37	0.33	0.33	0.37	0.40	0.50	0.57	0.50	0.50
Year	0.32	0.33	0.31	0.30	0.30	0.32	0.35	0.41	0.48	0.55	0.58	0.60

range of gusts in mph is  $c$ , the gustiness factor is given by  $c/b$ . It may be mentioned that a gust of importance to aviation is defined as a positive deviation (departure) of the wind from the mean velocity (over a ten-minute period) equal to or in excess of 10 knots during at least one second but not more than 20 seconds (CD Washington, 1947 : 131 and page 64, OMI publication No. 78). This new definition would, however, make no difference to the general conclusions drawn or the discussion of the results in this paper.

#### 4. Importance of gustiness near the ground

Eddy motion in the lowest layers of the atmosphere is caused mainly (i) by the local heating of the surface layers by the ground, *i.e.*, by convection currents giving gusts and lulls and (ii) by friction between air and earth (*e.g.*, by obstacles on the ground) resulting in gustiness near the ground. Variations in the amount of gustiness at aerodrome level are of importance to the aviator. The eddies contain up and down currents which make gusty air feel 'bumpy' to pilots. Pronounced gustiness at aerodrome level may cause

sudden changes of aircraft altitude calling for greater caution when taking off and landing. Just as in the case of cliffs and hill ridges, tall hangars have severe down-currents on their leeward side on windy days, making it risky to take off or land over them.

#### 5. Diurnal variation of gustiness

The mean hourly values of the gustiness factor for each hour of the day for each month of the year and for the whole year, based on the observations during the period January 1939 to December 1941 (3 years) are given in Table 1. The gustiness of wind begins to increase rapidly after sunrise and reaches a maximum value by about 1300 to 1400 IST. Thereafter it begins to decrease. The gustiness is comparatively small and practically uniform during the night hours. The mean value of gustiness is 0.43. Table 2 has been prepared from the data in Table 1 and gives the absolute range of the diurnal variation of gustiness, period of day variation and the epoch of maximum gustiness. The following facts are brought out from the data in this table—

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at Vishakhapatnam

13	14	15	16	17	18	19	20	21	22	23	24	Mean
0.47	0.43	0.43	0.43	0.43	0.37	0.27	0.27	0.17	0.13	0.10	0.10	0.26
0.57	0.63	0.60	0.63	0.57	0.57	0.43	0.30	0.20	0.20	0.13	0.10	0.31
0.70	0.63	0.67	0.67	0.63	0.53	0.47	0.37	0.37	0.30	0.33	0.27	0.43
0.73	0.77	0.77	0.63	0.67	0.57	0.50	0.43	0.43	0.37	0.37	0.33	0.51
0.63	0.63	0.60	0.53	0.50	0.40	0.37	0.40	0.37	0.37	0.37	0.37	0.43
0.63	0.63	0.60	0.60	0.53	0.40	0.40	0.37	0.37	0.33	0.33	0.30	0.45
0.70	0.67	0.67	0.67	0.67	0.63	0.50	0.57	0.50	0.43	0.57	0.47	0.58
0.63	0.67	0.63	0.60	0.63	0.53	0.50	0.47	0.43	0.40	0.40	0.43	0.51
0.63	0.63	0.63	0.60	0.60	0.50	0.43	0.37	0.37	0.33	0.30	0.27	0.43
0.50	0.47	0.47	0.43	0.47	0.40	0.43	0.37	0.30	0.30	0.27	0.30	0.38
0.50	0.53	0.50	0.47	0.53	0.50	0.47	0.47	0.43	0.40	0.40	0.40	0.47
0.50	0.50	0.50	0.43	0.47	0.47	0.47	0.40	0.33	0.33	0.33	0.33	0.41
0.60	0.60	0.59	0.57	0.56	0.49	0.44	0.40	0.36	0.32	0.33	0.31	0.43

(i) The maximum value of mean hourly gustiness (0.77) during the day hours occurs in April while the minimum value of mean hourly gustiness (0.03) occurs in the month of February in the night hours.

(ii) The diurnal range of gustiness is maximum in February and minimum in November. The mean value for the diurnal range for the year as a whole is 0.38.

(iii) The mean period of day variation of gustiness is from 0700 to 1900 IST, *i.e.*, the duration is 12 hours. The epochs of commencement and termination of the day variation of gustiness lags behind the times of sunrise and sunset by about an hour. The epoch of maximum hourly gustiness generally occurs in the afternoon.

(iv) So far as annual variation of gustiness is concerned, the mean of day values shows that the maximum occurs in July and the minimum in January. This is understandable in as much as eddy motion in the surface layers of the atmosphere drives

its energy from the kinetic energy of the wind. The mean hourly speed of wind during the day is the highest in July at Vishakhapatnam. On the other hand, in January, the winds are very weak. It may be mentioned that eddy motion also depends on the height and intensity of the ground inversion. This will have a maximum value in winter.

Considering the different types of wind at Vishakhapatnam, the mean of day value for the gustiness factor is 0.49 for the southwest monsoon winds and 0.42 for the northeast monsoon winds. During the hot season\* (April and May), the value is 0.47 while the value is the lowest (0.33) in the dry season (January to March). The hourly value of gustiness factor at Vishakhapatnam is always less than one, the highest value during the 3 years being 0.8. This value is rather low when compared with the maximum value of gustiness factor obtained at Agra<sup>1</sup> which is an inland station.

\* The seasons into which the year at Vishakhapatnam may conveniently be divided are—

(i) Dry season—January to March

(ii) Hot season—April and May

(iii) Southwest monsoon season—June to September

and (iv) Northeast monsoon season—October to December

TABLE 2

Annual and diurnal variation of gustiness of wind

Month	Hourly gustiness				Period of day variation (IST)		Duration (hr)	Epoch of max gustiness (IST)
	Mean of day	Max	Min	Max-Min	From	To		
Jan	0.26	0.53	0.10	0.43	0800	2000	12	1100
Feb	0.31	0.63	0.03	0.60	0800	2200	14	1400
Mar	0.43	0.70	0.17	0.53	0800	2100	13	1300
Apr	0.51	0.77	0.27	0.50	0700	2100	14	1400-1500
May	0.43	0.67	0.23	0.44	0700	1800	11	1200
Jun	0.45	0.63	0.30	0.33	0800	1900	11	1300-1400
Jul	0.58	0.70	0.43	0.27	0500	1800	13	1300
Aug	0.51	0.67	0.40	0.27	0500	1800	13	1400
Sep	0.43	0.63	0.23	0.40	0700	1800	11	1200-1500
Oct	0.38	0.50	0.20	0.30	0700	1900	12	1100-1300
Nov	0.47	0.60	0.37	0.23	0700	2000	13	1000
Dec	0.41	0.57	0.30	0.27	0700	2000	13	1000
Year	0.43	0.63	0.25	0.38	0700	1900	12	1200-1400

#### 6. Diurnal distribution of gusts

The maximum gust on any day is measured directly from the highest excursion made by the velocity pen on the record. Diurnal distribution of such gusts for each month of the year and for the whole year during the period January 1939 to December 1941 is shown in Table 3. This table shows that taking the year as a whole, a great majority of the highest gust for the day occurs between 1000 and 1700 IST and that such gusts are not of frequent occurrence during the night hours. During the northeast monsoon season, there

is a tendency for the gusts to occur most frequently at about midday. Considering the year as a whole, the greatest frequency of the times of occurrence of the gusts at Vishakhapatnam is found to be between 1200 and 1300 IST, *i.e.*, in the afternoons.

#### 7. Speed, direction and duration of the gusts

The data of maximum gust for each day have been tabulated according to the strength of the wind on the Beaufort Scale and the frequencies of speeds of gusts for the different months of the year and for the

TABLE 3

Frequencies of maximum gusts

Month/ Hour	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	Re- main- ing hours
Jan	0	2.0	6.0	6.7	5.0	6.0	3.7	1.0	0	0	0	0.3
Feb	0	0.3	3.0	5.0	6.3	8.7	3.0	1.7	0	0	0	0
Mar	0	1.3	2.7	5.7	5.7	8.0	2.7	1.3	2.0	1.0	0.3	0
Apr	0	1.0	6.3	7.3	2.7	5.3	4.0	1.3	1.0	0.3	0	0.7
May	1.3	1.3	4.7	6.0	5.3	2.7	2.0	2.0	0.7	0.7	1.3	3.0
Jun	0.3	2.0	3.7	2.3	1.3	3.7	4.3	1.0	0	0.7	0.7	10.0
Jul	1.3	0.7	1.7	2.3	4.3	4.7	2.7	1.3	0.7	0.7	0.7	10.0
Aug	0	0.7	3.3	3.7	5.3	5.3	4.7	1.7	0.7	0.7	0	5.0
Sep	0.3	1.0	3.3	4.0	5.3	5.0	4.0	3.0	1.0	0.7	0.7	1.7
Oct	0.7	2.0	5.0	4.3	4.3	3.7	3.0	0.7	1.0	0.3	1.0	5.0
Nov	1.3	3.7	3.7	4.7	3.7	3.0	2.7	0.7	1.0	0.3	1.0	4.3
Dec	1.7	4.7	5.7	5.7	6.3	2.7	1.7	0.7	0.7	0	0.3	1.0
Year	6.9	20.7	49.1	57.7	55.5	58.8	38.5	16.4	8.8	5.4	6.0	41.0

whole year are given in Table 4. Gusts of wind force 6 to 7 are the most frequent but gusts of gale force (8 or above on the Beaufort Scale) also occur. Gusts of wind force 8 to 9 occur occasionally during the months of May to August and again in the month of November. Gusts of wind force 10 to 11 visit rarely, their frequency being 1 or less per month during May to July and nil during the remaining months.

The frequencies of directions of gusts for each month of the year and for the

whole year are given in Table 5. During the months of February to May, the most frequent direction of the gusts is southerly; during the southwest monsoon months, southwesterly becomes the frequent direction of the gusts while during the period of the northeast monsoon, the gusts come with the northeasterly or easterly winds. For the year, the most frequent direction of the gusts is southerly. The duration of the gusts at Vishakhapatnam is largely variable but it is generally of the order of few minutes.

TABLE 4

Frequencies of wind speeds of the maximum gusts

Month	Beaufort Scale of wind force					
	5	6	7	8	9	10
Jan	14.0	6.7	2.0	0	0	0
Feb	12.3	8.7	2.7	0.3	0	0
Mar	6.7	16.3	5.3	1.0	0.3	0
Apr	2.3	14.3	11.7	1.3	0	0
May	3.7	9.7	10.7	4.0	2.0	0.7
Jun	3.3	8.7	10.7	5.7	1.3	0.3
Jul	1.0	9.3	10.7	7.7	1.3	1.0
Aug	2.3	12.3	11.0	4.0	0.7	0
Sep	8.3	10.0	7.3	1.3	0.7	0
Oct	12.7	6.3	4.3	1.0	1.0	0
Nov	7.3	11.0	5.7	5.0	0	0
Dec	9.0	10.7	5.0	1.3	0.3	0

#### 8. Speed of the highest gust in each year

It is interesting to examine the speed of the highest gust recorded by the anemograph at Vishakhapatnam in each one of the three years for which the data have been considered in this paper. An examination of the time, day and month of occurrence of the highest gust in each year shows that the strongest gust during the period occurred at 2120 IST on 16 May 1940; its velocity was 60 mph and it came with a NEly wind. The strongest gust in 1939 and 1941 attained a speed of 49 and 51 mph respectively and came with SW and NNW wind. These occurred in June/July and May respectively. These extreme gusts came in the early part of the night or afternoon/evening.

The highest mean hourly wind recorded in each one of the three years 1939 to 1941 has also been examined. It is seen that the highest mean hourly wind occurred at 1800 IST on 9 July 1939 with a speed of 27 mph and its direction was SWly. In 1940 the highest mean hourly speed was 23 mph at 1600 IST (Sly) on 5 March and at 1500 IST on 9 July (Wly). In 1941 the highest mean hourly wind occurred at 1100 IST on 7 October with a speed of 26 mph its direction being SSE. The mean value of speed for the three highest gusts ( $G_{xm}$ ) works out to be 53 mph while the mean of the 3 highest hourly means ( $H_{xm}$ ) is 25 mph. The ratio  $\frac{G_{xm}}{H_{xm}}$  serves to illustrate

TABLE 5

Frequencies of wind directions of the maximum gusts

Month	S	SE	E	NE	N	NW	W	SW
Jan	3	7	13½	7	0	0	0	0
Feb	11	8½	6	1½	0	0	0	1
Mar	22	2	1	0	0	0	1	3
Apr	21	1½	0	0	0	0	1	6½
May	19	1½	1	3	1	½	0	5
Jun	9	1	½	2	1½	2	3½	11
Jul	7	1	½	½	½	1	5	16
Aug	12	1	0	0	0	1½	4½	11
Sep	11	2½	2½	2	1	2½	2½	6
Oct	3½	6	12½	6	1	1	½	1
Nov	0	1	11	16	2	½	0	0
Dec	2	3	9	15	1	1	0	0

roughly the character of the exposure of the instrument at the station. The value of this ratio for Vishakhapatnam works out to be 2.1 which compares fairly well with the values obtained elsewhere.<sup>2</sup>

#### 9. Other features of the structure of wind

In addition to gustiness, the wind at Vishakhapatnam shows squalliness as well as certain other interesting seasonal features such as waves in the speed and direction traces, etc. It is proposed to discuss these characteristics of the wind records at Vishakhapatnam in a subsequent paper.

#### 10. Acknowledgement

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