

SEASONAL VARIATION OF WIND DIRECTION FLUCTUATIONS vs PASQUILL STABILITIES IN COMPLEX TERRAIN

(Research Note)

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Abstract. The authors have studied the seasonal variation of σ_θ (the standard deviation of wind direction fluctuations) vs Pasquill stabilities over complex terrain. It is found that the values of σ_θ are quite high in the month of April in contrast with other months. Values are also high when compared with those estimated over flat terrain and at a coastal site.

1. Introduction

The concept of 'atmospheric stability' is very useful in studies of environmental air quality. Variations in atmospheric stability serve to explain qualitatively much of the variation in the capacity of the atmosphere to dilute pollutants; in fact, stability is an excellent parameter for stratifying a variety of meteorological and other statistics relating to air pollution (Stern, 1976).

Several indicators of atmospheric stability are used in micrometeorology, e.g., temperature lapse rate, wind direction fluctuation, wind profile, cloudiness and wind, and Richardson Number. But in complex terrain, 'wind direction fluctuation' is the most useful and is the easiest to relate to atmospheric stability as it directly reflects the turbulence.

Several scientists have used wind direction fluctuation as an indicator of stability, of course with slight variations. Singer and Smith (1953) proposed a gustiness classification defined by the range and appearance of the horizontal wind direction trace. They concluded that gustiness is closely related to lapse rate and solar radiation, while its association with wind speed and Sutton's index of turbulence is not as distinct. McElroy (1969) slightly modified the gustiness classes given by Singer and Smith. Slade (1968) related Pasquill stability classes to standard deviation of horizontal wind direction fluctuations (σ_θ) and corresponding lapse rates. Such relations are useful when classifying meteorological data from continuous records of wind and temperature. On the other hand, the basic parameters used by Pasquill (1961) include visual observations of cloudiness, which though simple to observe, are not generally available except at first-order weather observing stations. So σ_θ values are very useful in dispersion studies. Islitzer (1961), Cramer (1959), Pasquill (1976) and others have also presented data

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which relate σ_θ to σ_y . In India also, some studies have used σ_θ values to determine stability. Shirvaiker (1965) estimated σ_θ values for a flat coastal site. Padmanabha Murthy and Gupta (1979) computed σ_θ values over flat terrain. However, their values may not be representative of irregular topography, as at Visakhapatnam.

Visakhapatnam ($17^\circ 42' \text{ N}$; $82^\circ 18' \text{ E}$) is a coastal city (Figure 1) situated on the Bay of Bengal coast of India between the hill ranges of Kailasa to the north and Yerrada to the south. The city is in a small basin surrounded by hills on three sides with a narrow zone protruding into the sea. The Bay of Bengal forms the eastern boundary of the area with the coastline running from north-east to south-west, with about 6 km of coastline from the Dolphin's Nose to Lawson's Bay. The western side of Visakhapatnam is an extensive tidal basin called Upputeru (Salt lake). Beyond Yerrada, there is a valley followed by another range of hills. Between the two dominating ranges is a vast expanse of lowlands (over 25 km in length) with a number of hillocks; this is a rugged landscape. The wind direction measurements used in this investigation were made at an aerodrome within these low-lands. A Dines P. T. Anemometer, No. 305, R. W. Munro, London, was installed at a height of 22 m above the ground, well away from buildings. Utilising these data, σ_θ values have been computed and compared with values of σ_θ determined by others.

2. Methodology

De Marrais and Islitzer (1960) showed that a reasonably good relationship exists between the standard deviation of wind direction fluctuation (σ_θ) over a given time interval and the absolute horizontal range of wind direction over the same interval. The computation of σ_θ is quite laborious when compared with the range determination, which simply involves the difference between the extremes over a given time interval. The use of range offers a simple approach for estimating the values of σ_θ for large quantities of wind direction data.

Values of σ_θ are determined utilising the continuous wind direction trace. The trace in any hour is subdivided conveniently into 10, 15, or 20 min periods depending upon the fluctuations. For example, if the trace is smooth and uniform, longer averaging periods would suffice. But, if the fluctuations are large, a shorter averaging period is chosen. In the present computations, 20-min intervals for smooth and uniform traces and 15-min intervals for large fluctuations have been selected. The difference in the smoothed extreme values of wind direction fluctuations is taken as the range during the sampling period. All such ranges during a one-hour period are averaged and considered as the range of wind direction fluctuations for the hour.

Approximate values of σ_θ were obtained by dividing the direction range values by 6.0 (Slade, 1968). This value was determined experimentally by De Marrais and Islitzer (1960) for wind speeds of 6 m s^{-1} using an aerovane. Values of approximately 6.0 were also found by Hosler *et al.* (1959) for lapse, neutral and inversion conditions using a Beckman and Whitley instrument. Even though this factor shows some variation with meteorological conditions and height of measurement, there seems to be sufficient

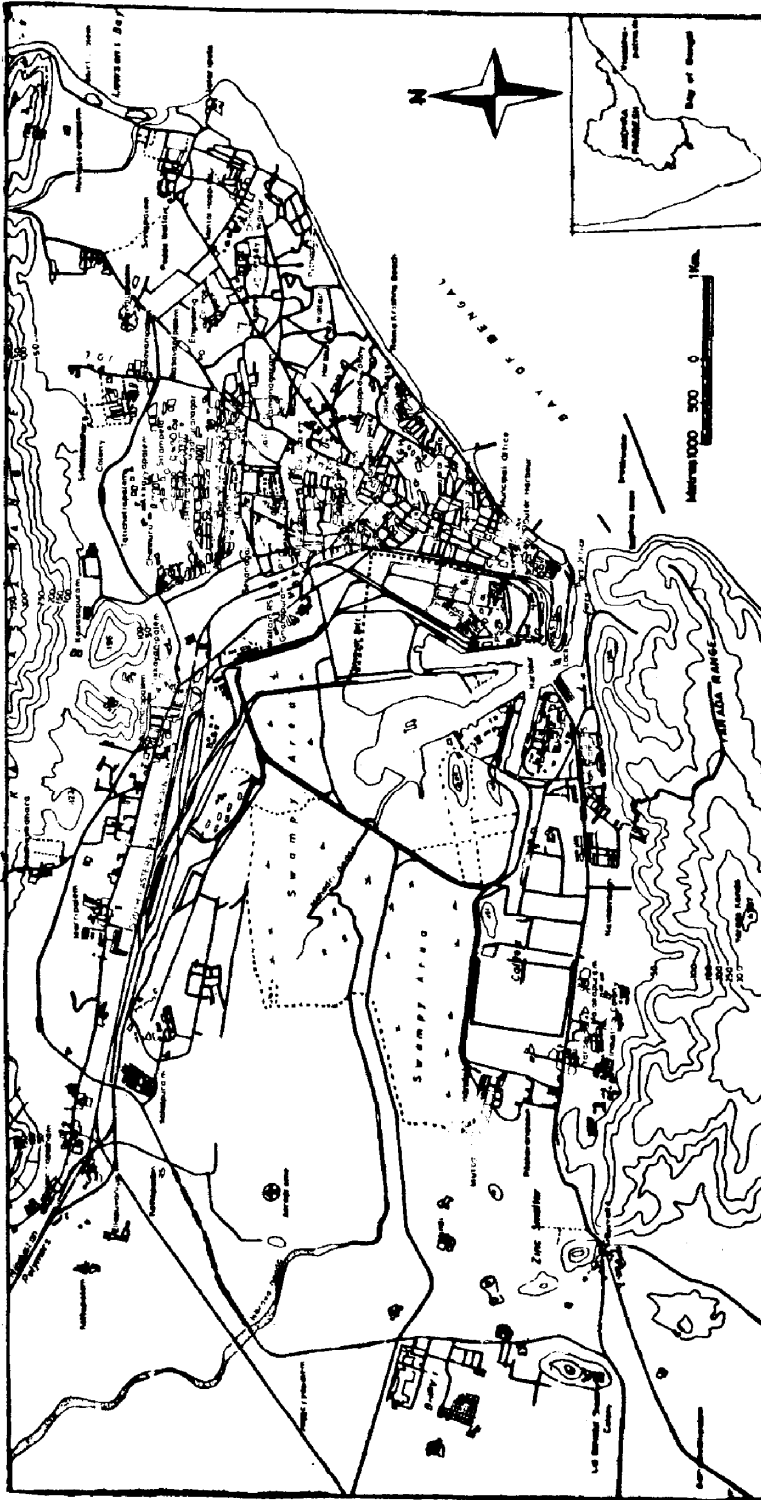


Fig. 1. Map of the city of Visakhapatnam, India.

justification for the use of the value of 6.0 to determine an approximate value of σ_θ (Slade, 1962).

In this article, mean, median and mode values of σ_θ have been worked out for 10 successive years from 1958 to 1967 for the months of January, April, August, and October typical of the respective seasons. These values are related to Pasquill stabilities.

TABLE I

Values of σ_θ corresponding to Pasquill stabilities at Visakhapatnam – January

Pasquill stability	Values of σ_θ		
	Mean	Median	Mode
A	16	16	16
B	12	11	9
C	8	8	7
D	6	6	6
E	6	6	5
F	4	4	4

TABLE II

Values of σ_θ corresponding to Pasquill stabilities at Visakhapatnam – April

Pasquill stability	Values of σ_θ		
	Mean	Median	Mode
A	17	17	18
B	13	13	10
C	9	8	8
D	8	7	7
E	6	7	7
F	6	6	5

TABLE III

Values of σ_θ corresponding to Pasquill stabilities at Visakhapatnam – August

Pasquill stability	Values of σ_θ		
	Mean	Median	Mode
A	12	11	9
B	10	9	8
C	7	7	7
D	7	7	7
E	5	5	5
F	4	5	5

3. Results and Discussion

Tables I to IV show the values of σ_θ corresponding to Pasquill stabilities in the four typical months of the respective seasons. Mean value of σ_θ in 'A' stability is high in April followed by January, October, and August. In 'B' stability, the maximum is again found to be in April followed by January, October, and August. In fact, all the stability categories recorded higher mean values of σ_θ in April than in other months. This may be due to the higher contributions of both mechanical and thermal turbulence which is quite possible in complex terrain in the pre-monsoon season. Median and mode values are also highest in April in all stability categories.

TABLE IV
Values of σ_θ corresponding to Pasquill stabilities at Visakhapatnam – October

Pasquill stability	Values of σ_θ		
	Mean	Median	Mode
A	14	13	12
B	10	10	9
C	8	8	8
D	7	7	7
E	6	6	7
F	4	3	3

TABLE V
Comparison of σ_θ values with those determined by others

Pasquill stability	Mean values of σ_θ given by the authors				Mean values of σ_θ (P and G)		Mean values of σ_θ given by	
	Jan.	Apr.	Aug.	Oct.	2.5 m	20 m	Slade	Shirvaikar
A	16	17	12	14	14	14	25	10
B	12	13	10	10	12	10	20	7
C	8	9	7	8	10	8	15	5
D	6	8	7	7	8	6	10	4
E	6	6	5	6	6	4	5	2
F	4	6	4	4	4	2	2	2

Table V shows a comparison of σ_θ values with those computed by Padmanabha Murthy and Gupta (1979), Slade (1968) and Shirvaikar (1975). The values determined by Padmanabha Murthy and Gupta (hereafter referred as P and G values) are representative of flat terrain whereas Shirvaikar determined his values at a coastal site. The values given by the present authors are also for a coastal site but with irregular topography like valleys, ravines and ranges of hills. The values given by the authors are thus quite high in all stability categories when compared with those given by Shirvaikar, though both data sets were for a coastal site.

The values in all stability categories in the month of April are higher at Visakhapatnam than given by P and G for 20 m height. This can be attributed to the irregular terrain.

4. Conclusions

Mean, median and mode values of σ_θ are high for all stability categories in the month of April when compared with values in other months.

The values given by the authors are found to be high when compared with values determined over flat terrain and at a coastal site. This clearly shows the effect of complex terrain on σ_θ values.

It is suggested that the seasonal variation of σ_θ is important in climatological diffusion studies.

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