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Diurnal and seasonal variation of Pasquill stability classes at a coastal station

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सार — वायु प्रदूषण अध्ययनों में वायुमण्डलीय स्थिरता एक सर्वाधिक महत्वपूर्ण तथा उपयोगी मौसम विज्ञानी परिमापक है। वायुमण्डल की स्थिरता निर्धारित करने के लिए बहुत से संकेतक हैं। इस लेख में लेखकों ने एक तटीय स्थान यथा विशाखापत्तनम् के लिए 10 वर्ष (1958–67) के आंकड़ों का उपयोग करके, पास्क्विल के अनुसार, स्थिरताओं का अभिकलन किया है।

अध्ययन से पता चलता है कि चार ऋतुओं के प्रतिरूपी चार महीनों, जनवरी, अप्रैल, अगस्त तथा अक्तूबर में रात की अस्थिर अवस्थाएं तथा दिन की स्थिर अवस्थाएं प्रेक्षित नहीं हुई हैं। सूर्योदय के तुरन्त बाद और सूर्यास्त के तुरन्त पहले उच्च प्रतिशतता बारम्बारता सहित उदासीन अवस्था दिन और रात में भी रहती है। स्थिरता पवन गुलाबों (रोजेज) के अध्ययन से पता चला है कि उच्च तथा मध्यम दर्जे की अस्थिर अवस्थाएं तथा स्थिर अवस्थाएं निम्न पवन वेगों से संबंधित हैं तथा थोड़ी सी अस्थिर व उदासीन अवस्थाएं उच्च पवन वेगों से संबंधित हैं।

ABSTRACT. Atmospheric stability is one of the most important and useful meteorological parameter in air pollution studies. There are several indicators to determine the stability of the atmosphere. In this article the authors have computed stabilities according to Pasquill for a coastal station, *viz.*, Visakhapatnam using a 10-year data (1958-67).

The study reveals that unstable conditions during night time and stable conditions during day time are not observed in all the four months, *viz.*, January, April, August and October typical of the respective seasons. Neutral condition is present at day and night with high percentage frequencies at the time of just after sunrise and before sunset. The study of stability wind roses indicate that highly and moderately unstable conditions and stable conditions are associated with low wind speeds and slightly unstable and neutral conditions are associated with high wind speeds.

1. Introduction

Familiarity with the concept of atmospheric stability is most useful for realising the complexity of environmental air quality. Variations in atmospheric stability gives a qualitative idea of the concentration of atmospheric pollutants, and stability is an excellent parameter for stratifying a variety of meteorological and other statistics relating to air pollution (Stern 1976).

Atmospheric stability influences both the vertical and horizontal mixing of pollutants. Many diffusion models require the knowledge of stability.

There are several indicators of atmospheric stability used in micro-meteorology. Some indicators of practical importance are temperature lapse rate, wind direction fluctuation, wind profile, cloudiness and wind, and Richardson's Number of which the last one represents the stability condition of a gravitating medium taking into account of gravity, velocity gradient and thermal situation. However, here Richardson's Number is not taken into account while classifying the stability categories.

In this article the authors have computed stabilities following the method suggested by Pasquill (1961) which is based on insolation, cloudiness and wind speed, at a coastal city, namely, Visakhapatnam.

2. Method

The specifications of Pasquill stability categories were slightly modified by Turner (1964) so that they could be determined objectively from cloud conditions, wind speed, observation time and date, and observation location.

The Pasquill system describes the stability conditions of the atmosphere in a qualitative manner. Stability categories are defined as follows :

A — Extremely unstable; B — Unstable; C — Slightly unstable; D — Neutral; E — Slightly stable; F — Stable; G — Extremely stable.

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In practical estimations it is observed that frequency of G category is very very small. So, in the present work the classes F and G are combined and represented as F only.

Table 1 gives the stability class as a function of wind and net radiation index. The net radiation index ranges from 4, corresponding to maximum value of positive net radiation (dirtcted toward the ground), to — 2 corresponding to maximum magnitude of negative net radiation (directed away from the earth). Unstability occurs with high positive net radiation and low wind speed, stability with high negative net radiation and light winds, and neutral or near neutral conditions with high wind speeds and other intermediate net radiation conditions.

The net radiation index is determined by the following procedure (Turner 1964):

(1) If the total cloud cover is 10/10 and the ceiling is less than 7000 ft, net radiation index is made equal to '0' (whether day or night).

(2) For night time (night is defined as the period from one hour before sunset to one hour after sunrise).

(a) If total cloud cover is $\leq$4/10, use net radiation index equal to —2.

(b) If total cloud cover is >4/10 use net radiation index equal to —1.

(3) For day time :

(a) Determine the insolation class number as a function of solar altitude from Table 2.

(b) If total cloud cover is $\leq$5/10, use the net radiation index in Table 1 correponding to the insolation class number.

(c) If cloud cover is > 5/10, modify the insolation class number by following these steps:

(*i*) Ceiling is < 7000 ft, subtract 2

(*ii*) Ceiling is $\geq$7000 ft, but <16000 ft, subtract 1

(*iii*) Total cover is equal to 10/10, substract 1 [This will only apply to ceiling >7000 ft, since cases with 10/10 coverage below 7000 ft. are considered in item (1) above]

(4) If insolation class number has not been modified by steps (1), (2), or (3), above, assume the class number equal to insolation class number.

(5) If modified insolation class number is less than 1, let it equal 1.

(6) Use the net radiation index in Table 1, corresponding to the modified insolation class number.

Following this procedure the stability categories are determined.

TABLE 1

Stability class as a function of net radiaton and wind speed

(Turner 1964)

Wind speed (kt)	Net radiation index						
	4	3	2	1	0	—1	—2
0, 1	A	A	B	C	D	F	F
2, 3	A	B	B	C	D	F	F
4, 5	A	B	C	D	D	E	F
6	B	B	C	D	D	E	F
7	B	B	C	D	D	D	E
8, 9	B	C	C	D	D	D	E
10	C	C	D	D	D	D	E
11	C	C	D	D	D	D	D
$\geq$12	C	D	D	D	D	D	D

TABLE 2

Insolation as a function of altitude

(Turner 1964)

Solar altitude (a)	Insolation class number
60° < a	4
35° < a < 60°	3
15° < a < 35°	2
a < 15°	1

3. Data

The wind speed at each and every hour in all days were noted for January, April, August and October, the typical months of winter, pre-monsoon, monsoon and post-monsoon seasons respectively for a period of 10 successive years starting from 1958 to 1967. As the cloud amount was not available at each hour, the computations have been carried out for three hourly interval.

4. Results and discussion

Table 3 shows the diurnal variation of the Pasquill stability categories in the month of January. The occurrence of stability A is observed from 0900 to 1200 IST with a maximum percentage at 1200 IST. B is observed from 0900 to 1500 IST and reaching

TABLE 3

Diurnal variation of frequency of Pasquill stability categories at Visakhapatnam — January

Time (IST)	Stability A	B	C	D	E	F
0	0	0	0	0	10	90
3	0	0	0	2	6	92
6	0	0	0	2	8	90
9	12	78	9	1	0	0
12	33	45	22	0	0	0
15	0	11	57	32	0	0
18	0	0	0	3	71	26
21	0	0	0	0	12	88

TABLE 4

Diurnal variation of frequency of Pasquill stability categories at Visakhapatnam — April

Time (IST)	Stability A	B	C	D	E	F
0	0	0	0	2	32	66
3	0	0	0	2	28	70
6	0	0	0	3	15	82
9	2	42	38	18	0	0
12	4	35	61	0	0	0
15	0	3	30	67	0	0
18	0	0	0	20	56	24
21	0	0	0	3	35	62

maximum at 0900 IST. C category is present from 0900 to 1500 IST with a peak value at 1500 IST. Stability D is observed with high frequency just before sunset and after sunrise. E is present between 1800 and 0600 IST with a maximum at 1800 IST. F is more persistent from 0000 to 0600 IST with a very high percentage frequency and is present between 1800 and 2100 IST with relatively low percentage when compared with the period mentioned above.

The diurnal variation of Pasquill stability categories in the month of April is shown in Table 4. A is present in between 0900 and 1200 IST and the highest percentage frequency occurred at 1200 IST. B is found from 0900 to 1500 IST with a maximum at 0900 IST. C is present from 0900 to 1500 IST with a peak value

TABLE 5

Diurnal variation of frequency of Pasquill stability categories at Visakhapatnam — August

Time (IST)	Stability A	B	C	D	E	F
0	0	0	0	4	35	61
3	0	0	0	7	31	62
6	0	0	0	6	46	48
9	11	41	30	18	0	0
12	16	36	44	4	0	0
15	3	30	33	34	0	0
18	0	0	0	21	69	10
21	0	0	0	6	35	59

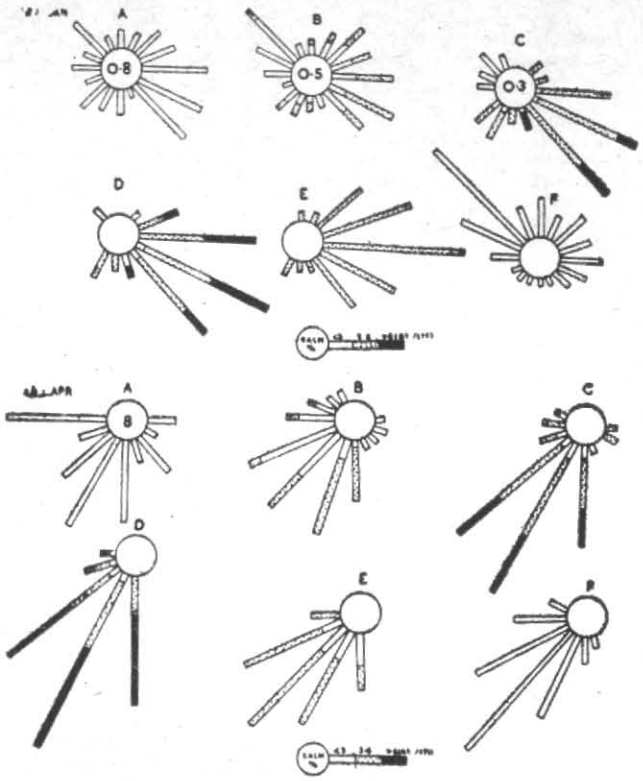
TABLE 6

Diurnal variation of frequency of Pasquill stability categories at Visakhapatnam — October

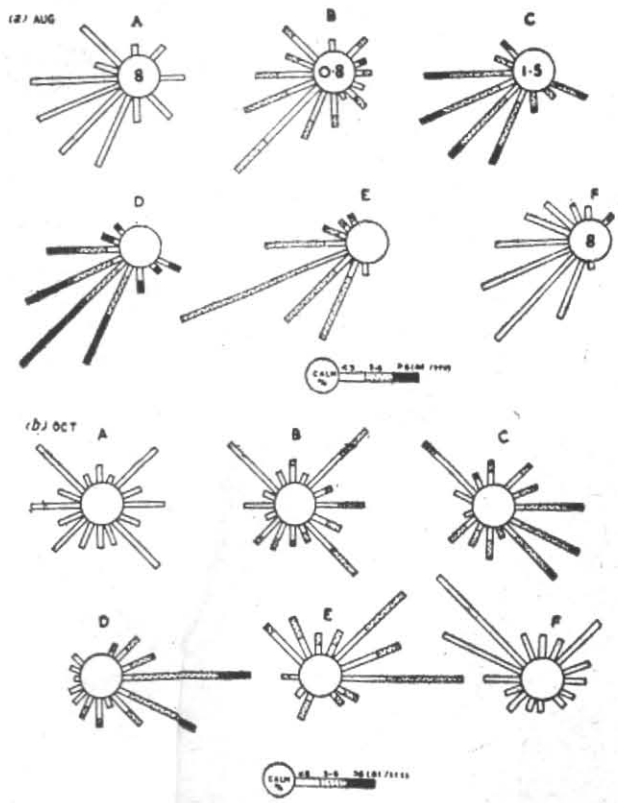
Time (IST)	Stability A	B	C	D	E	F
0	0	0	0	5	12	83
3	0	0	0	5	15	80
6	0	0	0	5	14	81
9	14	72	11	3	0	0
12	40	45	15	0	0	0
15	2	43	45	10	0	0
18	0	0	0	5	25	70
21	0	0	0	4	23	73

at 1200 IST. D occurred between 0000 and 0900 IST and from 1500 to 2100 IST with highest percentage at 1500 IST. Excepting 1200 'D' is present throughout the day. E is observed from 1800 to 0600 IST with a maximum at 1800 IST. F is also present in the same period with highest frequency at 0600 IST. The percentage frequency of F category is small in this month when compared with January.

Table 5 depicts the diurnal variation of Pasquill stabilities in the month of August. A is found in between 0900 and 1500 IST with highest percentage at 1200 IST. B is present from 0900 to 1500 IST with a maximum at 0900 IST. C occurred between 0900 and 1500 IST with a peak at 1200 IST. Neutral condition (D) is present throughout the day. This may be due



Figs. 1 (a&b). Stability wind roses for Visakhapatnam
(a) January and (b) April



Figs. 2 (a-b). Stability wind roses for Visakhapatnam
(a) August and (b) October

TABLE 7

Percentage frequency of pasquill stability categories for Visakhapatnam

Months	Stability							
	A	B	C	D	E	F	A+B+C	D E+F
Jan	5.2	17.6	10.7	5.0	12.0	49.5	33.5	5.0 61.4
Apr	1.0	10.0	16.3	14.0	20.3	38.4	27.3	14.0 58.7
Aug	3.6	13.6	13.3	12.0	23.5	34.0	30.5	12.0 57.5
Oct	7.1	20.8	8.7	4.1	11.7	48.4	35.8	4.1 60.1

to the presence of high cloud amount and wind speed generally observed in the southwest monsoon season. E is present throughout the night starting from 1800 to 0600 IST with a maximum percentage frequency at 1800 IST. F is also present during the same period with a high percentage frequency at 0300 IST.

Observing the Table 6 one can find that A is present from 0900 to 1500 IST with a maximum at 1200 IST. B is present in between 0900 & 1500 IST with a maximum at 0900 IST. Stability C occurred from 0900 to 1500 IST with a high value at 1500 IST. D is present throughout the day excepting at 1200 and the highest value is found at 1500 IST. E is found in between 1800 and 0600 IST with maximum percentage at 1800 IST. F is present in between 1800 and 0600 IST with a maximum value at 0000 IST.

In general the percentage frequency of unstable (A, B, C) conditions is zero at night time. The percentage frequency of stable conditions (E, F) is zero during day time. Highest precentage frequency of A is observed at 1200 IST in all the four months. Highest percentage in D category is found at 1500 IST in all the months. Very high percentage frequencies are observed in all the months in F category when compared with the other categories.

Seasonal variation of Pasquill stability classes has been studied and is presented in Table 7. The three hourly data of wind speed and cloud amount are used to obtain percentage frequencies of different stabilities and are presented in the Table 7. The percentage of 'B' is high in January and October compared with other stabilities. Percentage frequency of 'E' is observed to be maximum in all months excepting January in comparison with other stabilities. In general A and B in October, C and D in April, E in August and F in January occurred with high percentage frequencies when compared with other months. The percentage frequency of F is found to be high in all the months when compared with the other categories. The percentage frequency of stable conditions is high (E+ F) in all months.

Stability wind roses — Stability wind roses which are representative for stability categories are very useful for pollution studies rather than simple wind roses which show direction and speed on a monthly or seasonal basis. Stability wind roses are constructed for all the Pasquill stability categories for the four typical months of the respective seasons and are shown diagramatically.

Fig. 1(a) depicts the stability wind roses in the months of January. The most predominant wind directions are SE in A, NW in B, SE and ESE in C, ESE in D, E in E and NW in F. Stability wind roses A and F are associated with the speed class $<$ 3 m/sec and E is associated with 3-6 m/sec. All the three classes, *viz.*, $<$ 3, 3-6, and $>$ 6 m/sec are observed in C and D categories, B is associated with $<$ 3 and 3-6 m/sec wind speed classes.

Fig. 1(b) shows the stability wind roses for the month of April. In this month the persistent wind directions are SSW and SW in A, SW and SSW in B and C categories respectively. Very high percentage frequency of wind speed class $>$ 6 m/sec is observed in D category.

The predominant wind directions in the month of August [Fig. 2(a)] are SW, WSW, W (same magnitude) in A, SW in B, SW and WSW in C, SW in D, WSW in E and SW in F categories.

In the month of October [Fig. 2(b)] NW in A, NW and NE in B, ESE in C, E in D, are the predominant wind directions. Percentage of calm conditions is zero in all the categories.

In general A and F categories are associated with wind speeds less than 3 m/sec in all the months. B and E are associated with $<$ 3 and 3-6 m/sec classes in all the months excepting January in which the class $<$ 3 m/sec is only observed. All three classes are found in C and D categories. This is quite obvious from Pasquill's classification. Very high percentage frequency of wind speed class $>$ 6 m/sec is observed in D category in April and August months. It seems that the predominant wind direction in all the stabilities are more or less following the prevailing wind directions in the months of April and August whereas such tendency is not much pronounced in January and October.

5. Conclusions

Percentage frequency of unstable conditions (A, B, C) is found to be zero at night time and the percentage frequency of stable conditions (E, F) is zero during day time in all the months. The neutral condition (D) is present at day and night with high percentage at the time of just after sunrise and before sunset.

It can be said that A and B are present between 0900 and 1200 IST and C is present from 0900 to 1500 IST in all the months. D is found throughout the day excepting a few hours in the mid-day. E and F categories are observed in between 1800 and 0600 IST in all the typical months.

Percentage frequency of F category is found to be very high in all the months when compared with the other categories.

The study of stability wind roses reveals that the predominant wind directions in all the stabilities are more or less following the prevailing wind directions in the months of April and August.

High wind speed class ($\geq$ 6 m/sec) with maximum frequency is observed in D category in April and August months which fall in premonsoon and monsoon seasons respectively.

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