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TECHNICAL NOTE

METROSE: A MODIFIED WINDROSE FOR AIR QUALITY MANAGEMENT

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Abstract A metrose is proposed for a pictorial representation of the meteorological parameters and is compared with the conventional windrose. In addition to the data represented by the windrose in relation to the wind speed and direction, the metrose includes the atmospheric stability persistence for each of the directions. The metrose is particularly more advantageous for applications in modeling and spatial planning and is more explicit than a windrose.

Key word index: Meteorology, atmospheric stability, data representation, air quality modeling, spatial planning.

INTRODUCTION

The concentration of the pollutants in the atmosphere is governed by the emission sources and micrometeorology of the region, and for air quality management, knowledge of both these parameters is vital. However, unlike the emissions, micrometeorological parameters cannot be under human control and hence its knowledge gains weightage for effective planning. The important micrometeorogical parameters relevant to air pollution studies are wind speed, wind direction, and atmospheric stability. Typically for spatial planning and for communicating the information to the planners, the diagrammatic representation is popular as it has a better visual impact than the numbers in tables or charts.

THE PICTORIAL REPRESENTATION

One of the most commonly used diagrammatic representation is the windrose (shown in Fig. 1) and it gives information on wind speed and wind direction along with their persistence for the fractional period of occurrence at a given location. Though a windrose has been widely used, the information obtained from it may not be quite realistic and accurate for planning as the stability considerations in addition to wind characteristics determine the "relative vulnerability" of the directions for pollutant concentration build-up. This highlights the need for modifying the windrose itself to represent the variation in both the wind characteristics and the atmospheric stability in a single diagram. The earlier attempt on modifying the windrose has been only on the aspects of the wind characteristics variation (Patterson and Benjamin, 1975) without much emphasis on the atmospheric stability. This work attempts to modify the conventional windrose to give more information relevant to the air quality planner by incorporating the atmospheric stability in a simple manner. The pictorial information obtained thus is referred to as "metrose".

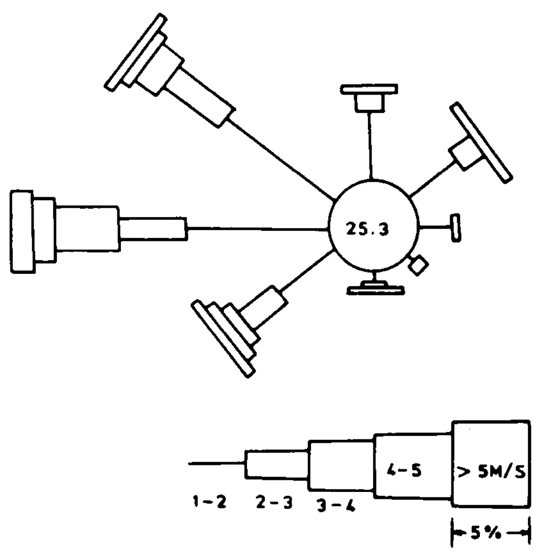

Fig. 1. A typical windrose generated for a period of one month.

THE METROSE

The metrose is aimed at providing a combined representation of the wind characteristics and the atmospheric stability variation. Specifically, the information that can be represented for each of the directions as shown in Fig. 2 is: (i) percentage occurrence of wind (length of each line within the circle), (ii) average wind speed (number at the end of the line within the circle), (iii) persistence of the stability class occurrences (length of each block of the spoke outside the circle with the alphabet representing the Pasquill stability), and (iv)

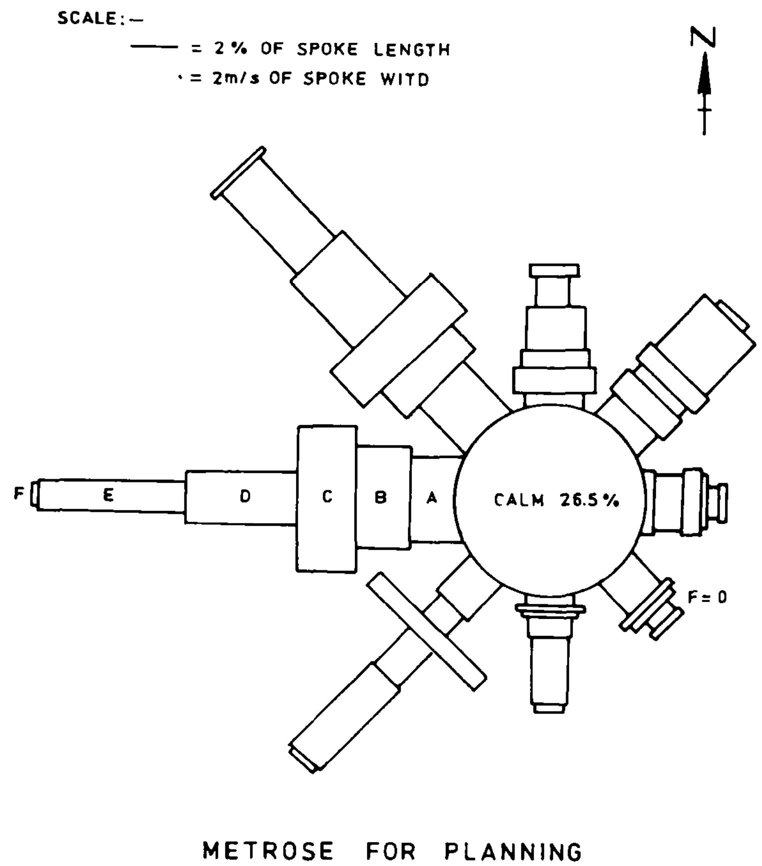

Fig. 2. A metrose as explained in the text ideally suited for modeling due to the well-resolved data (sum of the stabilities for each direction equals 100%).

average wind speed of each stability class (width of each block in the spoke). For any direction when any stability class is absent it is written as zero near the spoke. The sum of the blocks for any direction will be 100% in this case. If, however, the data resolution is not required, the stability persistence can also be represented as the percentage variation for the total time period of the metrose rather than for the fractional time the wind blows from a particular direction. In this second case of the "total" variation the length of the arms itself indicate the percentage occurrence of the wind from that direction and the lines within the circle are not required. Hence for this the total of the stability occurrences for all the directions and the percentage occurrence of calm should equal 100%. Figure 3 is obtained accordingly.

The metrose can thus be generated from a data set which is generally available on a routine basis. Also it can be noted that metrose can be "drawn" from the software packages that "draw" a windrose, with slight modifications in the program as per requirements.

ADVANTAGES OF A METROSE

On comparing Figs 1 and 2 which are plotted for the same data (of one month), it is quite difficult to give a relative "ranking" to the directions in order of their vulnerability for possible concentration build-up using a windrose. However, a relatively correct "ranking" can be given by the metrose understanding the combination of the stable atmospheric conditions and the lower wind speed and their nexus with higher concentrations. This is important in terms of spatial planning. Additionally, Fig. 3 is obtained for seasonal meteorological data and is quite explicit in delineating the persistence of the meteorological parameters for every direction, and can be more useful for spatial planning as compared in Figs 1 and 2.

Another, important application of meterological parameters is in design of air quality models for spatial planning. Thus, the data from the metrose can also be used for estimating the locations of the maximum concentration points (X_{max}) and the location of the critical distance for any particular industrial pollutant source of physical stack height h. Any of the available formulae for (X_{max}) can be used like from Pasquill and Smith (1978)

$$X_{max} = (h/1.414c)^{1/d} \quad (1)$$

where c and d are the constants defining the vertical dispersion coefficient σ_z. After calculating the X_{max} for each stability class the critical distance for a direction can be estimated from the matrix

$$X_{critical} = [P_A, P_B, \ldots, P_F] \cdot [X_A, X_B, \ldots, X_F]^T \quad (2)$$

where P refers to the percentage occurrence of the stability divided by hundred with the suffix indicating the stability and X is the corresponding distance of maximum concentration location as estimated from equation (1) and T indicates the transpose of the latter matrix. The lower the critical distance the higher would be the probable vulnerability of the direction. This thus reduces the subjective interpretation of the "ranking" to the directions.

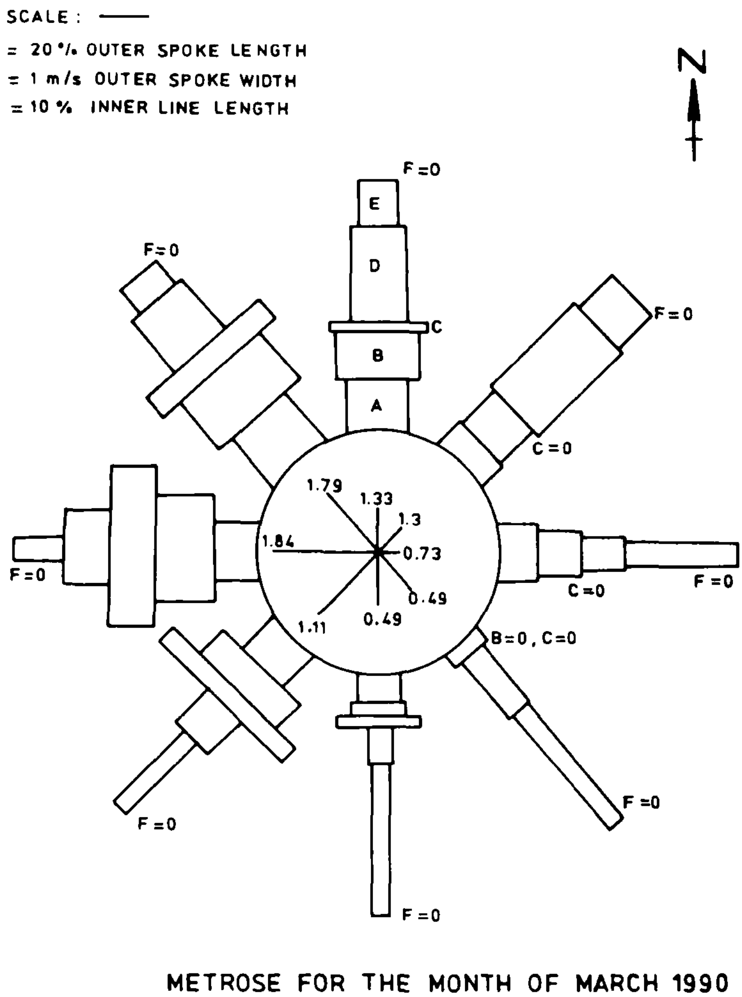

Fig. 3. A metrose ideally suited for spatial planning.

Metrose has another advantage in that unlike the windrose, it is well-suited for dispersion modeling and can be directly used for data input as all the essential parameters can be deduced. Further, the metrose uses the average wind speed without assigning it different classes and hence has the option of not including the "zero class" or the "calm" which cannot be analysed from the presently available models. The Gaussian model gives the ground level concentration (C) on the plume centerline as

$$C = Q/(2\pi\, u\, \sigma_y\, \sigma_z). \quad (3)$$

For a known source strength (Q) the concentration of the pollutant can be easily estimated by knowing the atmospheric stability and the dispersion coefficients while the wind speed (u) for that stability class is already known from the metrose. Then from a matrix similar to equation (2) the effective concentration of the pollutant is estimated as

$$C_{eff} = \{[C_A, C_B, \ldots, C_F].[P_A, P_B, \ldots, P_F]^T\}.P_{direction} \quad (4)$$

where C refers to the concentration (as from equation (3)) and P is same as in equation (2). The product of the two matrices is finally multiplied by the actual percentage of the wind blowing from the direction (indicated by $P_{direction}$) divided by 100. Thus a metrose can also be used for quick estimation of the pollutant transfer from a known source to a point of interest.

CONCLUSION

The metrose described is overall more explicit than the windrose. It could be particularly useful for developing countries with poor resources which widely rely on windroses for initial estimations and can yield fast yet reliable methods for planning.

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