Direction and Velocity of Surface Wind in Bangkok

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Abstract

Surface wind is one of the most significant climatic elements in building design pertaining to low energy cooled housing. The surface wind velocity in Bangkok was analyzed statistically in order to develop simple correlations to determine the hourly surface wind velocity. Correlations were developed based on hourly data from the last decade (1991-2000) recorded by Bangkok meteorological observation station. Surface wind velocity estimation was conducted using a regression technique with a periodic function. Correlation coefficients were in the range of 0.88-0.97. Additionally, frequency distribution curves and monthly surface wind directions were generated and graphically presented.

Kewords: surface wind, low energy cooled housing, regression technique, periodic function, correlation coefficients,

1. Introduction

The motions of the atmosphere exist at various spatial scales ranging from thousands of kilometers down to fractions of a centimeter. Correspondences exist between spatial scales and time scales. Various scales of climate reflect the cascade of energies. Actually, the main climatic scales refer to the macro, regional, meso, local and micro scales. Surface terrain influence a very close control upon the pattern of airflow, particularly within the lower few thousand meters of the atmosphere (the boundary layer) [1]. Exell R. H. B. [2] stated that the principal features of the low-level circulation patterns create the climates of tropical and subtropical Asia (January circulation pattern and July circulation pattern). Generally, the upper atmospheric circulation affects the lower one. In Asia, monsoon plays an important role on low-level wind. During the summer the whole Asian continent is heated considerably while during the winter it is subjected to strong cooling. Thus, in the early summer the temperature contrast between the Asian continent and the surrounding seas increase. This is the start of the southwest monsoon. From this time on, Asia receives most of its precipitation. In fact, the release of the latent heat of condensation is an important driving force in the whole monsoon circulation. When the Asian continent starts to cool and the southwest monsoon dies away (during the winter), there is instead an outflow of colder and drier air. This northeast monsoon bring dry weather, except in the mountains in southeast Asia, where rain occurs during the winter [3].

Concerning wind, there are many local factors that affect the wind at a particular place. Some of these effects on low-level wind are due to a roughness change, e.g. from sea to land, others are due to changeable aerodynamic characteristics of different terrain features. Moreover, the flow change depends on changing thermal properties, e.g. sudden heating or cooling from below [4].

The climate of Thailand is classified as tropical which is commonly known as hot and which is humid. Discomfort due to heat and humidity is the dominant problem. Wind is one of the climatic elements, which affects comfort inside a building. Wind has a twofold influence on the thermal system of a building by the thermal surface resistance and the ventilation rate. With open windows, outside wind speed also influences the air movement inside a room, affecting therefore the thermal comfort. Thus, the knowledge of wind direction, speed and frequency throughout the year is an important factor to consider as it can effectively negate the discomfort arising from high humidity and temperature [5].

Researches studying outdoor winds in Thailand started being conducted in 1984 by Suwantragul B. and Sitathani K. [6]. Thailand wind data have been analyzed statistically using data from meteorological station over a period of 15 years (1966-1978 and 1981-1982) in order to determine wind velocity distributions. The data were normalized to 10 meters using logarithmic law. Calm conditions were analyzed with respect to the topography of Thailand. Weibull shape in the non-calm period and Weibull scale parameter were also investigated. Furthermore, annual mean wind velocity, power density and Weibull parameter maps were developed. Extensive review of wind analysis was also reported on [6]. Later, Exell R.H.B. et al. [7] assessed the degree of wind potential at a height of 600 meters. The results have been used to indicate wind energy potential at favorable sites in Thailand. Details on relation between wind velocity at the surface and above the boundary layer in Thailand and India were published by the Asian Institute Technology (AIT) [7].

Recently, the Department of Energy Development and Promotion (DEDP), Ministry of Science, Technology and Environment (MOSTE) [8] has assessed the potential of wind resources in Thailand. The project was supported by the National Energy and Policy Office (NEPO). Wind data were obtained from various sources, for instance, meteorological department, DEDP, Electricity Generating Authority of Thailand (EGAT), Royal Thai Air Force, Royal Thai Navy, National Climatic Data Center (NCDC) which is one of the units of the National Oceanic and Atmospheric Administration (NOAA), Satellite data, National Research Council of Thailand (NRCT) and Unocal (Thailand) Ltd. The data were first qualified under the World Meteorological Organization (WMO)'s regulation before loading them into computer software MS Excell™ and Windmap™. Next, surface wind, offshore wind, wind data along the coast line of the Gulf of Thailand and upper wind data were analyzed statistically in order to produce graphically the frequency of wind velocity and direction. A wind potential map was developed based on the Numerical Objective Analysis of Boundary Layer (NOABL). This assessment, in fact, was aimed at investigating the potential of wind for power generation in Thailand. The frequency of wind velocity and direction excluding and including calm, K-shape parameter and C-scale parameter were also analyzed. The results of surface wind analysis indicated that most of surface wind occurred during the day and reached the maximum around 1 p.m.. The extent of the surface wind velocity, excluding calm was about 1.8-3.4 m/s.

Although informative, the usefulness of the pervious studies is limited as they do not provide any simple correlation to determine surface wind velocity at any time of the year. In fact, such information is important, for example, for building simulation, outdoor energy system analysis, site selection, etc. Moreover, the measurement of wind velocity and direction at site location is expensive. Therefore, the purpose of this study is to develop simple correlations to determine the hourly surface wind velocity.

2. Methodology and Data Analysis

A preliminary analysis of hourly surface wind data indicates that its main characteristic is periodicity. Thus a sine function was used to fit curve surface wind data at 11-m height recorded by the Bangkok Meteorological Department during the last decade (1991-2000). Simple statistical analysis and regression technique were adopted for data handling as follows:

Preliminary data were transformed into approximate format before loading into computer software (Statistica 5.0).

The hourly surface wind velocity and direction data were used to generate the monthly wind frequency distribution and wind map, whereas the monthly mean daily surface wind data were used in regression.

The periodic function used in the regression analysis is given below.

$$v(t) = v_{mean} + a \cdot sin[\omega \cdot (t + b)]$$

Where $v(t)$ is surface wind velocity at an arbitrary time (t) of the day (t in hr), v_{mean} is mean surface wind velocity (m/s), $\omega = \frac{2\pi}{24}$, and a and b are regression coefficients.

3. Results and Discussion

The results of annual and monthly maximum, minimum and mean wind velocity are given in Table 1. Regression coefficients (a and b) and correlation coefficients (R) for each month are given in Table 2.

Table 1. Maximum, minimum and mean wind velocity in Bangkok for the whole year.

Period	Vmax m/s	Vmin m/s	Vmean m/s	SD
Jan	2.3	0.3	1.07500	0.56280
Feb	2.5	0.6	1.43333	0.64246
Mar	2.8	0.7	1.84167	0.69402
Apr	2.5	0.5	1.55000	0.66201
May	2.2	0.3	1.24167	0.63309
Jun	2.3	0.3	1.26250	0.72521
Jul	2.4	0.3	1.31667	0.73937
Aug	2.3	0.4	1.28750	0.70545
Sep	1.8	0.2	0.92500	0.57502
Oct	1.8	0.3	0.88333	0.52558
Nov	2.1	0.5	1.07500	0.56971
Dec	1.6	0.4	0.90833	0.44907
Annual	2.2	0.4	1.23750	0.60059

Figure 1 (a) and 1 (b) illustrate the regression for each month. It can be seen that a simple periodic relationship between surface wind velocity correlates with the mean hourly data. Therefore, it can be used to predict representative hourly surface wind velocity at any time of the year.

Wind velocity frequency distribution curves and wind direction map are shown in Fig. 2 (a) and 2 (b). From the wind velocity distribution curves, it can be seen that most of wind velocity occurs in the range of 1-3 m/s. The minor degree of wind velocity is above 4 m/s. Also, high wind speed is much less frequent.

Table 2. Annual and monthly regression coefficients and correlation coefficients.

Period	a	b	R*
Jan	-0.68714	3.32146	0.88191
Feb	-0.79471	3.02296	0.89349
Mar	-0.89711	2.17187	0.93368
Apr	-0.88684	1.93007	0.96762
May	-0.85681	2.21390	0.97757
Jun	-0.98340	2.82319	0.97948
Jul	-0.99502	2.86094	0.97207
Aug	-0.95193	3.08825	0.94769
Sep	-0.0.77215	3.10651	0.96993
Oct	-0.68819	4.21121	0.94579
Nov	-0.73658	4.67600	0.93389
Dec	-0.58303	5.04446	0.93778
Annual	-0.79381	3.05878	0.95470

R* = Correlation Coefficient

The wind direction map shown in Fig. 2 clearly demonstrates the effect of upper atmospheric circulation especially southwest monsoon and northeast monsoon on the surface wind direction. Southwest monsoon plays an important role from May until September, whereas the northeast monsoon effects the surface wind direction from October until February. The southerly wind appears strong in March.

From the results of the analysis above, it can be deduced that the dominant surface wind velocity in Bangkok is 1-2 m/s approximately. Although southern and northern winds are more frequent, there is practically no prevailing wind condition all year round. Such characteristics limit the benefit of the use of wind as a "main" parameter for designing naturally ventilated building.

Consequently, building design recommendations in Thailand should include other alternatives such as solar chimney-based on ventilation system [9-11], which is suitable to integrate in building design especially in Bangk for maximizing the occupant's thermal comfort.

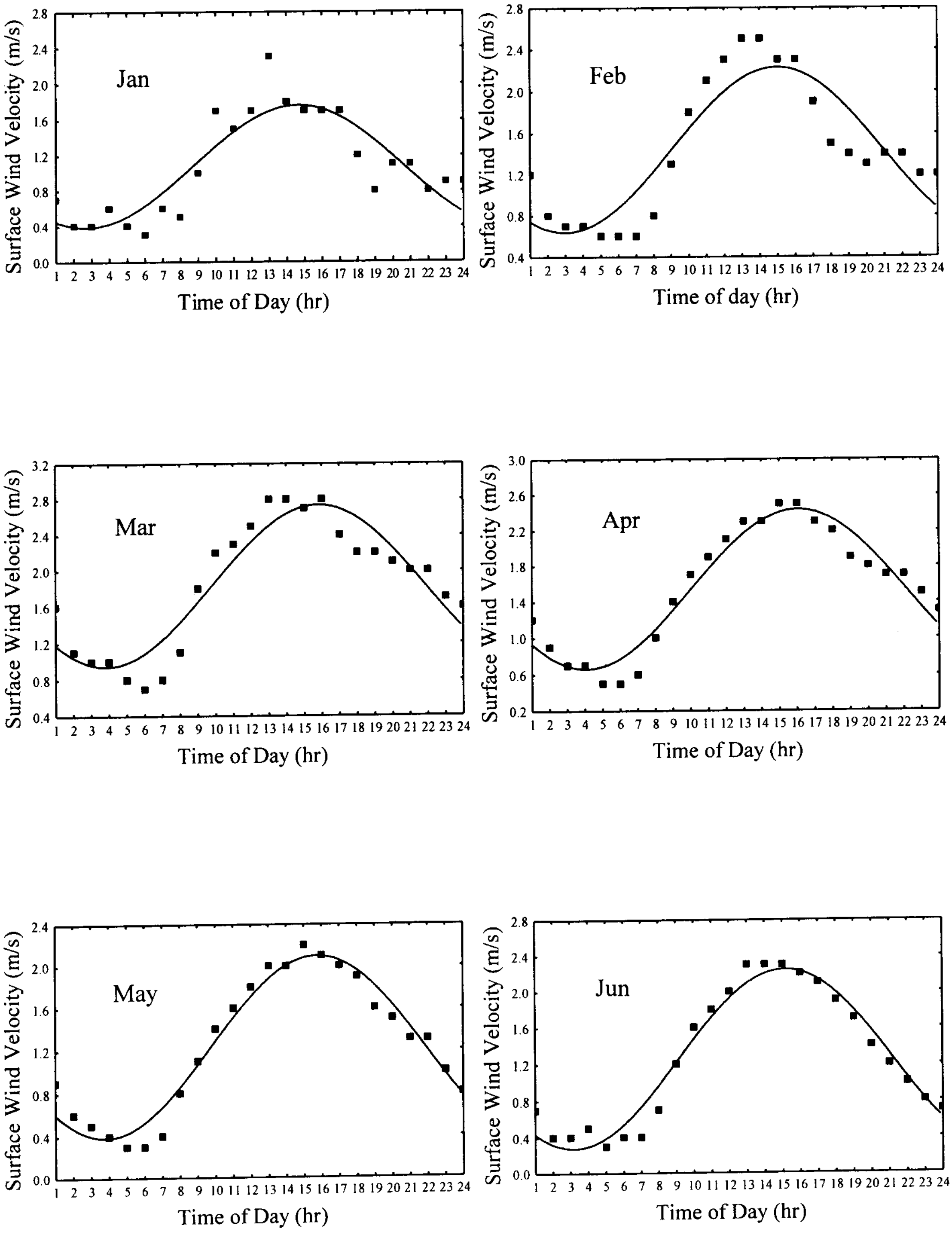

Fig. 1 (a) Hourly mean surface wind velocity (January-June)

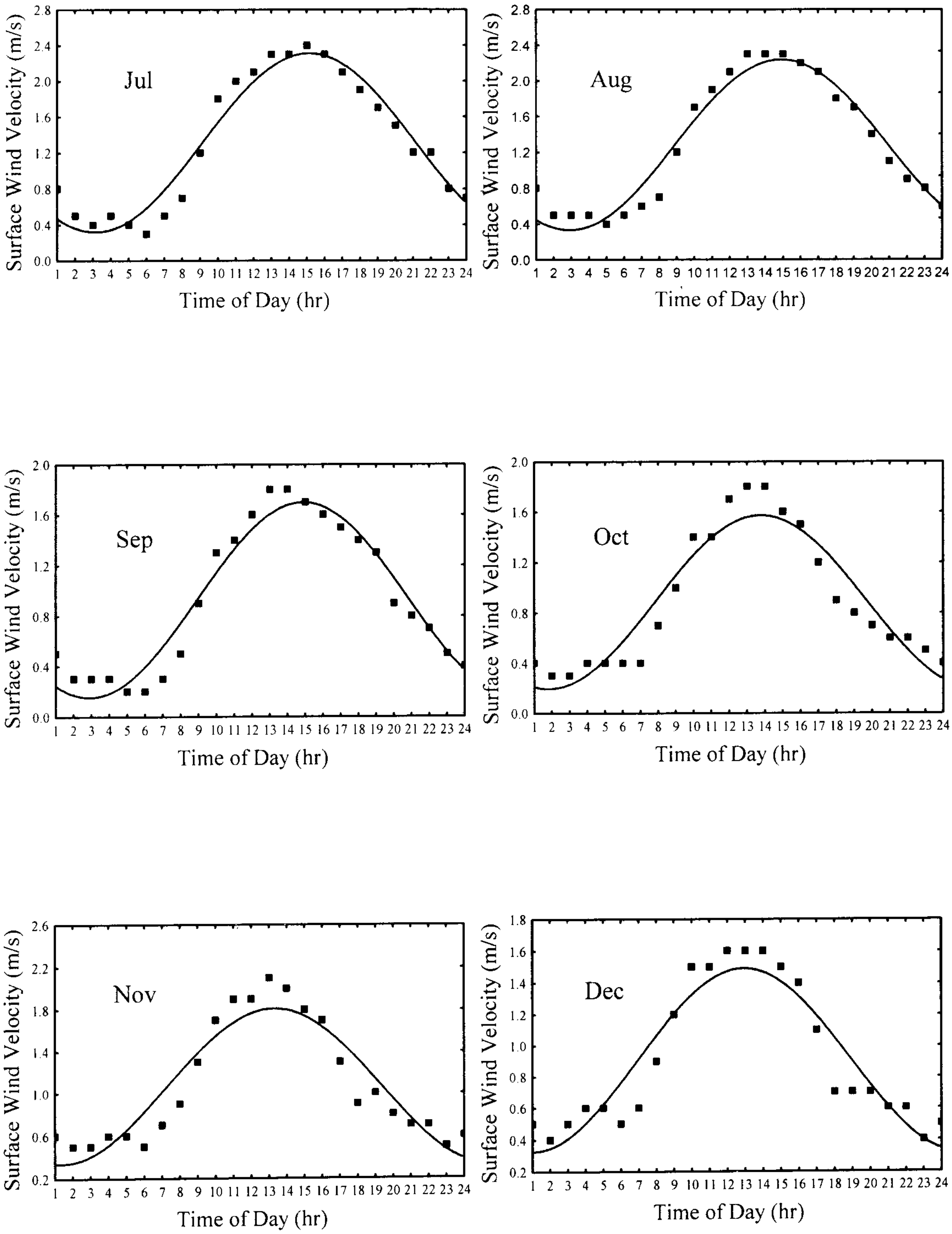

Fig. 1 (b) Hourly mean surface wind velocity for each month (July-December)

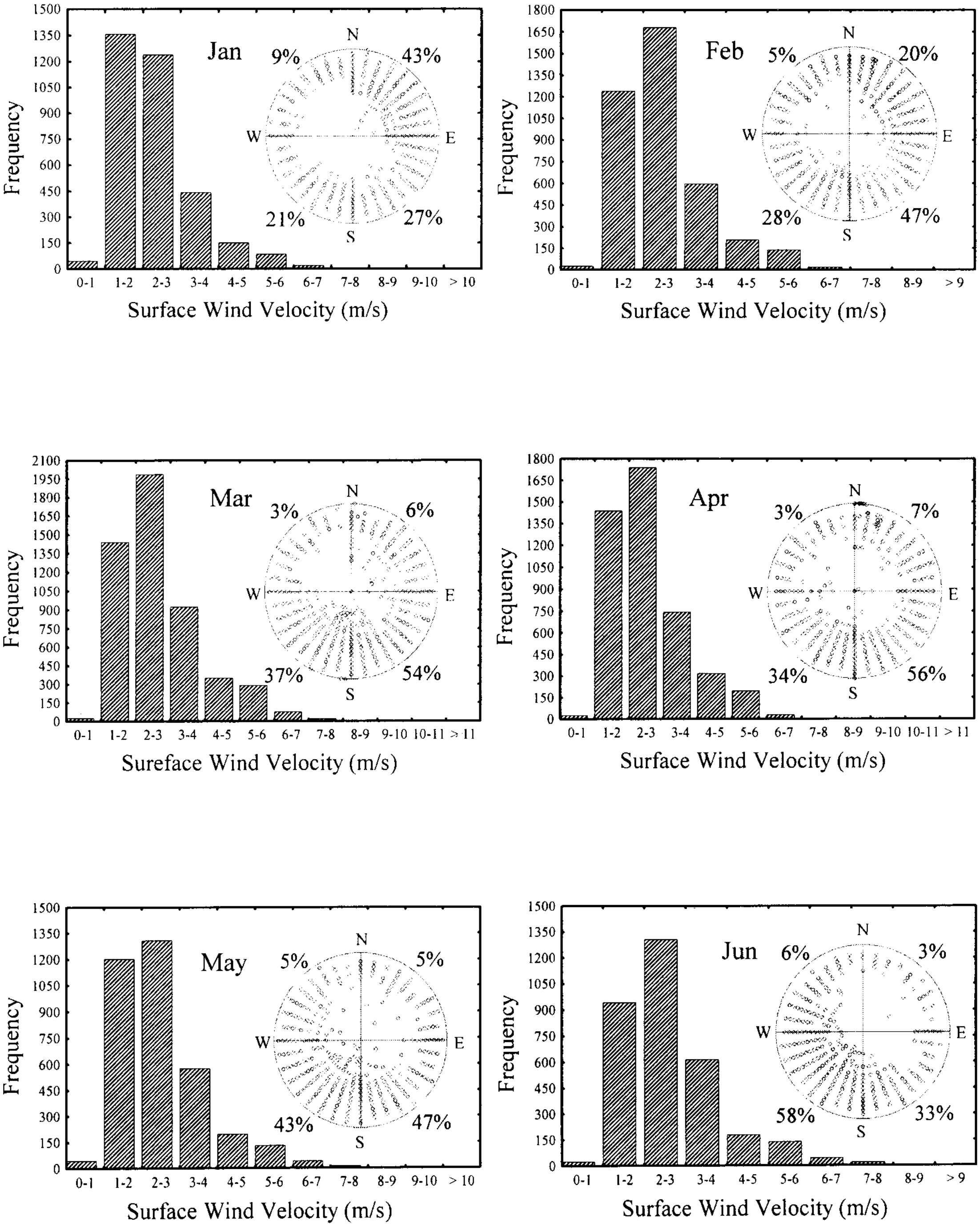

Fig. 2 (a) Surface wind frequency distribution and direction map (January-June)

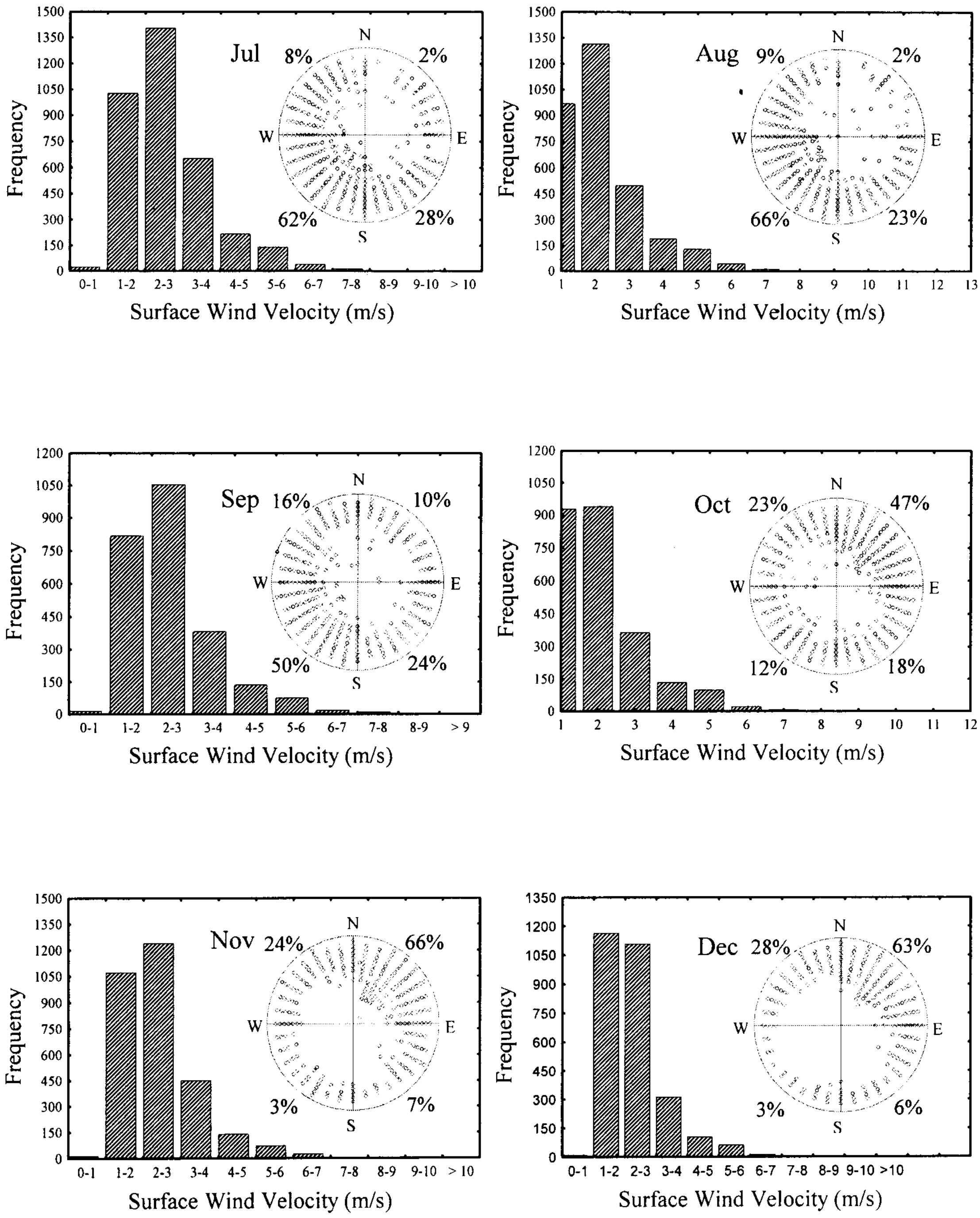

Fig. 2 (b) Surface wind frequency distribution and direction map (July-December)

4. Conclusion

Based on a simple statistical analysis, a correlation for determining surface wind velocity at an arbitrary time of the year was calculated. The direction of surface wind was strongly affected by the southwest monsoon from May to September and northeast monsoon from October to February. Strong southern wind appeared in March. The frequent wind velocity was about 1-3 m/s while the annual mean value is about 2.2 m/s.

This clearly indicated that only wind could not be used effectively to provide significant indoor air motion in Bangkok residential buildings such as single house, row house etc. However, the main benefit from the study is a guidance of building orientation to apply natural ventilation in design with a simple correlation for calculating wind velocity for building simulation.

5. Acknowledgement

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