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On the Annual Change of Surface Wind at Seocheon, Korea

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The characteristics of the basic statistics and steadiness of wind and the monthly normality test of surface wind distribution are investigated by using the observed wind data compiled from 10m meteorological observation tower at Seocheon district, where is located in the western coastal region of Korea, during the period from Feb. 7, 1996 to Feb. 7 1997. The northerly is appeared to be even in August and Sepember due to the influences of local circulation such as land and sea breeze. The correlation coefficients(γ_{uv}) between two wind components are seemed to be positive during the in the period of from June to September and negative from October to April, respectively. The constancy of wind is high in winter and low in summer. It is evident that the modal values of S decrease and their maximum values shifts to lower values with increasing sampling time. It is found from monthly normality test based on the skewness and the excess of kurtosis coefficients that the distribution of zonal wind component is normal in spring and meridional one is normal in late summer and early autumn.

Key words : basic statistics, wind steadiness, normality test, surface wind, Seocheon district

1. Introduction

The variability of wind direction, wind speed and dispersion conditions is completely taken into account for the calculation and the prediction of the hourly mean concentration from a continuous point sources. A simple technique(Smith *et al.*, 1967) for estimating dosages for longer time periods involves calculating the concentration for the shorter periods of interest, and expanding the evaluation in time by summation of successive periods. However, this technique cannot be readily used in estimating the worst possible conditions that might accompany a release of material, either accidental or routine, due to the limitation of available data. For periods up to several hours, one may assume that extremely adverse dispersion conditions could exist from any direction, but for longer periods this assumption is unrealistic, and the least favorable conditions are usually determined by the lack of variability in the wind direction.

There are many reports about the basic statistics of the surface and the upper winds such as the correlation of the surface winds among Pusan, Kimhae, and Gadeogdo and the occurrence frequency of sea breeze over Pusan coastal area(Jeon *et al.*, 1994), the monthly steadiness of wind in each level(surface, 850hPa, 700hPa, 500hPa, and 300hPa) in the central part of Korean peninsula by using the routine surface and aerological observation wind data(Kim, 1984). Pleiss(1951) calculated the annual steadiness at several stations in America and showed that its value at high land was greater than that of low land. Schuepp et al. (1963) and Flemming(1964) calculated seasonal change of wind steadiness on high mountains, having shown that it is greater in summer than in winter at Davos, Switzerland and that the maximum value appears in October and the minimum one in August. Maher *et al.*(1964) analyzed and tabulated the estimates of a series of basic parameter of the wind distribution such as the mean direction and the mean speed of wind vector and the wind steadiness in Australia. In view point of the practical use of wind data, the simulation and forecasting of wind speed and wind power at Cheju through the statistical time series model was carried out by Moon et al.(1996). They pointed out that the determination of distribution of wind speed data is very important for building appropriate statistical models for wind speed. There have been numerous studies on mesoscale wind such as the land and sea breeze, coastal wind and on local wind such as the Nopsae wind(Moon *et al.*, 1997).

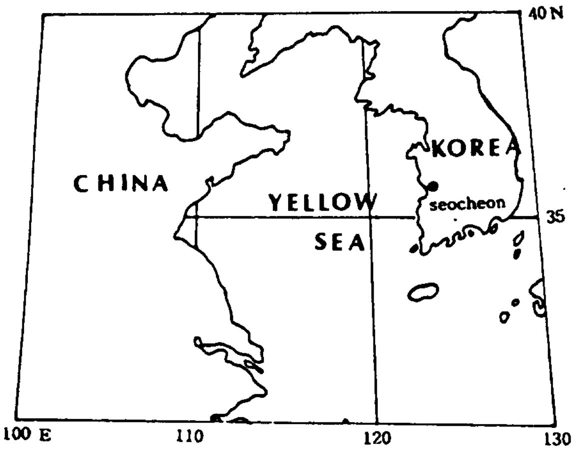

Fig. 1. Location of observation site.

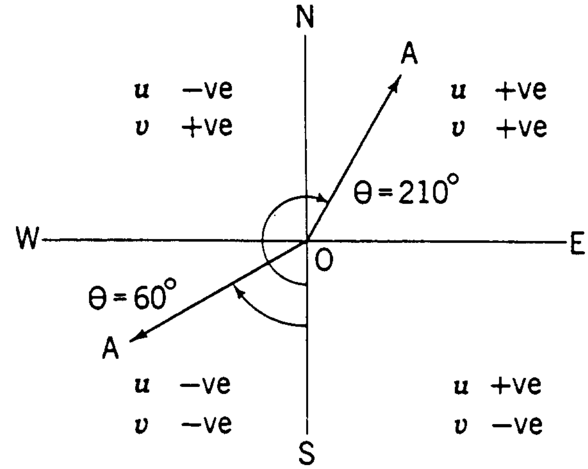

Fig. 2. Representation of wind vector.

On the other hand, through the direct surface and upper meteorological observations, the vertical structure of sea breeze in the western coastal region of Korea, the characteristics of wind within the urban area(MRI/KMA, 1980), the low level strong wind at the downwind side of the Kumjeong mountain, Pusan(Lim *et al.*, 1996), the influences of sea breeze on lower layer atmosphere at Gori nuclear power plant(Jeon *et al*, 1996), and the wind variances of above and within the coastal internal boundary layer at Cheju(Moon, 1994) are investigated. The above-mentioned researches mainly confined in the shorter observed time period less than 2 months. In addition, the fact is that there are only a few studies on the statistical characteristics on the observed wind for long time period in the coastal region in which a potential air pollution problem is high in case of constructing of any new plant or facility. In this paper, therefore, we put focus on the characteristics of the basic statistics as well as the steadiness of wind and the estimation of normality of wind components on the bases of the calculated skewness and kurtosis coefficient data using the hourly observed wind data for 1 year at Seocheon(Fig.1) in the western coastal region, Korea.

2. Data and Method of Analysis

The hourly wind data compiled from the 10m meteorological tower at Seocheon from Feb. 7, 1996 to Feb. 7, 1997 are used in this study. Refering to Fig.2, we have a wind vector(wind speed, V) represented by $\vec{OA}$. Then if u and v are W-E wind component and N-S wind component, respectively, we have $u=-V\sin\theta$ and $v=-V\cos\theta$ where θ is determined from Artan $(\bar{v}/\bar{u})$. The various basic statistics for samples of n observation may be defined as follows:

The standard vector deviation of wind and the correlation coefficients between W-E and N-S wind components can be defined by

$$s_V = \left(\frac{\sum V^2 - n\bar{V}^2}{n-1}\right)^{1/2} = (s_u^2+s_v^2)^{1/2} \quad (1)$$

$$\gamma_{uv} = \frac{\overline{u'v'}}{s_u s_v} \quad (2)$$

where $s_u (= ((\sum u^2 - n\bar{u}^2)/n-1)^{1/2})$ and $s_v (= ((\sum v^2 - n\bar{v}^2)/n-1)^{1/2})$ represent the standard deviations of W-E and N-S wind components, respectively.

The covariance of u and v is estimated by

$$\overline{u'v'} = \overline{uv} - \bar{u}\,\bar{v} \quad (3)$$

where

$$\overline{uv} = \sum(uv)/n \quad (4)$$

The skewnesses of W-E and N-S wind components are calculated from

$$(\hat{\gamma}_1)_u = \frac{\sum u^3 - 3\bar{u}\sum u^2 + 2n\,\bar{u}^3}{n s_u^3} \quad (5)$$

$$(\hat{\gamma}_1)_v = \frac{\sum v^3 - 3\bar{v}\sum v^2 + 2n\,\bar{v}^3}{n s_v^3} \quad (6)$$

The excess of kurtosis of W-E and N-S wind components can be defined by

$$(\hat{\gamma})_{2u} = \frac{\sum u^4 - 4\bar{u}\sum u^3 + 6\,\bar{u}^2\sum u^2 - 3n\,\bar{u}^4}{n s_u^4} - 3 \quad (7)$$

$$(\hat{\gamma})_{2v} = \frac{\sum v^4 - 4\bar{v}\sum v^3 + 6\,\bar{v}^2\sum v^2 - 3n\,\bar{v}^4}{n s_v^4} - 3 \quad (8)$$

In this study, the total number of hourly wind samples is about 8,760. It is emphasized therefore that the number of samples used in the calculation of a particular statistic, should always be taken into consideration.

Table 1. The list of basic statistics of the surface wind for each month at Seocheon

Element / Month	θ	$\overline{V}$	$\overline{u}$	$\overline{v}$	s_V	s_u	s_v	n	r_{uv}	q	$\hat{\gamma}_{1u}$	$\hat{\gamma}_{1v}$	$\hat{\gamma}_{2u}$	$\hat{\gamma}_{2v}$
Jan.	309	1.6	1.21	-0.98	2.43	1.59	1.84	744	-0.01	51	0.21	-0.19	-0.09	-0.08
Feb.	310	1.4	1.08	-0.92	3.38	2.30	2.48	690	-0.45	46	0.27	-0.21	-0.12	-0.14
Mar.	314	1.4	1.00	-0.97	3.56	2.57	2.47	744	-0.16	43	-0.01	0.18	-0.98	1.70
Apr.	298	1.3	1.11	-0.58	3.22	2.38	2.17	720	-0.26	43	-0.06	-0.49	-0.59	1.19
May.	271	1.2	1.21	-0.01	2.86	2.05	1.99	744	0.00	47	-0.04	0.84	-0.25	3.04
Jun.	224	1.0	0.69	0.72	3.45	2.33	2.54	720	0.26	35	-0.60	1.38	1.42	3.19
Jul.	202	0.9	0.34	0.86	3.26	2.32	2.29	744	0.13	33	0.37	1.22	-0.45	1.63
Aug.	351	0.6	0.10	-0.62	2.28	1.89	1.28	744	0.02	30	0.34	-0.04	-1.05	1.07
Sep.	355	0.7	0.06	-0.66	2.10	1.69	1.25	720	0.02	35	0.69	0.09	-0.61	1.98
Oct.	311	1.3	1.01	-0.87	2.03	1.66	1.17	744	-0.12	48	0.68	0.05	-0.58	1.08
Nov.	309	1.5	1.18	-0.97	1.94	1.61	1.09	720	-0.08	49	0.65	-0.08	-0.23	0.09
Dec.	308	1.7	1.31	-1.01	2.50	1.58	1.94	744	-0.09	51	0.59	-0.23	-0.11	-0.02

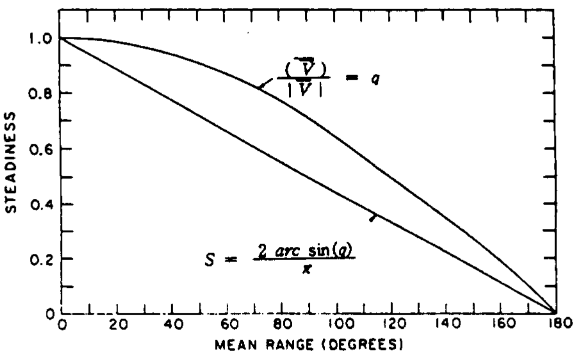

Fig. 3. Variation of S(steadiness) with mean wind direction range(Singer, 1967).

In many atmospheric diffusion problems, a description of the steadiness of the wind direction is desired. For intervals of approximately an hour the mean wind direction is usually well defined and constant, but for longer intervals this may not be so, and a description of the variability of the mean direction with time is needed. It is proposed that the constancy of the wind(q), defined as the mean vector wind divided by the mean scalar wind

$$\frac{(\vec{V})}{|V|} = q, \qquad (9)$$

can be used for simple classification purposes. The constancy(q) of the wind is shown in Fig. 3. A value of unity designates that the wind direction has not changed over the averaging period and a value of zero suggests a completely symmetrical distribution. In this paper, a trigonmetric transformation is used to linearize the variation of constancy with the mean angular range of direction. This function, called the "steadiness" S,

$$S(steadiness) = \frac{2\ \text{arc}\ \sin(q)}{\pi} \qquad (10)$$

is then computed for various time intervals. Angular deviations varying from 0 to 180° show the nonlinear decrease of q with the mean angular range. Thus, a change of 0.1 in S is represented by a deviation of 18° as shown in Fig. 3.

3. Results

3.1 Basic Statistics

In order to examine the statistical characteristic of wind in the coastal region, i.e., at Seocheon district, we analyzed the basic statistics of hourly wind data. Table 1 shows the list of basic statistics of the surface wind for each month at Seocheon. For the direction of monthly mean wind vector, the northwesterly prevails during the period of October to April, while the southwesterly is dominant in June and July. The northerly is appeared to be even in August and September which the southerly is thought of the prevailing wind due to the influence of summer monsoon circulation. It can be also seen that the wind speed of monthly mean wind vector is the strongest(1.7m/s) in January and the weakest(0.6m/s) in August. The zonal component($\overline{u}$) and the meridional component($\overline{v}$) of wind represent the westerly (easterly) and southerly(northerly), when they are positive(negative). In the zonal wind component, the westerly is seemed to become more dominant than the easterly throughout the year. It can be found clearly that the strongest westerly appears in December with 1.31m/s and the weakest in September with 0.06m/s, judging from the hourly wind data at 10m meteorological tower at Seocheon during one year. In addition, the meridional wind component is the strongest(0.86) in July and the weakest(-1.01) in December. The standard deviations of wind vector are somewhat larger during the period of February to July with a maximum of 3.56m/s in March than during that of from Au-

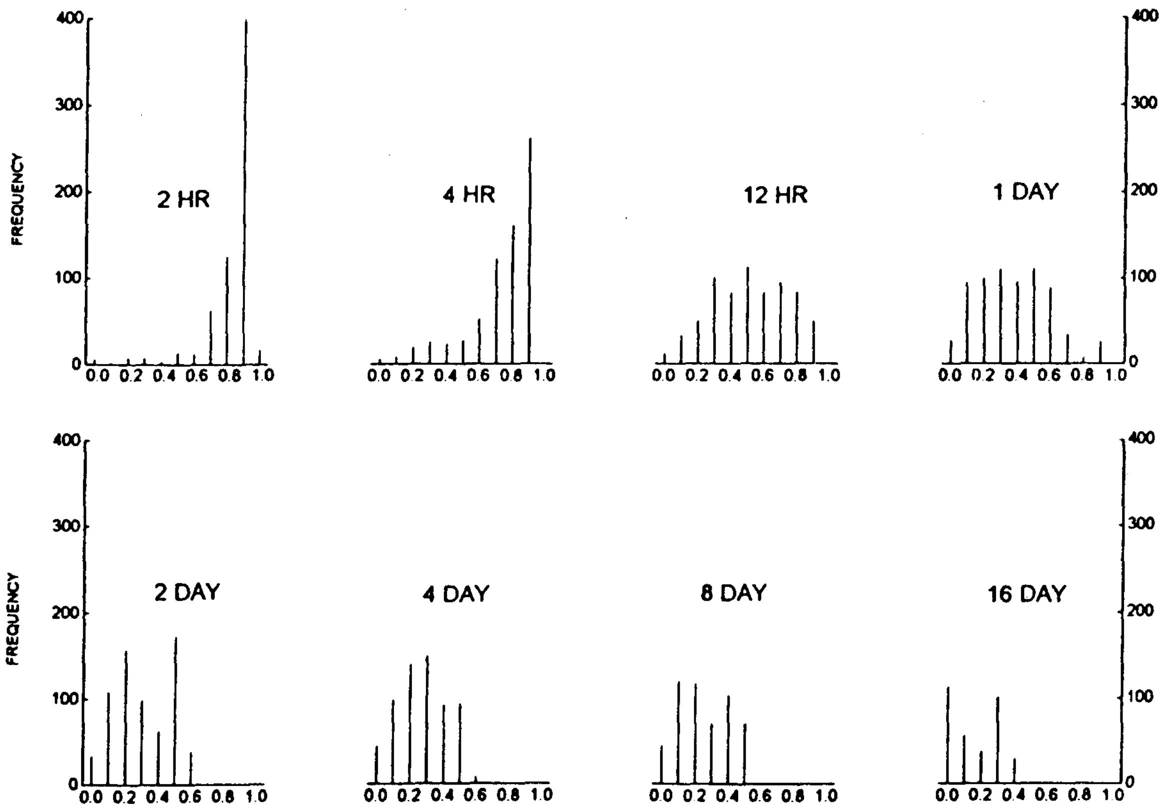

Fig. 4. Mean frequency distributions of values of S for various time periods at Seocheon.

gust to January with a minimum of 1.94m/s in November. The standard deviation of zonal wind component, is appeared to be the largest with 2.57m/s in March and the smallest with 1.58 in December. There are the highest(2.54m/s) in June and the lowest(1.09) in November in case of the standard deviation of meridional wind component. It is suggested from these results that the standard deviations of wind vector in warm season (April~September) are higher than those in cold season(October~March) due to the influence of persistent northwesterly inflowed toward observational site in cold season. The correlation coefficients between two wind components(γ_{uv}) appear to have the positive value from May to September and the negative one from October to April. This means that the southwesterly prevails in former period and the northwesterly in latter period, respectively.

3.2 Steadiness of the Wind

As seen in Table 1, the constancy of wind(q) is generally high in winter and low in summer. In particular, it is shown that the constancy of wind vector(q) is at a maximum with 51% in December

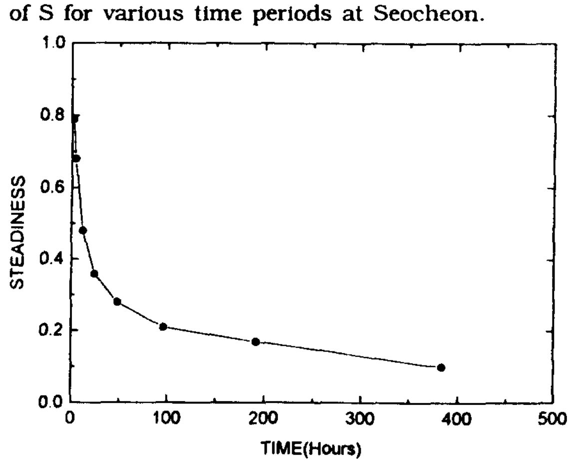

Fig. 5. Progression of the mean values of S for various averaging times at Seocheon.

and January, and at a mininum with 30% in August. It can be found that these results are similar to those of previous studies(Kim,1984). In this section, we'd like to apply a meteorological evaluation technique known as steadiness, a tool to examine the fluctuations of wind direction in the coastal site as function of time. Fig. 4 shows the mean annual distributions of S for 2, 4, and 12 hours as well as for the periods ranging from 1 to 16 days.

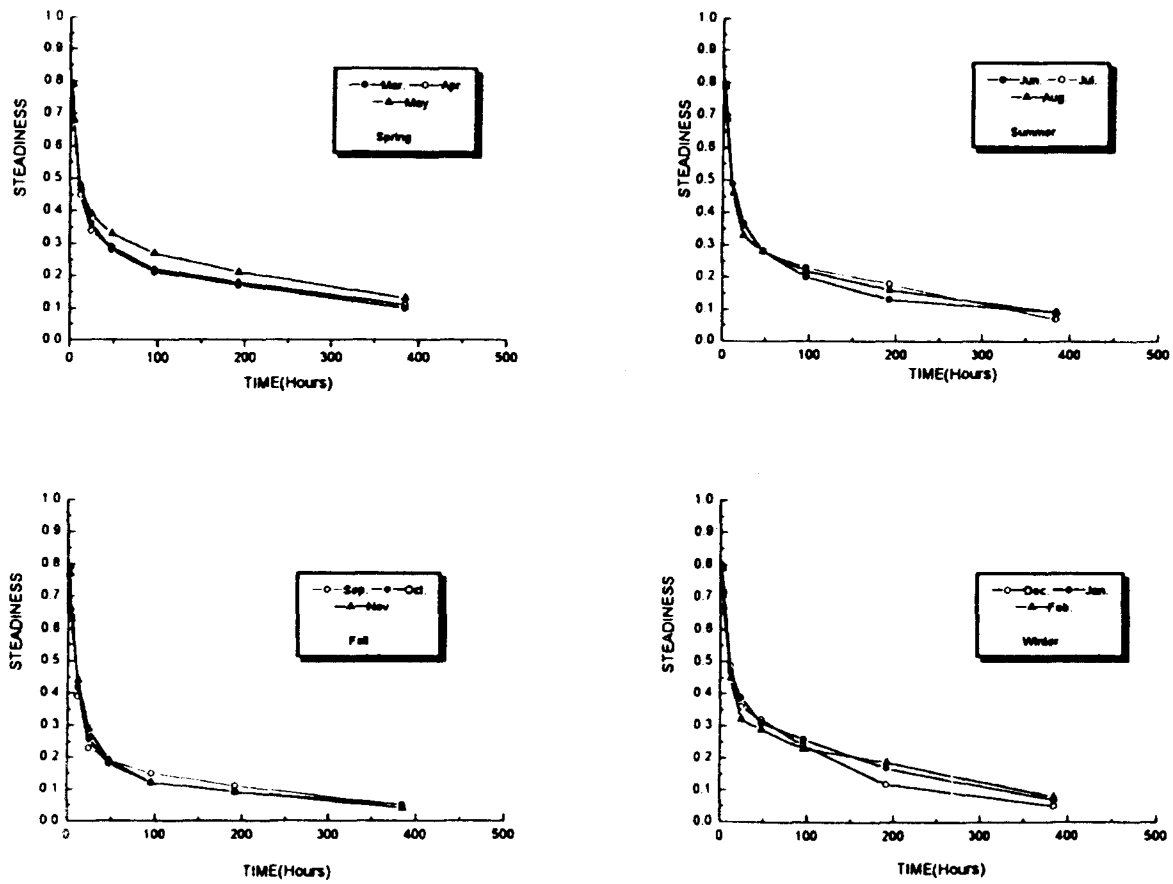

Fig. 6. Same as Fig. 5 except for each season.

The individual characteristics of distributions are described as follows:

In case of S=0.9 and 2 hour time period, the 62.8% of all cases are occupied. Considering the values of S greater than 0.7, we can find that the occupation percentage of all cases is 91.2% with the mean range of wind direction from 0 degree to 54 degree. This means that the mean range of wind direction is significantly small during 2 hours. The 4-hour plot is similar to the above-described distribution. However, there is a slight shift of the maximum value toward lower values with S=1.0 disappeared. The values of S greater than 0.7 is occurred with 75.6% of all cases. For the longer time periods than 4 hours, the fundamental distribution patterns are converted to an approximate Gaussian distribution. There is, however, a time lag by about 12 hours, compared with the results obtained from hourly values of wind direction and speed from the 300-ft level of the Brookhaven National Laboratory(BNL) meteorological tower for five years(Singer, 1967). The number of cases for 12-hour time period is appeared to be 7 times for S=0.0. For period from 12 hours to 2 days, the maximum frequency is shifted toward lower values, especially in case of S=0.5. It is shown from the 1-day distribution of S values that the mean range of wind direction mainly occurs beyond 90 degrees.

It is evident that the modal values of S decrease and its maximum value shifted to lower values is predominate with increasing sampling time. An important feature, however, is that the values of S greater than 0.7 don't exist at all periods up to 4 days.

Progression of the mean values of S for various averaging times at Seocheon is shown in Fig. 5. There is a sharp decrease of S with a time between 2 hours and 24 hours. For longer time period than 1 day, the decreasing rate of S becomes small the mean range of wind direction is over 90 degrees with its center be about 12 hours. From the results that the mean of S value is appeared 0.79 and 0.48 for 2 hours and 12 hours averaging time, respectively, we can find that. In addition, the largest difference of the decrease of S is revealed at a time between 4 hours and 12 hours averaging time to the value of 0.2.

Fig. 6 shows the seasonal progression of the mean values of S for various averaging times at Seocheon. The large decrease of S for 12-hour averaging time still don't occur. However, there are some differences of S in case of the longer averaging times than 12 hours. For example, the values of S in May are found to be higher than those of March and April. This means that the variation of wind direction in May is smaller than other months over this averaging time. The distribution pattern in summer is similar to that of spring. On the other hand, the values of S are smaller in spring than in summer for averaging times greater than 8 days. For the longer averaging time than 4 hours, the values of S in autumn are somewhat smaller, especially to value of 0.1 for 24-hour averaging time, than those of other seasons. It may be thought that this pattern is close linked with the synoptic situation such as the migrating anticyclonic system. The monthly variation of S in winter are larger than those of other seasons. It can be also inferred that the larger S in winter are associated with the winter monsoonal flow, that is, the persistent northwesterly. Furthermore, the meteorological conditions associated with the large value of steadiness for each season are still to be studied.

3.3 Normality of Wind Components using Skewness and Kurtosis Coefficients

The monthly normal distributions of wind components are investigated by using skewness and the excess of kurtosis coefficients of each wind component. In general, a method of dealing with the problem of testing for non-normality is obviously needed. The chi-squared test has been discarded because of the amount of calculation involved. It also takes into account only the magnitude of the differences between observed and expected group frequencies and not their sign and arrangement. There is also the disadvantage that it is necessary to group together small tail frequencies.

Tests based on estimates of skewness and kurtosis coefficients are more convenient. Departure of skewness from the "normal" value of zero and of kurtosis from the "normal" value of 3 may be used. For large samples, n greater than 200 say, rough tests of normality may be obtained by comparing the sample estimates of γ_1(skewness) and γ_2 (excess of kurtosis) with the approximate values of their standard errors which are respectively $(6/n)^{1/2}$ and $(24/n)^{1/2}$(Brooks and Carruthers, 1953).

The distribution of a series of estimates of skewness calculated from a series of random samples of size from a normal distribution is such that, as an approximation, it may be assumed that, 95 times out to 100, single estimates will lie between -1.96 and +1.96 times 0.09 of the standard error, $(6/n)^{1/2}$ of the estimate of skewness. Based on this 95% range, the distribution of zonal wind component is normal in spring, that is, March, April and May and of meridional wind component is normal in late summer and early autumn, that is, the period of from August to November.

In the case of kurtosis coefficient, the sampling distribution of estimates is markedly skew, so that the approximate standard error cannot be used except as a rough approximation with large values of n. In this study($n \fallingdotseq 730$), the approximate standard error $(24/n)^{1/2}$ of the estimate of kurtosis is 0. 18, and assuming a symmetrical normal distribution, 95% of values should be between -0.36 and +0.36($\pm$1.96 times 0.18). It can be found from the excess of kurtosis coefficients that in winter season the zonal and the meridional wind distributions are generally normal. Generally speaking, the wind in summer is not normal distribution. It may be explained that this is related with the weaker wind speed in summer than in winter.

The results of this study are available for building the time series models, simulating and forecasting hourly wind speed and wind power that is essential for the wind speed distribution as fundamental data.

4. Summary and Concluding Remarks

The observed wind data from 10m meteorological observation tower at Seocheon, located in the western coastal region in Korea during the period of Feb. 7 1996 to Feb. 7 1997 are used to investigate the characteristics of the basic statistics including the wind steadiness and the monthly normality test of surface wind distribution.

The northerly is appeared to be even in August and September which the southerly is regarded as the prevailing wind due to the influence of summer monsoon circulation. This may be explained due to the reason that the observational site is located in coastal region, so local mesoscale circulation such land and sea breeze contribute to the surface wind of 10m meteorological tower. The standard deviations of wind vector in summer season are higher than those of winter season due to the influence of the persistent northwesterly inflowed toward observational site in cold season. The correlation coefficients(γ_{uv}) between two wind components seem to be positive from June to Septermber and negative from October to April, respectively.

In general, the constancy of wind vector is high in winter and low in summer. In particular, it is found that the constancy of wind vector is at a maximum with 51% in December and January, and at a mininum with 30% in August. From the mean annual distributions of S for various time periods, we can find that the mean range of wind direction is significantly small during 2-hour time period. For the longer time periods than 4 hours, the distribution pattern of S is approximately the Gaussian distribution. It is evident that the modal values of S decrease and its maximum value shifted to lower values is predominate with increasing sampling time. In addition, the values of S in autumn are smaller than those of other seasons for the longer averaging time than 4 hours. The values of S in winter is larger and which is associated with the winter monsoonal circulation like the strong and persistent northwesterly.

Through the estimation of normality of the surface wind at Seocheon using the skewness and the excess of kurtosis coeffcients, the distribution of zonal wind component is normal in spring and meridional wind component is normal in late summer and early autumn. The results obtained by using the excess of kurtosis coefficients are very similar to those of skewness.

Finally it is thought that this kind of study is important and useful not only for calculating and predicting the hourly mean concentration of air pollution from continuous point sources where mainly are located in the western coastal region, but also for determining the availability of wind power resources owing to the poterntial for obtaining electrical energy from wind power. Furthermore, the meteorological conditions associated with high values of wind steadiness are still to be studied in the future.

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서천지방의 지상풍 연변화에 관하여

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(1997년 6월 13일 접수)

우리나라 서해안에 위치한 서천지방 연안에 10m 기상 관측탑을 설치하여 1년동안 관측한 바람자료를 사용하여 지상풍의 기초 통계량, 정상도 및 월별 정규성 검정을 조사하였다. 해륙풍과 같은 국지순환의 영향으로 8월과 9월에 조차 북풍계열이 나타났다. 두 바람성분간의 상관계수는 6월과 9월사이, 10월과 4월사이 기간동안에 각각 양(+)과 음(-)의 값으로 나타났다. 바람의 정상도는 겨울철에 높게, 여름철에 낮게 나타났다. 샘플링 시간이 증가함에 따라 S값의 modal이 감소하고 최대 발생빈도값이 S값의 낮은 영역으로의 이동이 뚜렷하게 나타났다. 왜도와 초가 첨도에 기초한 월별 정규성 검정으로 부터 바람의 동서성분은 봄철에, 남북성분은 늦여름과 초가을에 각각 정규분포를 가짐을 알 수 있었다.