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Temporal and Spatial Characteristics of Sea Surface Winds over the Adjacent Seas of Korean Peninsular - Spectral Analysis.

HEUNG-JAE LIE*, JUNG-YUL NA**, and SANG-KYU HAN**

INTRODUCTION

Surface wind field over an ocean plays a· very important role not only to generate wind-driven current, but also to control heat exchange between ocean and atmosphere. However, the surface wind-field used for the ocean circulation and heat exchange is usually estimated by indirect methods because of lack of observed wind data and incomplete spatial coverage. Furthermore, wind data collected at the coastal stations are seriously distorted due to the topographic effect of land and contain significant diurnal signals of land-sea breeze, so the data observed at the coastal stations are not very useful for estimating the wind field on the sea surface in the Korean neighboring seas. The surface wind field over the Korean seas have been studied on the basis of data indirectly estimated (Kim and Choi, 1986; Na et al., 1992; Kang et al., 1994). The previous studies commonly pointed out the outstanding seasonality of the prevailing wind field. However, their spatial structures and magnitude of the local wind fields are not identical, especially for the curl fields. We attempt to investigate basic spatial and temporal characteristics of the wind fields and to compare wind fields of the three different basins, East Sea (ES), Yellow Sea (YS), and East China Sea (ECS) for spatial coherence.

DATA AND PROCESSING

For this study, the database of Na et al. (1992) was complemented to cover the Korean neighboring seas and part of the northwestern Pacific and elaborate methods such as statistical and spectral analyses were applied to the extended gridded time series. The spatial coverage is 20 to 50° N and 120 to 150° E (Fig. 1). The computation of surface wind was performed by Cardon's model. The new database composes of gridded time series for a period of 10 years between 1978 and 1987. The grid spacing is 128 km and the sampling interval is twelve hours, so the data are narrow and short enough to resolve local wind structures and temporal variations with high statistical reliability. The twelve hourly wind data are first spatially smoothed to reduce erroneous values and then low-passed to remove high frequency signals above 0.5 cycles per day (cpd), possibly caused by the land-sea breeze. The land-sea breeze with a periodicity of 1 cpd and amplitude of several m/s is known to be spatially variable around the Korean peninsula and it exceeds sometimes the synoptic wind. The low-passed daily time series

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* Physical Oceanography Division, KORDI, Ansan, 425-600, Seoul, Korea
** Department of Earth and Marine Sci., Hanyang Univ., Ansan, 425-600, Korea

are subject to the basic statistical and spectral analysis. Spectrum and cross-spectrum analysis are made at pre-selected grid points shown in Fig. 1. The piece-average method is used for the spectra.

ANNUAL AND MONTHLY MEAN WIND FIELDS

Spatial patterns of long-term annual mean wind fields over the three basins ES, YS, and ECS are different each other in terms of prevailing direction and strength (Fig. 2). The standard deviation exceeds the mean value, reflecting important variability in time. Prevailing winds over ES is northerly with strong stress of about 0.5 dyne/cm^2 (herafter the unit dyne/cm^2 is omitted) in the northen basin north of 40° N and northwesterly in the southern basin with weaker stress less than 0.4. Northerly winds are predominant over the whole YS and the northern ECS north of 30° N, while over the southern ECS, the northeasterly wind is prevailing. The long-term annual mean has a pattern very similar to the long-term monthly mean during the winter season. This means that the wintertime mean wind field is much stronger than the summertime one. The curl over ES is positive over the northern and central parts, but negative in the Honshu coastal area. Two positive maxima exist in Wonsan Bay and the northeastern ES, The negative curl dominates the whole YS and ECS, with a minimum value in the Chinese coast between the Shantung peninsula and Changjiang River mouth.

Monthly variations of the synoptic wind are examined. Over ES, the northwesterly wind is prevailing from October to April of the following year, with positive curl in the northern area and negative in the southern area. The demarcation zone where the curl sign changes advances toward the south from September through January during the developing phase of the northerly wind, but retreats to the north from January to April during the weakening phase. Over YS and ECS, the prevailing winds in winter are northerly over the northern basin north of 30° N and northeasterly in the southern ECS, and the curl sign is negative. The demarcation zone is also displaced northward or southward between 22° and 28° N, moving to the south (north) when the northerly wind is strengthened (weakened). During the summer season, the prevailing winds are southerly or southeasterly, with mean speed much reduced. The positive curl and large temporal variability over ECS are related to the subtropical wind system, especially to frequent passage of typhoons over ECS during the summer season.

SPATIO-TEMPORAL CHARACTERISTICS

The spectra for the v-wind show that the seasonal change is the most important signal at all grids considered. However, the u-wind has two peaks at 1 and 2 cpy at all grids, though the density level is dependant upon location of grids. The annual variation is found to be more important at grids where the mean wind is stronger. The semi-annual periodicity is significantly high, especially in the southwestern ES and YS, but its spectral energy is not so important as that of the annual cycle. The annual cycle is closely related with the synoptic wind system controlled by the Siberian high pressure and the subtropical Pacific high pressure, while the semi-annual cycle might be expected to represent transit phases during spring and autumn when the Siberian high pressure is at the beginning and extinction phases.

Between winds at the central and northern ES (grids E3 and E1), the coherence for the v-wind is significantly high with small phase difference over the full range of frequency, with an exception of frequency band of 0.02-0.06 cpd, but the coherence for the u-wind is significant only at of 1 and 2 cpy, with relatively large phase differences. Between the central and southern ES (E3 and E4), the coherences for both winds are much higher than the confidence limit over the full frequency range, with slight phase differences. This indicates that the central and southern ES is under influence of the same wind system. For the western and eastern ES (E5 and E6), the v-winds are significantly correlated in frequencies lower than 0.01 cpd and higher than 0.1 cpd, but the u-winds are highly correlated over the long distance in the east-west direction in the full range. In YS, the v-wind is well correlated along the north-south line (grids W1, W2, and W3), but the u-wind between the western and eastern YS (W5 and W6) is significant only in the low frequencies less than 2 cpy. The u-wind is correlated along the north-south line, but the coherence is lower than that for the v-wind. It is noteworthy to see that the u-winds at W5 and W6 are closely correlated with higher coherence than that for the v-wind.

YS and ES are geographically separated by the north-south stretch of the Korean peninsula. Spatial correlation between YS and ES are estimated for two pairs of grids, W1-E1 and W2-E3 (Fig. 3). The v-wind at 1 cpy is spatially very coherent with no phase difference, but the u wind is significantly high only at the two peak frequency with certain phase difference. The u wind at E1 advances that at W1 for 1 cpy, but lags behind W1 for 2 cpy. For the pair of W2 - E3, the situation is reversed: the u-wind at E3 lags behind that at W2 for 1 cpy and advances W2 at 2 cpy. For winds over YS and ECS which are not disturbed by the Korean peninsula, the v-wind at 1 cpy is highly coherent with a very slight phase difference, even over a large distance between two grids W2 - W4. The u-wind at 1 and 2 cpy is also spatially correlated with phase difference of about 90 degrees. The u wind at W4 advances that at W2 at both frequencies, which is different from the case for YS and ES. One remarkable feature is that for pairs of W1-E1 and W2-E3, phase increases linearly with frequency in the high frequency range larger than 0.02 cpd. Furthermore, the phases of both wind components are nearly the same over the frequency range. The linear increase in phase is observed only for the two pairs of grids separated by the Korean peninsula.

CONCLUSION

The spatial patterns of long-term annual mean wind stresses and curls have a strong resemblance with the long-term monthly mean structures during the winter season. The annual variation is the most pronounced periodicity, explaining for most of temporal variability. The synoptic wind field, dominated by the annual cycle is spatially very coherent over the neighboring seas, but its basin-scale pattern differs to some extent from one basin to another one. The semi-annual periodicity is characteristic of the synoptic winds over the study area. Its contribution to the total variance in time is much smaller than the primary annual cycle, but u-winds are found to be locally affected by the secondary periodicity, especially in YS and the southern ES where its spectral density is comparable to that of the annual periodicity. The semi-annual periodicity may reflect transit phases in spring and autumn of the synoptic winds controlled by the Siberian and subtropical high pressure systems. The wind at 2 cpy is characterized by a negative curl. Therefore, the semi-annual periodicity may be closely associated with moving high pressures crossing the Korean peninsula during the transit periods, though sophisticated analysis is required to elucidate this point.

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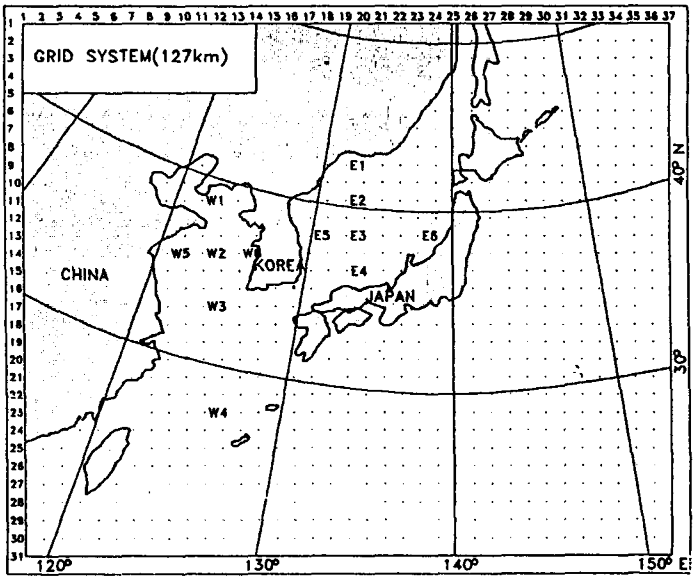

Fig. 1. Study area and grid system for computation of sea surface wind. Grids E1-E6 and W1-W6 are selected as representative ones for spectral and cross-spectral analyses.

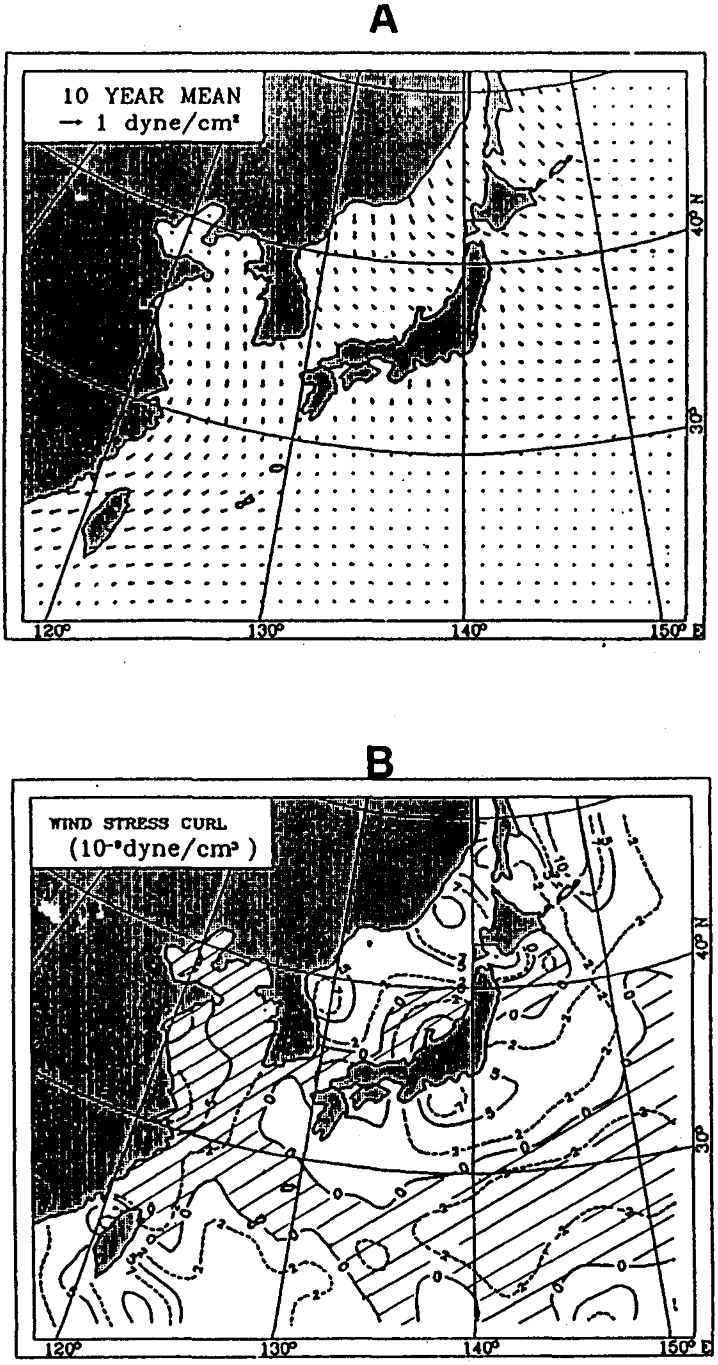

Fig. 2. Long-term means of surface wind stress and curl over the Korean neighboring seas. (a) wind stress and (b) wind stress curl. Units are dyne/cm^2 for stress and 10^{-9} dyne/cm^3 for curl. Shaded area in (b) indicates negative curl.

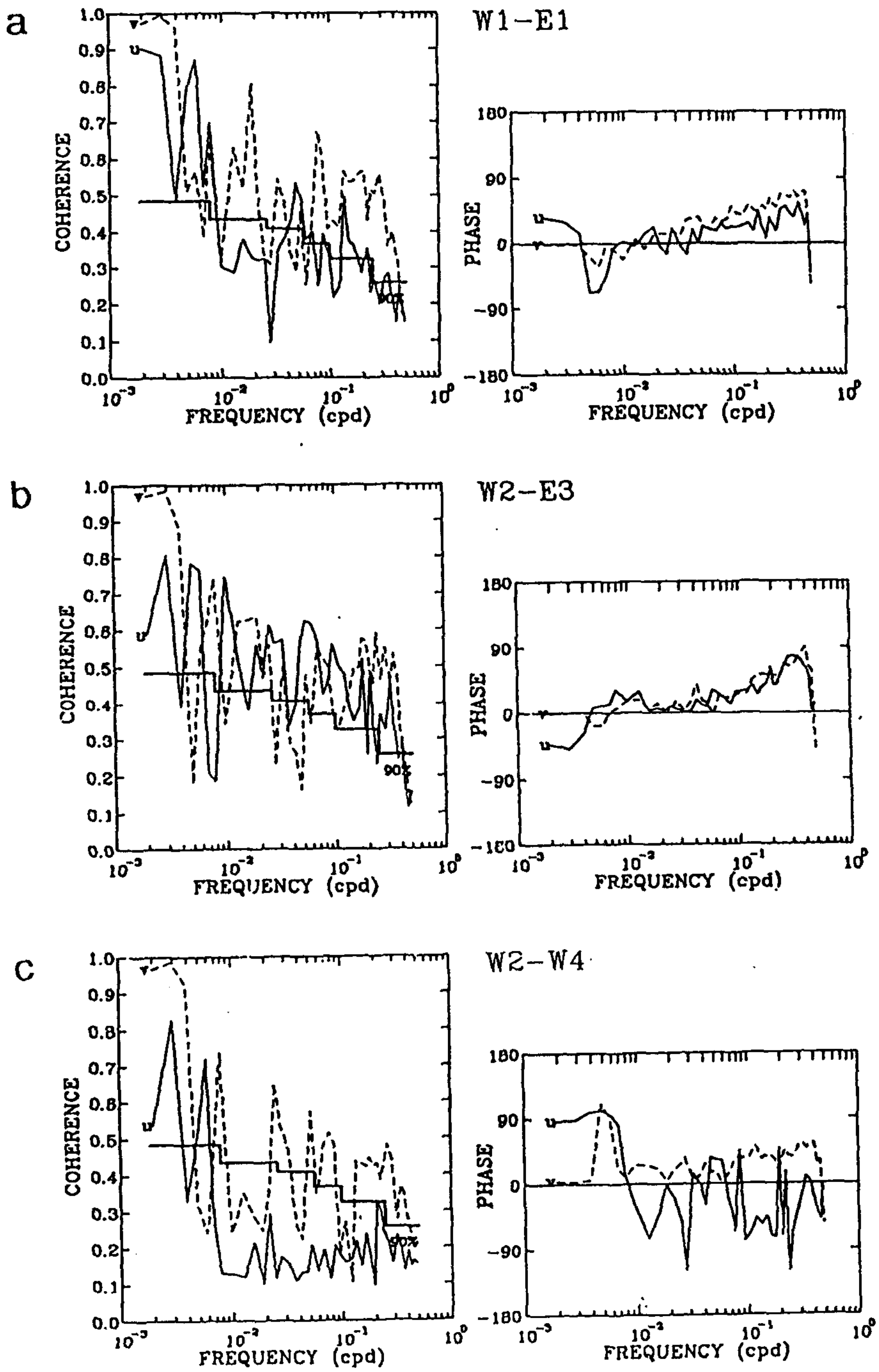

Fig. 3. Coherence and phase difference of wind stresses between the Yellow Sea and East Sea or East China Sea. (a) W1-E1, (b) W2-E3, and W2-W4. Solid and dashed lines correspond to the eastwad and northward components, respectively. The grids are marked in Fig. 1.