Influence of Southern Oscillation on Precipitation in Korea

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ABSTRACT: The impacts of El Niño/Southern Oscillation (ENSO) have been linked to climate anomalies throughout the world. However, the specific impact is not so clear in middle to high latitude, including Korea. So far, no direct relationship between Southern Oscillation Index (SOI) and precipitation in Korea has been found. Therefore, in the present study, categorized SOI are used to reveal quantitative and statistically significant influence on monthly precipitation at Busan, Mokpo and Inchon in Korea. The results show a slight difference in cross-correlation between categorized SOI and precipitation for each station. The impact of strong La Niña revealed highest cross-correlation in Inchon and lowest in Mokpo at 5 % significance level. However, the influence of strong La Niña revealed an opposite tendency at Mokpo station compared to Busan and Inchon where it is associated with less precipitation. Especially, significant correlation at the 1 % level was obtained with the lag time of four month under the "Strong La Niña" category (SOI>2) at Busan station.

1 INTRODUCTION

The El Niño/Southern Oscillation (ENSO) results from the interactions between large-scale oceanographic and atmospheric circulation processes in the equatorial Pacific Ocean. There has recently been considerable interest in the El Niño/La Niña, which are known as extremes of Southern Oscillation.

The impacts of the phenomena have been studied in many countries. One of the studies describes the relationship between SOI and seasonal rainfall in Southern Europe and shows the correlation has increased towards the end of the 20th century (Rodo et al., 1997). The potential for forecasting the hydroclimate variables in Australia was also investigated by assessing the lag correlations between rainfall, streamflow and ENSO several months earlier and the results shows that ENSO indicators can help to forecast the hydroclimate variables (Chiew et al., 1998).

However, despite the global impact of the Southern Oscillation, there has been little evidence of El Niño/La Niña influence in middle to high latitude, especially at eastern part of Asia, including Japan and Korea. For the first time, the cross-correlation between SOI and precipitation in Fukuoka, Japan on a monthly basis was obtained when using SOI data categorized into five groups according to their magnitudes (Kawamura et al., 2000). Shin (2002) showed that the significant influences on flood and drought of El Niño and La Niña in Korea.

In the present study, the method of categorization of SOI was also applied and revealed the cross-correlation between categorized SOI and precipitation in Korea. Therefore, based on the above background, this study is aimed at evaluating the possible influence of ENSO in Korea. Hence, using categorized SOI data and monthly precipitation data from three stations in Korea, this study is able to detect statistically significant correlation between the categorized SOI and the corresponding precipitation.

Consequently, possible influences of El Niño and La Niña are assessed and presented in respect of the precipitation distribution pattern in the study area. In this study, the categorized SOI is used to investigate the relationship with monthly precipitation that are collected from three stations which are located in the southeast, southwest and northwest part of Korea, respectively.

2 STUDY AREA AND DATA USED

The data used in this study were collected from three stations. The data are from modern observation stations at Busan, Mokpo and Inchon in Korea that were established in 1904 by the Chosen Governor-general Division (Ahn, 2001). The three stations have longest period of precipitation in Korea. First, the Busan station (129°E, 35.1°N) is located in the southeastern part in Korea and has a record of precipitation from 1904-2000. Second, the Mokpo station (126.4°E, 34.8°N) is located at the southwestern part of Korea and also has a record of precipitation from 1904-2000. The third station is Inchon station that is located to the northwestern part of Korea and also has a record of precipitation from 1904-2000 like other two stations, but there are some missing values during the period of Korean War between 1904 and 1953. Therefore, only data from 1952 were used in this study and thus datasets comprise monthly values with different periods for each station. The periods are shown in table 1 and the locations of the three stations are shown in Fig. 1.

Table 1. Data periods for each station in Korea

Station	Data Period	Month
Busan	1904.04 – 2000.12	1161
Mokpo	1904.04 – 2000.12	1161
Inchon	1951.10 – 2000.12	591

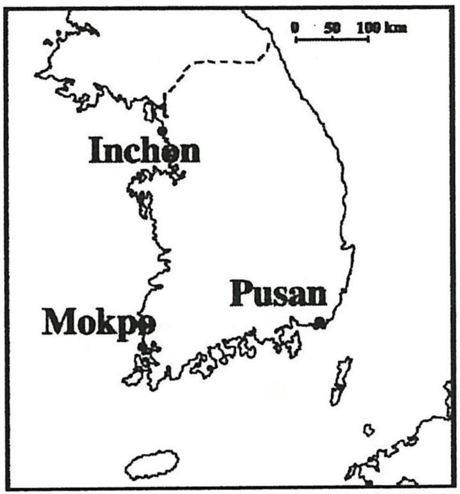

Figure 1. Location of three stations in Korea

Box-plots were used to show the statistical summary of three stations in Korea where values of median, quartiles, maximum and minimum precipitation are presented in Fig. 2 ~ 4, respectively. The maximum mean precipitation was revealed in July for the three stations. Remarkably, some months with no precipitation (less than 0.1 mm) occurred at Busan between December and March, at Mokpo in September and at Inchon in February and September.

Cubic root transformation was carried out to normalize the precipitation in all of the stations and then the normalized monthly precipitation values were standardized to a mean of zero and a standard deviation of one by subtracting the normalized monthly mean values from the monthly values and dividing by the normalized monthly standard deviations, using the whole data period for computation of means and standard deviations.

The SOI data were calculated using the monthly mean sea level pressure (MSLP) at Papeete, Tahiti (149.6°W, 17.5°S) and Darwin, Australia (130.9°E, 12.4°S). The MSLP data starting from 1882 are available through web sites such as NOAA Network Information Center. However, some missing values exist for the Tahiti pressure data. Ropelewski and Jones (1987) filled in all missing values using newly found pressure data for Tahiti. Furthermore, they completed the pressure time series since 1866 by supplementing and interpolating the data of Tahiti before 1882. Allen et al., (1991) also augmented the pressure data at Darwin before 1882 by using older records and by correlation with data from other observation stations. As a result, the pressure data at Darwin were also completed since 1866.

In the present study, we used Troup's method (Troup, 1965). The $SOI(y,m)$ in year y, month m (m=January to December) is calculated by the following equation:

$$SOI(y,m) = [\{P_T(y,m) - P_D(y,m)\} - M_{30}(m)] / S_{30}(m) \qquad (1)$$

Here, $P_T(y,m)$ and $P_D(y,m)$ are MSLP (hPa) at Tahiti and Darwin, respectively; $M_{30}(m)$ and $S_{30}(m)$ are the mean value (hPa) and its standard deviation (hPa) of MSLP difference between Tahiti and Darwin for the base period of 30 years (usually 1951-1980), respectively. The SOI is expressed as the MSLP difference between Tahiti and Darwin which is normalized to zero mean and a standard deviation of one. Note that a standard deviation of 10 is also commonly used. Generally, El Niño conditions occur when the SOI is less than –1, and La Niña conditions when the SOI is more than 1. Strong El Niño/La Niña conditions prevail when the SOI absolute value exceeds 2.

The categorization method for SOI is conceptualized as data classified into five groups according to their magnitudes, such as "Strong El Niño (SOI<-2)", "Weak El Niño (-2≤SOI<-1)", "Normal Condition (-1≤SOI≤1), "Weak La Niña (1<SOI≤2)", and "Strong La Niña (2<SOI)". This categorization of SOI is for easy association with the El Niño and La Niña phenomena.

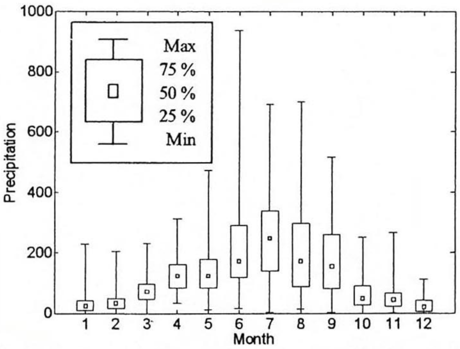

Figure 2. Box-whisker plot of precipitation in Busan

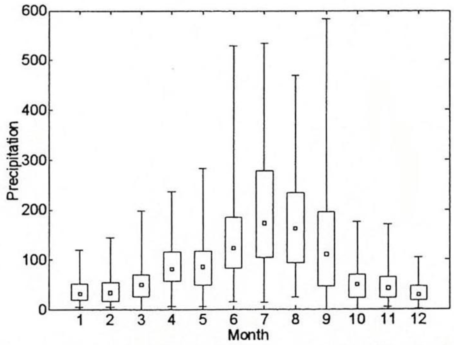

Figure 3. Box-whisker plot of precipitation in Mokpo

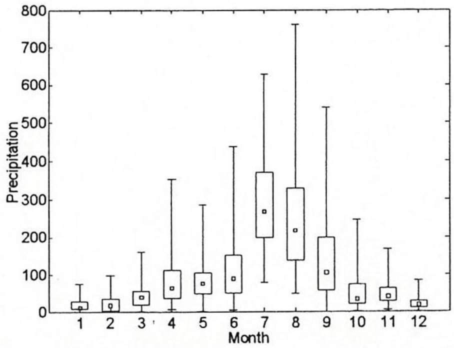

Figure 4. Box-whisker plot of precipitation in Inchon

3 CROSS-CORRELATION BETWEEN CATEGORIZED SOI AND PRECIPITATION

The statistically significant correlation between categorized SOI and the transformed precipitation were detected from the results. The normally standardized precipitation was used for investigating the relationship with categorized SOI and the results are shown in figures below for each station. The cross-correlation between categorized SOI and transformed precipitation were calculated with various lag times for each station (see Fig. 5, 8, 11). Generally, the correlation coefficients under the "Normal Condition" are almost zero at any lag time and

La Niña events are more strongly correlated to the precipitation data than El Niño events for all of the stations.

3.1 Busan station

For the Busan station, the result of cross-correlation between categorized SOI and normally standardized precipitation is shown in Fig. 5. The highest correlation of –0.607 with lag time of 4 months at significance level of 1 % was observed under the category of "Strong La Niña", while the correlation of –0.436 with lag time of 2 months for the same category was statistically significant at 5 % level (see Fig. 6, 7). However, no statistically significant value was found at any lag time under the category of El Niño. Therefore, the result shows the general tendency that the stronger the La Niña event, the less the precipitation at Busan 4 months later. Among three stations, only Busan showed the 1 % significance level with the relatively high correlation strength with SOI.

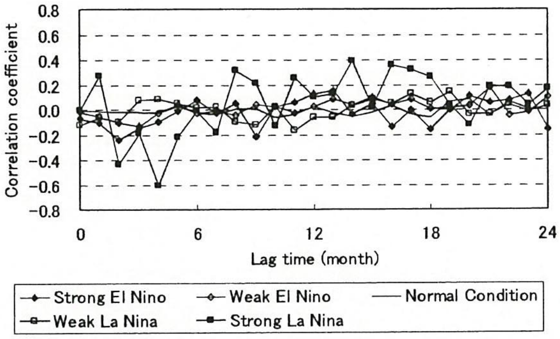

Figure 5. Cross-correlation between categorized SOI and corresponding precipitation at Busan

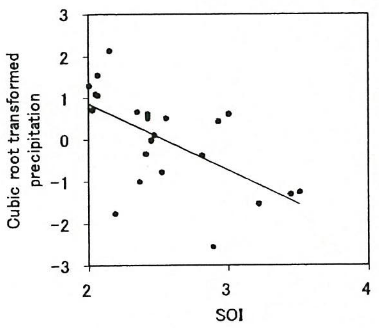

Figure 6. Scatter plot for the "Strong La Niña" at Busan (Lag Time = 4 months)

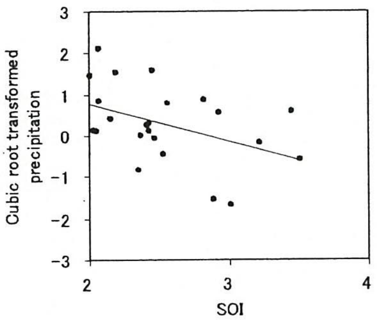

Figure 7. Scatter plot for the "Strong La Niña" at Busan (Lag Time = 2 months)

3.2 Mokpo station

In the case of Mokpo, which is located at the southwestern part of Korea, the highest correlation coefficient of 0.448 was observed with the lag time of 22 months under the "Strong La Niña" category at the 5 %significance level and the correlation of 0.418 was also detected with the lag time of 11 months at 5 % significance level under the same category. The scatter plots of these significant correlation are drawn in Fig. 9 and Fig. 10, respectively. Fig. 9 revealed a tendency which show that the stronger the La Niña event, the more the precipitation 22 months later at Mokpo. Fig. 10 also shows the same tendency with Fig. 9. The influence of ENSO on monthly precipitation at Mokpo revealed the opposite tendency compared to Busan and Inchon where are associated with the less precipitation under the "Strong La Niña" category (Inchon station is described below). However, no statistically significant value was found at any lag time under the category of "Strong El Niño".

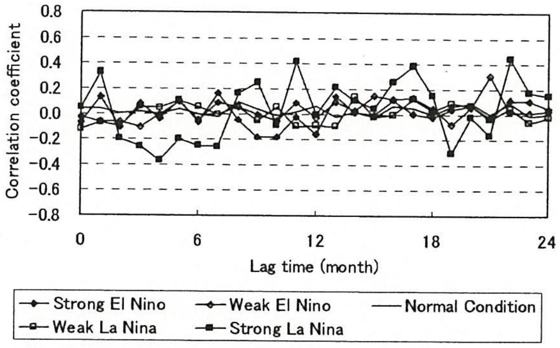

Figure 8. Cross-correlation between categorized SOI and corresponding precipitation at Mokpo

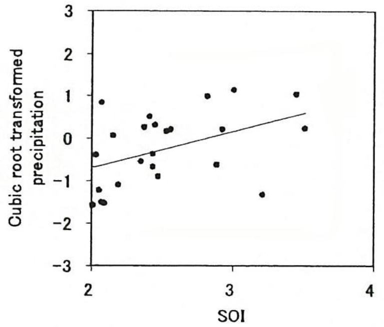

Figure 9. Scatter plot for the "Strong La Niña" at Mokpo (Lag Time = 22 months)

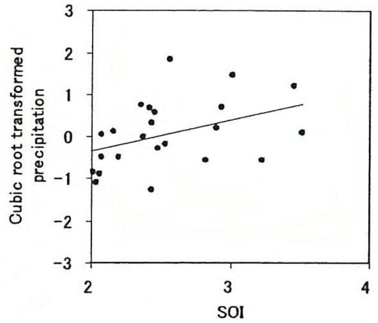

Figure 10. Scatter plot for the "Strong La Niña" at Mokpo (Lag Time = 11 months)

3.3 Inchon station

The highest correlation coefficient among all the four stations was found in Inchon station under the category of "Strong La Niña" with a value –0.688 for time lag of 23 months and statistically significant at 5 % level. Even though the magnitude of the correlation is highest among all stations, the correlation is just significant at 5 % level, because the number of the data for the calculation of the correlation is less than those of the other two stations. In addition, correlation coefficient of –0.426 under the "Strong El Niño" category was also found at lag time of 17 months and significance level of 5 %, too. The scatter plots for the lag times of 23- and 17-months are drawn in Fig. 12 and Fig. 13. As is seen clearly in the figures, the tendency shows that the stronger the La Niña event, the less the precipitation at Inchon. The tendency at Inchon is the same with Busan but the opposite of Mokpo.

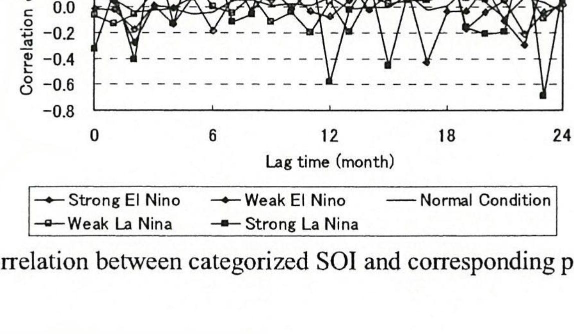

Figure 11. Cross-correlation between categorized SOI and corresponding precipitation at Inchon

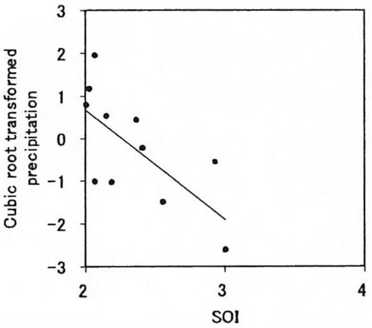

Figure 12. Scatter plot for the "Strong La Niña" at Inchon (Lag Time = 23 months)

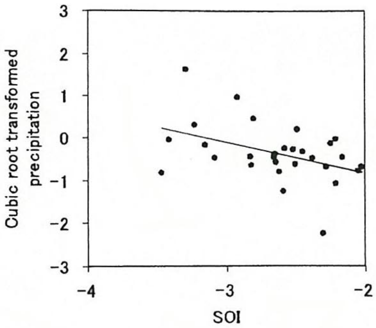

Figure 13. Scatter plot for the "Strong El Niño" at Inchon (Lag Time = 17 months)

4 CONCLUSIONS

In the present study, the precipitation data of three stations at Busan, Mokpo and Inchon stations in Korea were collected because the three stations have the longest data in Korea. Brief statistics of the monthly precipitation data were described by the box-whisker plots for each station and the relationships with categorized SOI were also evaluated with the primary objective of assessing the possible influence of the SOI on the monthly precipitation in Korea. Firstly, the results for the Busan station show a general tendency in which the stronger the La Niña event, the less the precipitation 4 months later. In the case of Mokpo station, the influence of La Niña was revealed. It should also be pointed out that there is the tendency that the influence under the "Strong La Niña" is associated with the precipitation in Mokpo as against the opposite trend in the other stations. However, the statistically significant influence of El Niño was not detected at Busan and Mokpo. For the Inchon station, the results revealed the same tendency like Busan station. The highest absolute value of correlation coefficient under the "Strong La Niña" category was observed for the Inchon station compared to other stations.

Conclusively, this study shows that in general the influence of El Niño is low in all the stations studied while the influence of La Niña is relatively high with Inchon having the highest influence of La Niña. However, the further studies are recommended for understanding the lag times physically that showed the significant correlation and evaluations of the possible factors that might be responsible for the observed varied trends.

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