APPLICATION OF CATEGORIZATION METHOD TO THE MONTHLY PRECIPITATION FOR THE DETECTION OF CROSS-CORRELATION WITH SOUTHERN OSCILLATION INDEX

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1. Introduction

A large scale weakening of the trade winds and warming of sea temperature in the eastern and central Pacific Ocean defines El Niño, which typically lasts 12 – 18 months and occurs irregularly at 2 – 7 year intervals. The opposite situation, La Niña, refers to the condition when sea surface temperature is lower than normal. The two situations define an inter-annual seesaw phenomenon called the Southern Oscillation (SO), in tropical sea level pressure between eastern and western hemispheres. This oscillation is characterized by a simple index, the Southern Oscillation Index (SOI). The features are known collectively as the El Niño/Southern Oscillation (ENSO) phenomenon.

During the latest several decades there has been considerable interest in the influence of ENSO on global and regional meteorological/hydrological variables, such as temperature, precipitation, streamflow, etc. However, the impact of ENSO on hydrological variables is not clear for middle to high latitudes, including Korea and Japan, which are the study area in the present paper. Even though we have been studying the influence of SOI on precipitation in the area, a significant correlation has not been found when using original time series of both SOI and precipitation. However, we have succeeded to reveal the significant and quantitative cross-correlation by categorizing the SOI at Busan in Korea and at Fukuoka in Japan [1), 2)].

In the present study, we applied the categorization to monthly precipitation, instead of SOI and estimated the influence of SOI on the precipitation in the study area.

2. Study Area and Data Used

Two precipitation stations with observed long time series were selected for the present study, Busan in Korea and Fukuoka in Japan. Busan is located in the southeastern part of the Korean peninsula at 129°E and 35.1°N, as shown in **Fig. 1**. This station has the longest period of precipitation observations in South Korea from 1904 to 2000. The Fukuoka station is located in the northern part of Kyushu Island at 130.4°E and 33.6°N, southern Japan as shown in **Fig. 1**. The Fukuoka station has observations during 1890-2000. The two stations were selected not only because of the long records but also due to that the two stations represent a meteorological and climatic area that is spanning across the strait between South Korea and Japan. This area is important for the understanding of the climatic features of the region. Consequently, a more complete and spatially correct understanding of the effects of ENSO can be obtained by studying stations representing this area.

As the first step for the categorization of precipitation, the cubic root transformation was carried out to normalize the precipitation data. The normalized data were then standardized to a mean of zero and a standard deviation of one. The Normally Standardized Precipitation (NSP) data were classified into five groups according to their magnitudes, such as "Severe Drought Condition (NSP<-2)", "Drought Condition (-2≤NSP<-1)", "Normal Condition (-1≤NSP≤1)", "More than Normal Condition (1<NSP≤2)", and "Much More than Normal Condition (2<NSP)". The boundaries of this categorization follow the deviation from the mean of zero.

Fig. 1. The location of study area

The SOI data were calculated using monthly mean sea level pressure (MSLP) at Papeete, Tahiti (149.6°W, 17.5°S) and Darwin, Australia (130.9°E, 12.4°S). Two commonly used methods to compute SOI from MSLP data at Tahiti and Darwin are Troup's method and the Climate Prediction Centre's method but the difference between the two methods is very small. In the present study, we used Troup's method [3)]. The $SOI(y,m)$ in year y, month m (m=January to December) is calculated by the following equation;

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

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.

3. Cross-Correlation between SOI and Categorized Precipitation

The categorized precipitation data were used to investigate the relationship with SOI. When using both SOI and precipitation without any manipulation like categorization, no significant correlation was found at the two stations. However, the correlation coefficient between SOI and categorized precipitation displayed significant relationships for the Busan station at several lag times. The correlation coefficients with various lag times are shown in **Fig. 2**.

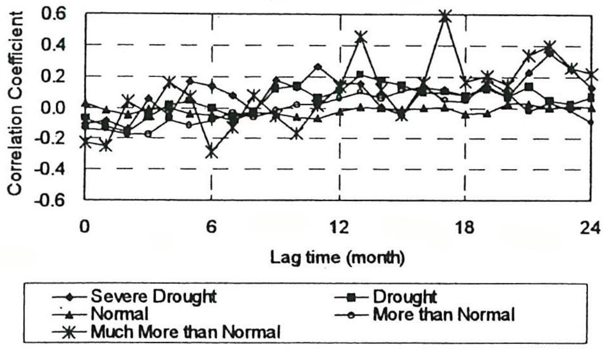

Fig. 2. Cross-correlation between categorized precipitation and the corresponding SOI at Busan station

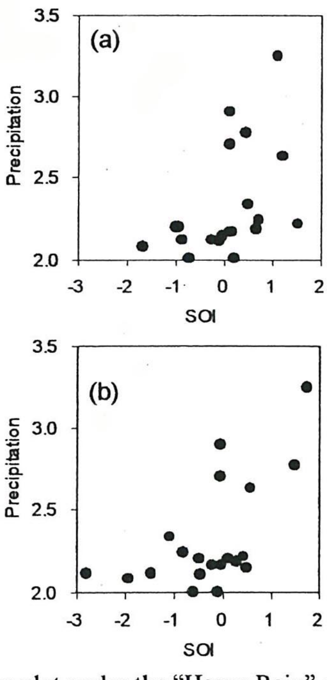

Fig. 3. Scatter plot under the "Heavy Rain" category with lag time (a) 13-months and (b) 17-months at Busan station

Generally, the correlation under the "Normal Condition" is almost zero at any lag time. The highest correlation of 0.60, which is significant at 1 % level, was obtained under the "Much More than Normal Condition" with lag time 17 months and its scatter plot is shown in **Fig. 3** (b). The second highest correlation of 0.46 was also obtained under the "Much More than Normal Condition" with lag time 13 months and it is significant at 5 % level. The scatter plot of the latter is displayed in **Fig. 3** (a). As are clear in the scatter plots, the tendencies show the bigger the SOI value, the more the precipitation at Busan station. However, no significant correlation was found under the other categories.

For the Fukuoka station, there is no statistically significant correlation at any categories (see **Fig. 4**). Comparing to the results at Busan station, the correlations under the "Severe Drought Condition" category are stronger than those from the other categories at Fukuoka station. However, the correlations under the "Much More than Normal Condition" category have the negatively bigger magnitudes with longer lag time.

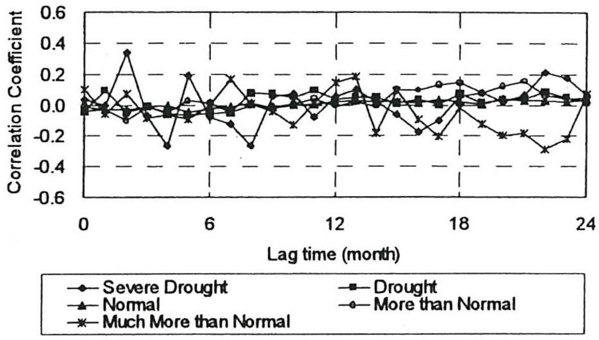

Fig. 4. Cross-correlation between categorized precipitation and the corresponding SOI at Fukuoka station

4. Conclusions

In the present study, we applied the categorization method to the monthly precipitation data at Busan, Korea and at Fukuoka, Japan. The two stations were selected not only because they have the well-observed precipitation data with long period but also due to that the two stations represent a meteorological and climatic area that is spanning across the strait between South Korea and Japan.

Surveying the results for the respective stations, we could detect the two statistically significant correlation coefficients between SOI and categorized precipitation into the "Much More than Normal Condition" at Busan, while no statistically significant correlation at any lag time for the Fukuoka. The correlations with 13- and 17-months lag time at Busan displayed the clear tendency that the bigger the SOI value, the more the precipitation.

Further study for the long lag times at Busan station should be carried out to better understand the relationship between SOI and precipitation physically.

References

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