EOF와 CSEOF를 이용한 한반도 강수의 변동성 분석

Investigation of Korean Precipitation Variability using EOFs and Cyclostationary EOFs

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Abstract

Precipitation time series is a mixture of complicate fluctuation and changes. The monthly precipitation data of 61 stations during 36 years (1973-2008) in Korea are comprehensively analyzed using the EOFs technique and CSEOFs technique respectively. The main motivation for employing this technique in the present study is to investigate the physical processes associated with the evolution of the precipitation from observation data. The twenty-five leading EOF modes account for 98.05% of the total monthly variance, and the first two modes account for 83.68% of total variation. The first mode exhibits traditional spatial pattern with annual cycle of corresponding PC time series and second mode shows strong North South gradient. In CSEOF analysis, the twenty-five leading CSEOF modes account for 98.58% of the total monthly variance, and the first two modes account for 78.69% of total variation, these first two patterns' spatial distribution show monthly spatial variation. The corresponding mode's PC time series reveals the annual cycle on a monthly time scale and long-term fluctuation and first mode's PC time series shows increasing linear trend which represents that spatial and temporal variability of first mode pattern has strengthened. Compared with the EOFs analysis, the CSEOFs analysis preferably exhibits the spatial distribution and temporal evolution characteristics and variability of Korean historical precipitation.

Key Word : Precipitation, EOF, CSEOF, Spatial Distribution, Temporal Evolution.

1. Introduction

In East Asia, interactions between the rapidly mixing atmosphere and the slowly changing oceans are mainly responsible for the monsoon season, particularly as they affect Korea, China and Japan. Recently, some periodically meteorological variations have attracted attention of a lot of meteorologists, because the agricultural production and hydrological management are largely impacted by the climate change (Trenberth, 1990). The major source of freshwater is the precipitation in East Asia. Precipitation changes in the timing and amount could lead to agriculture failure or flood hazards.

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When precipitation totals are analyzed across more than two stations or spanned over different seasons or months, the poor statistical trend could be obtained, even though one station is examined for a long time or information of individual station are merged into a region. Thus, the spatially distribution and temporal trends of precipitation is still an ongoing research. By adequately using and analyzing the most comprehensive datum set, our study will uncover the spatial patterns and temporal patterns of precipitation trends and investigate the potential causes of these characteristics by EOFs method and CSEOFs methods.

2. Methodology and Data

The techniques employed in this study are empirical orthogonal function (EOF) and Cyclostationary empirical orthogonal function (CSEOF). These techniques are particularly useful for extracting time-dependant spatial modes.

In the EOF analysis, space-time data $T(\hat{r},t)$ are represented in terms of the loading vectors (LV) and their principal component (PC) time series:

$$T(\hat{r},t) = \sum_{n} PC_n(t) LV_n(\hat{r})$$

The CSEOF analysis is described in detail by Kim and North (1997). In the CSEOF analysis, a space-time datum are represented as

$$T(\hat{r},t) = \sum_{n} PC_n(t) LV_n(\hat{r},t) \qquad LV_n(\hat{r},t) = LV_n(\hat{r},t+d)$$

The Water Management Information System has provided hourly precipitation measurements recorded by over 76 stations distributed countrywide since 1904. The stations are generally well-distributed across the country and five major river basins. The available station data maintained from the WAMIS is extensive quality control and calculation of monthly data. Therefore, as shown in Figure, 61 stations which have 36 years (1973-2008) records of monthly precipitation data are used for the current study.

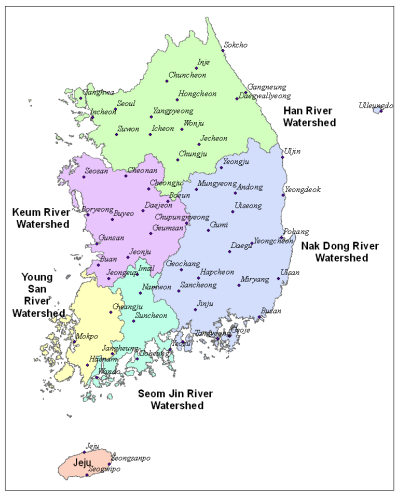

Fig. 1 Location of the 62 Korean Precipitation Stations

3. Results and Discussions

The EOF technique and CSEOF technique have been applied to the monthly precipitation data of 62 stations during 35 years in Korea. The twenty-five leading EOF and CSEOF modes respectively account for 98.06% and 98.49 of the total monthly variance. The main motivation for employing this technique in the present study is to investigate the physical processes associated with the evolution of the precipitation from the observation data.

An EOF analysis was performed on the unnormalized monthly precipitation data, the first leading EOF modes account for 75.93% of the total monthly variance. Hence, these first mode properly decomposed the time-space data structure. The spatial patterns associated with the two precipitation modes and temporal variability of EOF represented by the expansion coefficients are described in Fig. 2 as homogeneous correlation maps.

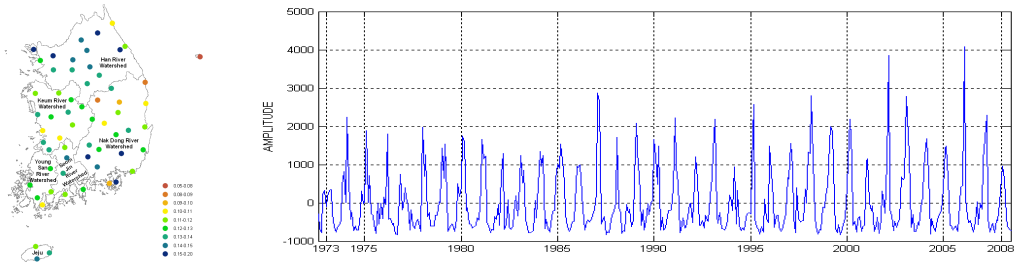

Fig. 2 Spatial Pattern and Principal Component Time Series of 1st EOF Mode

Fig. 2 exhibits an evident northern and southern symmetrical trend; Han River Watershed, South of NakDong River Watershed and SeomJin River Watershed have the higher values than the central parts of Korea, although the difference of those values is inconspicuous. The corresponding PC time series, present an unsymmetrical oscillation with 1-yr period and a slight fluctuation at a longer timescale. The figure commendably describe the spatial distribution characteristic and temporal evolution characteristic of Korean historical precipitation.

In applying the CSEOF technique, d (nested period) is set to 12 months since the annual cycle is to be extracted in this study. Based on the monthly precipitation data, the first leading CSEOF modes account for 73.67% of the total monthly variance. As shown in Fig. 3, the monthly spatial patterns and temporal patterns associated with the two precipitation modes of CSEOF are depicted respectively.

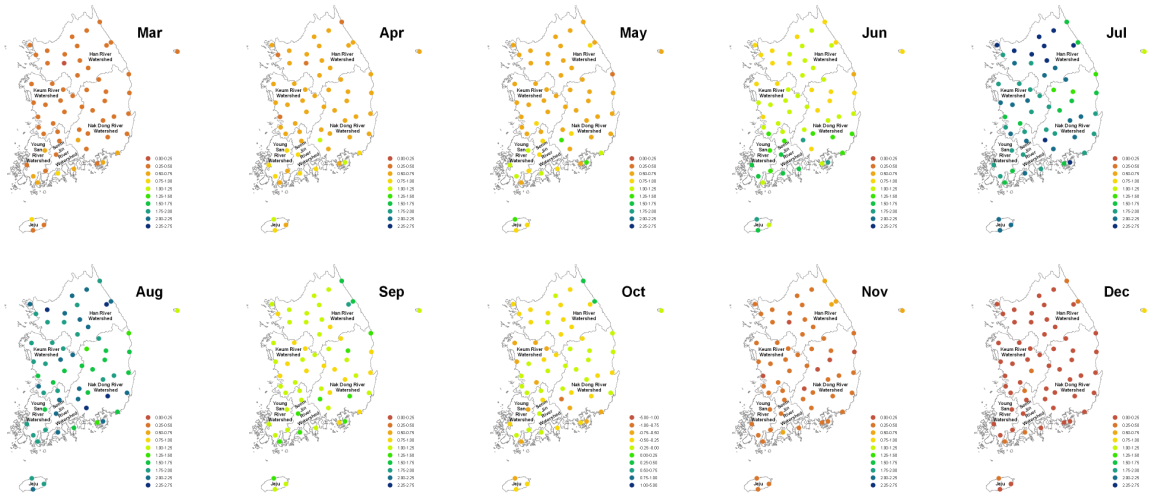

Fig. 3 Monthly Spatial Pattern and Principal Component Time Series of 1st CSEOF Mode

The first mode of CSEOF in Fig. 3 mainly describes the annual cycle since it is the representation in all of the modes. These cyclostationary loading patterns are nearly identical with the composite annual cycle. This set of spatial patterns reflects some familiar observations; the most pronounced feature is that the patterns' spatial distribution are varying along with the seasons: the patterns hold less value which are spread uniformly over the area of Korea in winter; and then the patterns present increasing values from spring to summer, come into autumn, all the patterns values are decreasing and are holding similar values, and then in October, when Winter arrives, the patterns present similarly low values over all the stations once more.

The advantage of CSEOF analysis is well demonstrated in the PC time series, as shown in figure, the first mode PC time series reveals the evolution of the annual cycle on a monthly time scale, The PC fluctuates around 0 and a value smaller or larger than average, which means a weaker- or stronger-than-normal annual cycle. The PC time series also exhibits an increased trend with a certain slope of 0.0035, that means the trend of precipitation is primarily increasing along with monthly time-scale.

4. Conclusions

The variability of precipitation and the associated temporal and spatial evolution of synoptic fields have been investigated by using EOFs and CSEOFs analysis respectively on a 36-yr time scales in Korea. The first leading EOF modes account for 75.93% of the total monthly variance, the spatial patterns of the modes exhibit the Northern and Southern symmetrical trend distributing characteristics, the corresponding PC time series show an unsymmetrical oscillation with 1-yr period around the value of 0. Hence, the first leading EOF modes commendably described the spatial distribution and temporal evolution characteristic of Korean historical precipitation. In CSEOF analysis, the first leading CSEOF modes account for 73.76%

of the total monthly variance, the first patterns' spatial distribution varying along with the seasons is the most pronounced feature, these spatial patterns clearly reflect some familiar observations, where the spatial patterns' regional distribution regularly transform from winter to summer then to winter. The corresponding mode's PC time series reveals the evolution of the annual cycle on a monthly time scale, and exhibits an increased trend in temporal patterns with a slope, that means the trend of precipitation is primarily increasing along with monthly time-scale.

In contrast to EOFs technique analysis, the CSEOFs technique analysis more comprehensively displays the spatial distribution and temporal evolution characteristics of Korean historical precipitation and variability along with recurrent seasons.

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