Spatiotemporal characteristics and assessment of historical drought in Korea

Kim D.W., Byun H.R.

in

López-Francos A. (comp.), López-Francos A. (collab.).
Economics of drought and drought preparedness in a climate change context

Zaragoza : CIHEAM / FAO / ICARDA / GDAR / CEIGRAM / MARM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 95

2010
pages 101-105

Spatiotemporal characteristics and assessment of historical drought in Korea

D.W. Kim and H.R. Byun

Department of Environmental Atmospheric Sciences, Pukyong National University,
599-1 Daeyon-dong, Nam-gu, Busan 608-737 (Republic of Korea)

Abstract. This study investigated the drought climatology over Korea based on long-term precipitation data from 1908 to 2008. Drought intensity was quantified by using the Effective Drought Index (EDI). Korea has been divided into four drought sub-regions (central, southern and east coast regions and Jeju Island) based on the similarity of drought characteristics (i.e., onset dates, duration, and severity). After that, the long-term drought maps have been prepared, which allow to indentify the spatiotemporal distribution of droughts for 101 years at a glance. It has been found that a total 63 droughts occurred with periodicities of 5, 14 and 33 years. 5 year periodicity was dominant over all the regions, while the periodicity of 14 and 33 years was observed over the southern region and the east coastal region, respectively.

Keywords. Effective Drought Index – Drought climatology – Drought map – Drought periodicity.

Caractéristiques socio-temporelles et évaluation de la sécheresse historique en Corée

Résumé. *Cette étude a porté sur la climatologie de la sécheresse en Corée en se basant sur les données de précipitations à long terme de 1908 à 2008. L'intensité de la sécheresse a été quantifiée en utilisant l'Indice Effectif de Sécheresse (EDI). La Corée a été divisée en quatre sous-régions pour la sécheresse (régions centrale, sud, côte est et île de Jeju) basées sur la similarité des caractéristiques de la sécheresse (à savoir dates d'apparition, durée, et sévérité). Ensuite des cartes de sécheresse à long terme ont été préparées, permettant ainsi d'indentifier la distribution spatiotemporelle des sécheresses sur 101 ans à simple vue. On a trouvé qu'un total de 63 sécheresses sont survenues avec des périodicités de 5, 14 et 33 ans. La périodicité de 5 ans était dominante sur toutes les régions, tandis que des périodicités de 14 et 33 ans étaient observées respectivement dans la région sud et la région côtière de l'est.*

Mots-clés. *Indice Effectif de Précipitations – Climatologie de la sécheresse – Carte de la sécheresse – Périodicité de la sécheresse.*

I – Introduction

The assessment on historical droughts and its spatiotemporal statistics become the basic data to estimate the potential droughts in future. However, enough basic data are not available for Korea as well as for any other country in the world. It seems that most researches tended to try the case analysis on specific droughts. Thus, it was very difficult to find out the scientific analysis and summary on overall history of droughts. Therefore, it is also difficult to compare the severity between present droughts and previous droughts. This study tried to accumulate the basic data enabling to estimate and prepare statistics of droughts by summarizing and assessing the historic droughts.

II – Materials and methods

1. Precipitation data

The daily precipitation data of Korea were observed from different years depending on the regions. There are the daily precipitation data observed over 4 stations since 1907. The number of available stations has been increasing in accordance with the lapse of time. The data measured over 60 stations all over the country are available since 1973.

2. The Effective Drought Index (EDI)

The EDI calculates the Effective Precipitation (EP, Eq. 1) accumulating the daily precipitation in consideration of the loss due to runoff and evaporation with the lapse of time; then it compares (Eq. 2) with climatological mean of EP (MEP) and standardizes the results (Eq. 3).

$$EP_i = \sum_{n=1}^{i}\left[\left(\sum_{m=1}^{n} P_m\right)\Big/ n\right] \quad (1)$$

$$DEP = EP - MEP \quad (2)$$

$$EDI = DEP/SD(DEP) \quad (3)$$

i (duration of summation) of Eq. 1 is 365, the most general precipitation cycle in the world.

III – Results

1. Drought sub-regions

A hierarchical cluster analysis was conducted based on the similarity of drought characteristics (i.e., duration, severity, onset, and ending dates) among stations. The estimation of drought similarity was based on the method by Dezfuli *et al.* (2009). Figure 1a presents the change of averaged similarity between merged clusters. The similarity gradually reduced as 60 clusters merged step by step into one cluster. The reduction ratio is the highest when 4 clusters are merged into 3 clusters. It means that the most appropriate number of clusters in Korea is 4. Figure 1b showed the spatial distribution of 4 clusters. The drought sub-regions in Korea are largely classified into the central region (G1; 21 stations), the southern region (G2; 30 stations), the east coast region (G3; 6 stations) and Jeju Island (G4; 3 stations).

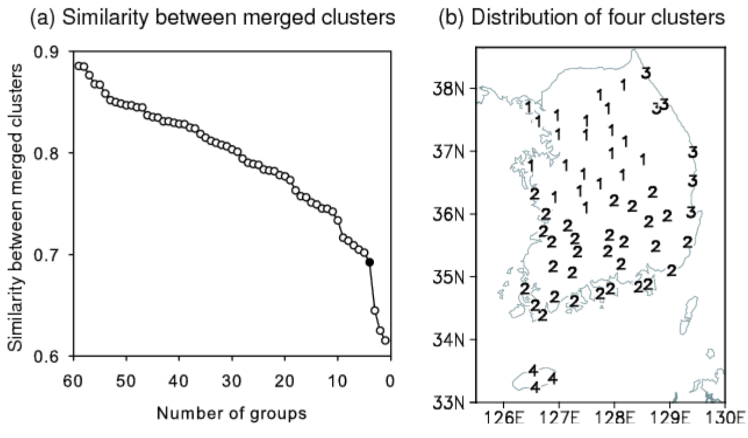

Fig. 1. Hierarchical clustering analysis from the EDI for period 1974-2008. (a) Similarity between merged clusters. The number of clusters is from 59 to 1. (b) Spatial distribution of four drought clusters.

2. Construction of a drought map

This study collected all available data to make the historical drought map (Table 1). Two station data exist in G1 and G2 for the period from 1907 to 1912 (A) and G3 and G4 had no data. The number of stations with available data in G2 is increased to three for the period from 1913 to 1950 (B) and one station data are available in G3 for the same period. One station data in G4 are available since 1925. The stations with available data from 1951 to 1973 (C) increased to 8 in G2 and 2 in G3. The data over all 60 stations are available from 1974 to 2008 (D). The EDI averaged over the available stations by each period (A, B, C and D) was standardized on the basis of the variability in that during the D period. The daily values were calculated from 1908 to 2008 for T-EDI, G1-EDI and G2-EDI, from 1913 to 2008 for G3-EDI and from 1925 to 2008 for G4-EDI. Based on the T-EDI and G-EDIs, the long-term drought map of Korea was created (Fig. 2), which allows identifying the period and regional intensity of drought a glance.

Table 1. Used stations for each period (first two numbers "47" is omitted)

Period	G1	G2	G3	G4	T (Total)
A (1907-1912)	108, 112	159, 165	–	–	108, 112, 159, 165
B (1913-1950)	108, 112	143, 159, 165	105	184	105, 108, 112, 143, 159, 165
C (1951-1973)	108, 112	135, 143, 146, 152, 156, 159, 165, 168	105, 138	184	105, 108, 112, 135, 138, 143, 146, 152, 156, 159, 165, 168, 184
D (1974-2008)	21 stations	30 stations	6 stations	3 stations	60 stations

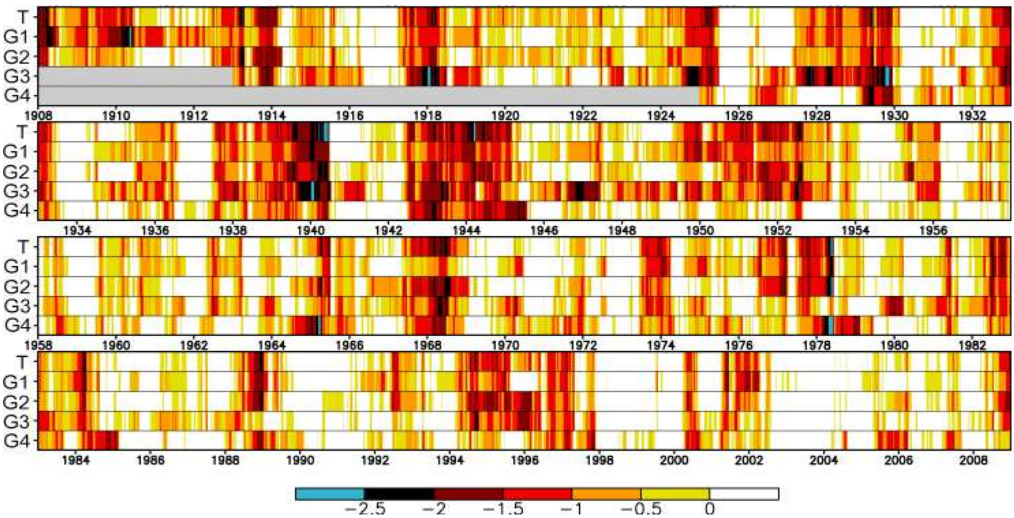

Fig. 2. Historical drought map (EDI) from 1908 to 2008. Data derived from "Chukwookee" dataset (1777-1907 in Seoul) is denoted by "C". "T" represents the averaged EDI over total stations. "G1", "G2", "G3" and "G4" denotes the averaged EDI over each drought sub-region, respectively.

3. Long-term variability of droughts

Figure 3 illustrates the monthly mean time-series of T-EDI and G-EDIs from 1908 to 2008.

Figure 4 shows results of Fourier spectral analysis on the time-series. A 4 to 6-year cycle was observed in all 4 sub-regions (Fig. 4a). A 4 to 6-year band-pass filter was applied to the T-EDI in Fig. 3a. It can be seen that the minimum peaks of raw time-series and those of filtered time-series coincided well. In recent 30 years, the droughts occurred in 1978, 1982, 1988, 1992, 1996 and 2001 associated with the 4-6 cycle. Other cycles observed in T-EDI include 14.4-year and 33.6-year cycle (Fig. 4). An around 14-year cycle component is shown in G2 and G3 (Fig. 4c and d). The thick line in Figs 3c and d illustrates the filtered time series of G2-EDI and G3-EDI by 12 to 16-year band-pass filter. Although the lowest peaks of monthly mean EDI did not exactly coincide with that of filtered time-series, it was found that the severe droughts mainly developed during the periods when the filtered time-series had negative values. It is identified that the 33.6-year cycle component in T-EDI originated from G1 (Fig. 4b). The time-series of G1-EDI filtered with a 33.6-year band-pass filter (Fig. 3b) showed the humid period and dry period three times each for 101 years. In particular, a few of long-term and severe droughts occurred during the period from 1940 to 1955 while ordinary droughts developed frequently in the period from 1975 to 1990. The 42-year cycle is seen only in G4. The dry periods corresponding this 42-year cycle are from 1925 to 1945 and from 1965 to 1985 (Fig. 3e).

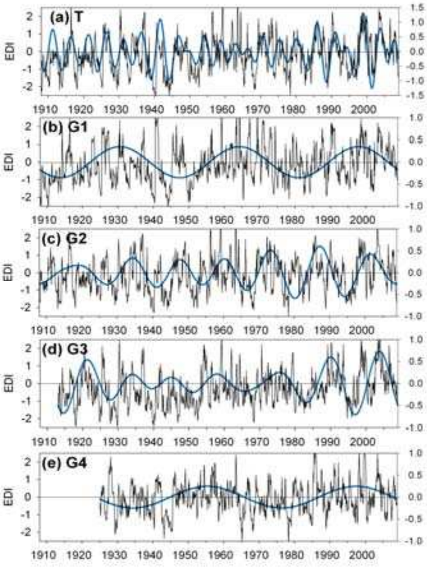

Fig. 3. Time-series of monthly mean T-, G1-, G2-, G3- and G4-EDI from 1908 to 2008. (a) 4-6 year, (b) 33 year, (c and d) 12-16 year, and (e) 42 year; band pass EDI are denoted by solid lines.

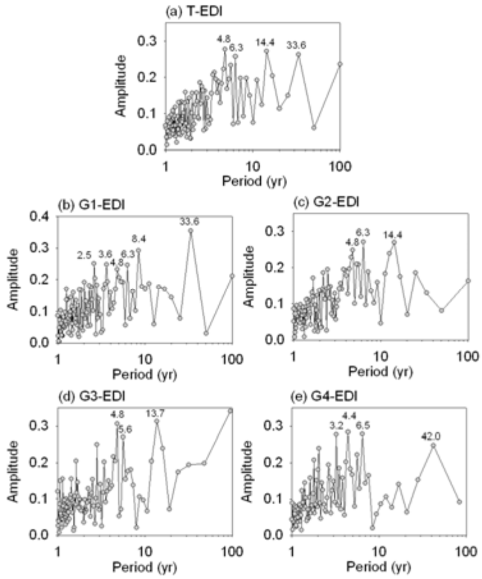

Fig. 4. Amplitude spectrum of Fourier transform of the monthly mean T-, G1-, G2-, G3- and G4-EDI.

IV – Conclusions

This study analyzed drought climatology and summarized historical drought for Korea from 1908 to 2008. Drought intensity was quantified by using the Effective Drought Index (EDI) based on daily precipitation. Hierarchical cluster analysis was performed to find the homogenous drought regions over Korea based on the similarity of drought characteristics (i.e., duration, severity, onset, and ending dates) among 60 stations from 1974 to 2008. As a result, 4 drought sub-regions were identified: central (G1), southern (G2), east coast (G3), and Jeju Island (G4) regions.

We collected the available precipitation data before 1974, and constructed the long-term time series of national EDI (T-EDI) and regional EDIs (G-EDIs) by averaging EDIs over Korea and drought sub-regions, respectively. On the basis of the time-series, the drought map was constructed in order to have a bird's eye view on the spatiotemporal distribution of droughts for 101 years.

In national scale analysis, 5-year, 14-year and 34-year cycles were found. A 5-year cycle was in common in 4 drought sub-regions. A 14-year cycle was dominant from G2 and G3, and a 34-year cycle was observed in G1. Besides, a 44-year cycle appeared in G4. The 34-year, 14-year and 5-year cycles identified in this study are similar to the results of study by Byun *et al.* (2008). However, they measured the intervals of actual droughts and this study examined the periodicity revealed by spectral analysis, so the results are not actually the same.

References

Byun H.R., Lee S.J., Morid S., Choi K.S., Lee S.M. and Kim D.W., 2008. A study on the periodicities of droughts in Korea. In: *Asia-Pacific Journal of Atmospheric Sciences*, 44, p. 417-441.

Dezfuli A.K., Karamouz M. and Araghinejad S., 2009. On the relationship of regional meteorological drought with SOI and NAO over southwest Iran. In: *Theoretical and Applied Climatology*, vol. 100 (1-2), p. 57-66. DOI: 10.1007/s00704-009-0157-2.