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Introduction of a drought monitoring system in Korea

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SUMMARY – This study introduces the drought monitoring system that has been operated since 2000. It serves variations of drought related variables such as intensity, duration, etc. It displays not only spatial but also temporal distribution of every station with daily time step after 1974. This system helps us to detect, early and easily, where and when the drought occurred, and how the drought situation is going. The onset and the withdrawal date of the drought can be defined clearly by this system. Also, it is useful to detect the change of the precipitation climate. The Effective Drought Index (EDI; Byun and Wilhite, 1999), an intensive measure that considers the water accumulation with the weighting function of time passage, is the main idea of the system. Other hydrological variables such as the available water resources index, the flood index, and the estimated precipitation index required to relieve drought are also provided.

Key words: Drought monitor, Effective Drought Index, drought intensity, drought duration, drought onset date.

Introduction

Because drought progresses slowly, it allows us to have enough time to prepare against damage. So we need the early detection of drought onset, and an exact recognition on the ongoing drought situation. Then, we prepared a system that can monitor it. There are some systems that monitor the drought. NDMC in USA is one of them.

Many countries have their own system as listed in Boken *et al*. (2005), but most of them are not available on everyday use. Most of the indexes they use are not intensive measure but extensive measure that has some weaknesses to detect drought condition. Moreover, because they are originally not daily based but monthly based data, they cannot detect precisely the onset and withdrawal date of the drought, the spatial distribution of drought severity, and the daily changes of drought severity. Effective Drought Index (EDI; Byun and Wilhite, 1999) is the only drought index that is developed as an intensive measure and a daily index originally.

Then this study introduces a drought monitoring system using EDI and its related variables. Parts of the system has introduced in Boken *et al.* (2005). Weaknesses of PDSI, SPI and other drought indexes are listed in Byun and Wilhite (1999). Merits of EDI in precipitation climatology are verified by Byun and Lee (2002), Choi and Byun (2005), Han and Byun (2006). Merits of EDI on drought monitoring have recognized from Yamaguchi and Shinoda (2002). After Morid *et al.* (2006), EDI has become one of the most important indexes in drought monitoring. Radic and Mihailovi (2006), Usman *et al*. (2006), Ajayi and Olufayo (2007), Kim and Byun (2007), Pandey *et al*. (2007), Smakhtin and Hughes (2007) and Akhtari *et al*. (2008) are examples. Smakhtin and Hughes (2007) has changed the daily index to monthly index for easier use. This drought monitoring system has been operated since 2000. Website is http://atmos.pknu.ac.kr/~intra.

Effective Drought Index (EDI)

The Effective Drought Index (EDI; Byun and Wilhite, 1999) is used to measure the intensity of droughts. The Index is most recently developed and overcomes the limitations of several drought indices. It is an intensive measure that considers the water accumulation with the weighting function of time passage.

This Index is calculated only by precipitation data so that it simply calculates the intensity of drought anywhere. And it is calculated with daily time step among several drought indices so that it analyzes precisely the drought climate. In addition, the EDI is advantageous to measure the extremely long-term drought by considering the consecutive dry duration. Though a rough meaning of EDI values are classified in Table 1, it is a kind of standardized value that means 66.7% of whole variance is in the range of ✻ 1.0. The details of information can be seen in Byun and Wilhite (1999). The calculation process of the EDI is as follows (Eq. 1):

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

i = Dry duration + 365
Pm = Precipitation of m days before
EP = Effective precipitation
MEP = Climatological mean of EP for each calendar day
ST = Standard deviation

DEP = EP - MEP
EDI = DEP/ST(DEP) (Eq. 1)

Table 1. Classification of EDI values

Classification	In late spring and winter	In rainy season	Other seasons
Moderate Drought	< -0.5	< -1.0	< -0.7
Severe Drought	< -1.0	< -1.5	< -1.2
Extreme Drought	< -1.5	< -2.0	< -1.7

Here the Effective Precipitation (EP) measures a current available water resources generated by past precipitation with reflecting the depletion by runoff and evaporation as time goes up. The concept of the EDI is a standardized daily difference between the EP and the climatological mean of EP (MEP) for each calendar day.

This system serves variations of drought related variables, not only spatial but also temporal distribution of every station with daily time step after 1974. This system helps us to detect, early and easily, where and when the drought occurred, and how the drought situation is going. The onset and the withdrawal date of the drought can be defined clearly by this system. Also, it is useful to detect the change of the precipitation climate.

While most of other systems are observing a drought by more than a week or a month, this system is observing with daily real time step. It can give the immediate warming to drought, thus allow us to a prompt preparation.

Other hydrological variables (Table 2) such as the available water resources index, the flood index, and the estimated precipitation index required to relieve drought are provided also.

Table 2. The meanings of thirteen variables that are served in our drought monitoring system.

Variables	Meaning
IAN	Consecutive days of positive(negative) water anomalies
APN	Accumulated precipitation during IAN
VPN	Normal value of accumulated precipitation during IAN
DPS	Anomaly of accumulated precipitation during IAN
APL	Accumulated precipitation during IAN+365
VPL	Normal value of accumulated precipitation during IAN+365
DPL	Anomaly of accumulated precipitation during IAN+365
PRN	Precipitation needed for return to normal
PRY	Precipitation needed for return to normal for 365 days
EDI	Effective Drought Index
PCN	Precipitation
AWR	Available water resources
FI	Flood Index

Practical application

Here we show practical applications. An extreme drought in 1988-89 was one of the worst droughts in Korea. In Fig. 1a we can know that 1988-89 drought was not a single drought but a series of multiple droughts. The major drought started on Jun. 10 1988 and ended on May 3 1989. Its duration was 236 days as shown in Fig. 1d. It is notable that there is the portent fluctuation in EDI time-series before the onset of the major drought. At the same time, moderate drought already developed across North to South Korea (Fig. 2a). Due to insufficient summer rainfall (Fig. 1b), the drought was getting worse and sustained until May 3 1989. During the duration, the minimum EDI was -2.0 which corresponds to a category of extreme drought. This extreme drought was widespread over most of Korea (Fig. 2b). It was temporally relieved by a heavy rainfall for a day of Mar 3 1989 (Figs. 2c and d). However drought was again developed as no or weak rainfall days continued.

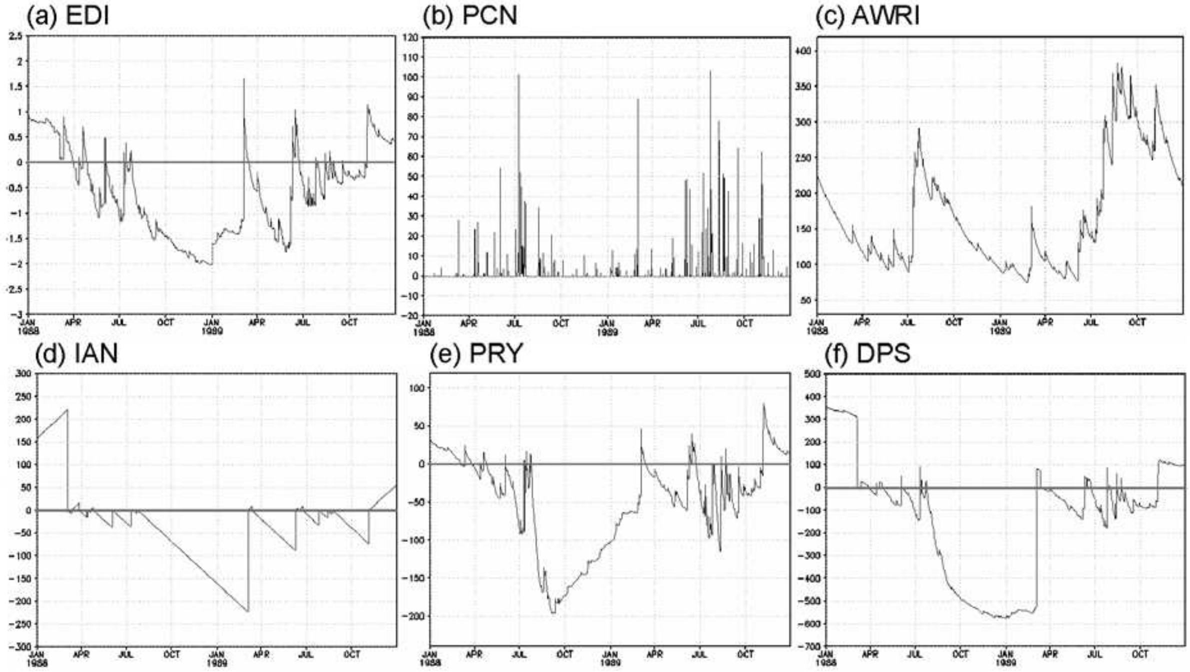

Fig. 1. Time series of (a) EDI, (b) PCN, (c) AWRI, (d) IAN, (e) PRY, (f) DPS relatively in Seoul from Jan. 1988 to Dec. 1999.

The 1988-89 drought ultimately ended on Oct. 30 1989. The AWRI, PRY and DPS time-series provide some assistant information. Application of the AWRI reveals that there was an actual water deficit in Apr. to Jun. 1988 as well as in Jan. to Jun. 1989 though EDI in the later period is much below than in the former period. Through Fig. 1e, we can easily recognize how much precipitation is needed for returning to normal. The DPS time-series shows an amount of deficit precipitation accumulated during IAN.

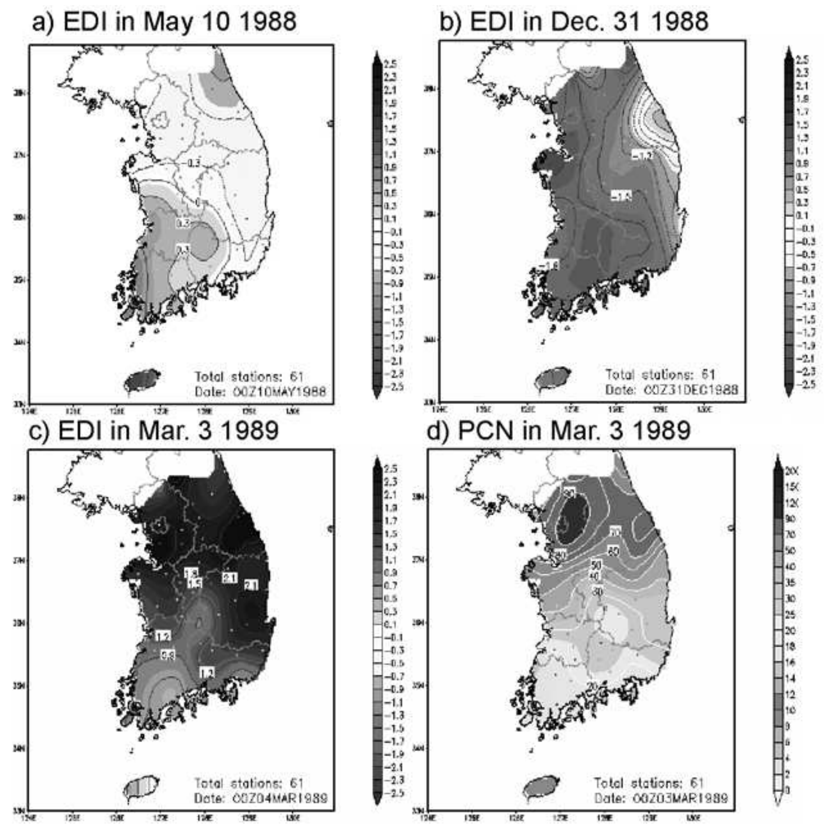

Fig. 2. The Spatial distribution map of EDI on (a) May 10 1988, (b) Dec. 31 1988, (c) Mar. 4 1989 relatively, and PCN on (d) Mar. 3 1989.

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