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Scaling characteristics of precipitation data in conjunction with wavelet analysis

Mehmet Özger [a,*], Ashok K. Mishra [b], Vijay P. Singh [b]

[a] Hydraulics Div., Faculty of Civil Engineering, Istanbul Technical Univ., Maslak 34469, Istanbul, Turkey
[b] Dept. of Biological and Agricultural Engineering & Department of Civil Engineering, Texas A&M University, College Station, TX 77843-2117, United States

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SUMMARY

A large set of monthly precipitation data from 43 stations throughout Texas was employed to investigate the spatial variability in the multiscaling properties of wet and dry spells. Special emphasis was given to dry spells which are related to meteorological droughts. Scaling properties deduced from the analysis of dry spells can be used in drought modeling and multiscale temporal variability of droughts. Using moment scaling exponents, scaling properties of wet and dry spells were examined for a median truncation level. No coherent regional differences were found from the spatial depiction of scaling parameters. Wet and dry spells showed different tendencies in simple scaling and multiscaling throughout the study area. Also, significant low frequency patterns of precipitation were found when the wavelet transform was used. Investigation of the relationship between scaling properties and significant cycles of precipitation data showed that annual cycles may contribute to the occurrence of simple scaling mechanism in wet and dry spell sequences. Such characterization of sequences of wet and dry spells is essential for addressing a multitude of hydrological problems, including estimation of flood and drought frequencies, construction of rainfall and runoff relationships, agricultural planning, to name but a few.

1. Introduction

Wet and dry spells can be described with their durations and magnitudes. Duration indicates the time elapsed between the beginning and the end of a wet or dry spell. The severity of the wet or dry spell is expressed by its magnitude which shows the total surplus or deficit according to a truncation level. For example, the number and magnitude of a two-month duration dry spell can be found by simply counting the dry spells which last two consecutive months and taking the cumulative sum of amounts that stay within each dry spell throughout the events, respectively. So far, scaling properties of the number of wet and dry spells has been investigated (Kadioglu and Sen, 1998). However, the scaling properties of spell duration and magnitude which are also important for hydrological modeling have not been investigated. Both durations and magnitudes of wet and dry spells are required for the planning of complex water resources systems in terms of estimating flood and drought frequencies (Fernandez and Salas, 1999).

The sequence of wet and dry spells has been examined by considering various approaches. The first definition of wet and dry spells goes back to the second half of the 20th century (Yevjevich, 1967; Sen, 1976; Dracup et al., 1980). Recently, Tolika and Maheras (2005) investigated the characteristics of wet spells using daily rainfall gauge data. Deni et al. (2008) focused on investigating the most appropriate distribution to describe the sequences of wet (dry) spells for rain gauge stations. Lana et al. (2008) obtained main statistical and spatial patterns of dry spell lengths by considering four different truncation levels of daily rainfall. Also, spatial trends of dry spells were explored by Deni et al. (2009).

Since its first proposal, wavelet analysis has been applied in various areas, especially in climate and hydrological studies. Torrence and Compo (1998) introduced a practical step by step guide to wavelet analysis with examples taken from large scale climate indices. Grinsted et al. (2004) discussed the cross wavelet transform and wavelet coherence for examining relationships in time frequency space between two time series. Anctil and Coulibaly (2004) proposed a wavelet based approach to describe the local interannual variability in streamflow, and to identify plausible climatic teleconnections that could explain these local variations. Kucuk et al. (2008) investigated the variability of lake levels using the method of continuous wavelet transforms and global spectra. Wavelet decomposition can also be used in prediction problems (Kucuk and Agiralioglu, 2006). Ozger et al. (2009) investigated the low frequency drought variability by employing the wavelet approach.

In this paper, the focus is on the scaling properties of wet and dry spells. Although several studies have analyzed the scaling properties of precipitation events, much less attention has been given to the scaling characteristics of wet and dry spells. A discrete multiplicative random cascade approach can be used to assess the scaling properties of wet and dry spells obtained from observed

* Corresponding author. Tel.: +90 5324957581.
E-mail addresses: mehmetozger@yahoo.com (M. Özger), amishra@tamu.edu (A.K. Mishra), vsingh@tamu.edu (V.P. Singh).

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rainfall amounts. The objective of this paper therefore is to: (1) quantify the scaling stability of wet and dry spells in terms of the duration and magnitude using long records, and determine the regions where there is a tendency towards simple scaling, (2) detect the significant cycles existing in precipitation during the period of record, and (3) relate some of these cycles to the scaling properties, and (4) investigate the effect of large scale climate indices of El Nino Southern Oscillation.

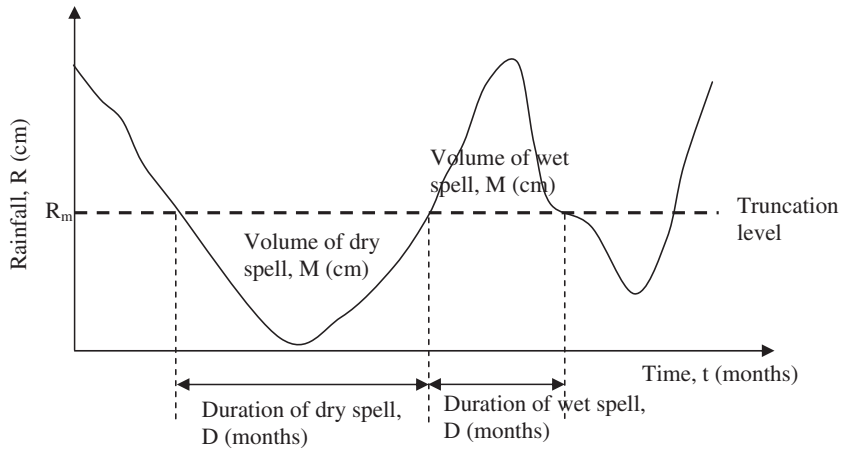

Fig. 1. Definition of variables used in the study.

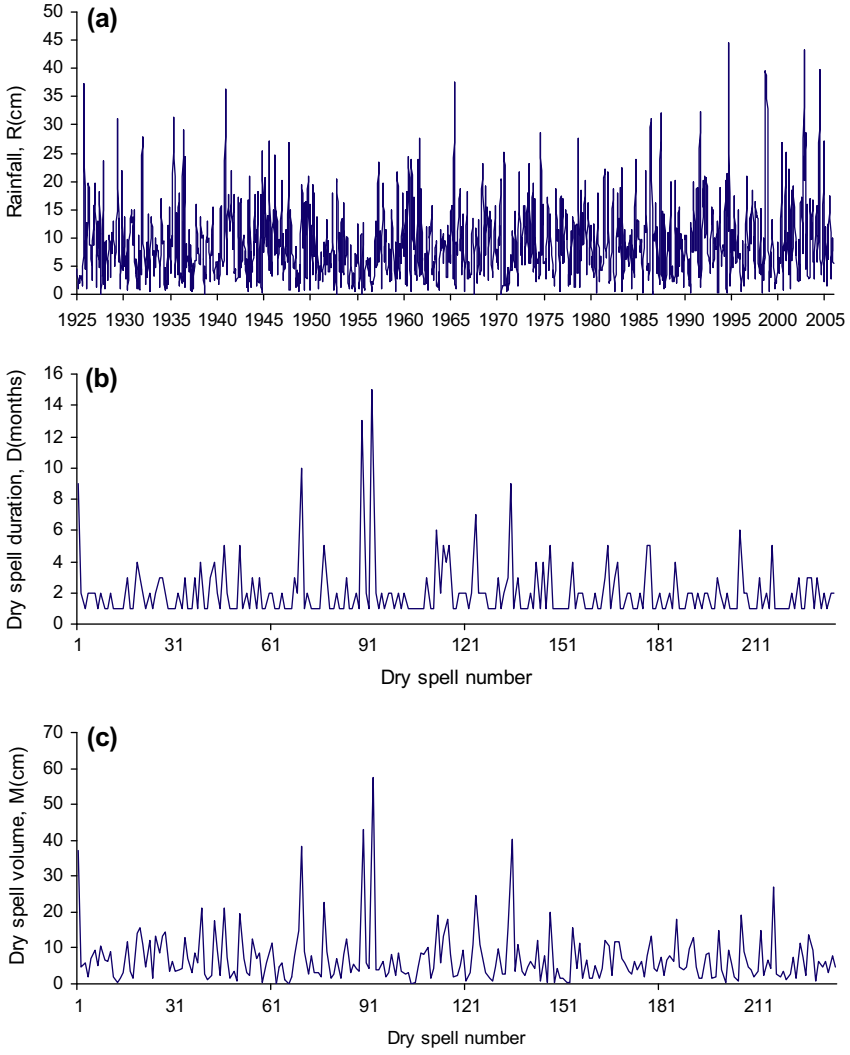

Fig. 2. (a) Rainfall time series for station 411048, variation of (b) durations, and (c) magnitudes with spell numbers after applying a median truncation level.