Journal of Hydrology: Regional Studies 9 (2017) 183–198

Contents lists available at ScienceDirect

Journal of Hydrology: Regional Studies

journal homepage: www.elsevier.com/locate/ejrh

# Exploring temporal and spatial variability of precipitation of Weizhou Island, South China Sea

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ARTICLE INFO

*Article history:*
Received 21 June 2016
Received in revised form 6 November 2016
Accepted 10 December 2016
Available online 23 December 2016

*Keywords:*
Rainfall trend
Innovative method
Mann-Kendall
Weizhou island

ABSTRACT

*Study region:* Weizhou Island, Northern part of the South China Sea.
*Study focus:* Research on precipitation variability is important for understanding the water cycle and to evaluate risk of flood and drought risks. We studied precipitation variability, including amounts and intensity, on a sea island (Weizhou Island) using a long time-series daily precipitation dataset. An innovative trend test (Şen trend test) and M-K trend test were used to analyze trends of rainfall variability. The Concentration Index (CI1) and the precipitation concentration index (CI2) were used, respectively, to evaluate the intensity and seasonality of rainfall. The continuous wavelet transform (CWT) was used to analyze CI1 and CI2. NCEP/NCAR data were used to determine if large scale circulation has an influence on Weizhou Island rainfall variability.

New hydrological insights: (1) Rainfall amounts had a non-homogeneous temporal distribution during periods of 1961–1990, 1981–2010 and 1961–2010 on Weizhou Island. (2) Large scale atmospheric circulation may be the major atmospheric driving force of precipitation changes. (3) Precipitation has a cyclical nature on Weizhou Island. (4) Precipitation pattern on Weizhou Island is also affected by oceanic climate. The results provide a scientific basis for water resource management on Weizhou Island.


## 1. Introduction

Climate change and climate variability are critical topics. Atmospheric warming appears to have modified the water cycle, and precipitation plays a key role in this cycle (De Luis et al., 2011). Precipitation is a key element that directly affects water resource distribution which significantly influences water availability for agriculture, industry, and domestic uses. Heavy rain has great potential to trigger natural disasters, such as floods and landslides. These extreme natural events put substantial economic pressure on local and national governments (Caloiero, 2014; Li et al., 2014). Research on the variability of daily rainfall enables better understanding of the water cycle and enhanced evaluation flood and drought (Wang et al., 2011).

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http://dx.doi.org/10.1016/j.ejrh.2016.12.079

Studies on precipitation variability have used various statistical methods. Increases or decreases in the number of rainy days have been detected in many areas (Sansom and Thompson, 2008; Norrant and Douguedroit, 2006; Gajic-Capka et al., 2015). Continental-scale trends in precipitation have been detected in Europe (Cortesi et al., 2012), central Asia (Xu et al., 2015), and also at national and regional scales (De Luis et al., 2011; Xu et al., 2003; Vincent et al., 2011; Guo et al., 2012; Alijani et al., 2008; Coscarelli and Caloiero, 2012). Precipitation variability on Weizhou Island, however, has not been studied.

Extreme weather events, including droughts, floods and other secondary disasters, are likely to occur more frequently in the future (Coscarelli and Caloiero, 2012). Higher precipitation concentration, indicated by a high percentage of the total annual precipitation falling within a short period, has significant potential for triggering floods and causing droughts during subsequent lengthy dry intervals (Santos et al., 2010; Raziei et al., 2009). The amount and intensity of precipitation may increase slope instability and the risk of soil erosion. Soil erosion will have negative effects on growing conditions and agricultural practices, especially on Weizhou Island which has a fragile ecosystem. Therefore, it is important to analyze rainfall variability to provide a scientific basis for water resource management.

The trend of rainfall amounts is an important aspect of rainfall variability. Changes of rainfall may alter groundwater recharge (Yu and Lin, 2015) and water availability (Hasan and Dunn, 2011). The Şen trend test method developed by Şen (2012) improves the ability to detect the trend degree (abrupt or gradual). Kisi and Ay (2014) used the Şen trend test to analyze water parameters. They noted that the Şen trend test had several advantages compared with the M-K trend test, and could be successfully used for trend analysis of low, medium and high values of water parameters. In addition, this method can also be used to analyze the trend of monthly pan evaporations. Kisi (2015) reported that the low, medium and peak pan evaporation values at some stations presented increasing and decreasing trends based on the Şen trend test, but no trend was detected at the same stations using the M-K test. This innovative method was also applied by Ay and Kisi (2015) to analyze monthly total precipitation data in Turkey. Therefore, the Şen trend test was used to analyze rainfall trends in this study. Rainfall amount is one important aspect of rainfall variability. Another important aspect of rainfall variability that merits consideration is intensity.

The Concentration Index (CI1), established by Martin-Vide (2004), is used to analyze the variability of daily rainfall, and has been widely used to analyze precipitation concentration. Martin-Vide (2004) used CI1 to detect the spatial distribution of daily precipitation concentration in Spain. Peninsular Spain was divided into two regions using CI1 values: an eastern area of high concentration (where 25% of the rainiest days represent 70% or more of the annual total), and the rest of the country, which had more evenly distributed daily rainfall amounts. Higher precipitation CI1 values mainly occurred in Southern Xinjiang, whereas lower CI1 values were mostly found in Northern Xinjiang (Li et al., 2011). CI1 values are noticeably higher in regions where both annual total precipitation and number of rainy days are low. CI1 showed an inhomogeneous temporal distribution of daily rainfall in Southwest China (Shi et al., 2015). To quantify the heterogeneity of monthly precipitation in one year, Oliver (1980) proposed the precipitation concentration index (CI2). Shi et al. (2015) noted that Southwest China had a significant seasonality of rainfall distribution. CI2 values, derived from a daily time-series dataset of 1916–2006, in southern Italy ranged from a minimum value of 13.4 to a maximum value of 20.5, and illustrated the seasonality of the pluviometric distribution (Coscarelli and Caloiero, 2012). CI1 and CI2 are two descriptors of rainfall intensity, and both were used in this study. The trend in rainfall intensity is another important aspect of rainfall variability. The Mann–Kendall (M-K) trend method (Shi et al., 2015; Cortesi et al., 2012; Wang et al., 2013) has been widely used to study precipitation trends, CI1 tend, or CI2 trend (either increasing or decreasing), was also used.

The goals of this study were to (1) evaluate trends of rainfall amounts at monthly, seasonal, and annual temporal scales; (2) study temporal patterns of CI1 and CI2 on Weizhou Island, (3) analyze the relationship between the variations of precipitation and large scale circulation patterns, (4) compare the rainfall variability of Weizhou Island with an adjacent mainland location (Malan, China).

## 2. Materials

### 2.1. Study area

Weizhou Island (20°54′–21°10′ E, 109°00′–109°15′ N) is the youngest and largest volcanic sea island in the Northern part of the South China Sea (Fig. 1). It has an area of 24.7 $km^2$ and a high elevation of 79 m. The annual average temperature is 23 °C, and the annual average precipitation is 1350 mm. Due to tourism, much native vegetation has been replaced by buildings, and other structures. This has led to serious soil erosion by water runoff. Tourism has greatly increased the use of fresh water. The majority of fresh water on this island comes from precipitation. Affected alternately by the winter and summer monsoons, the temporal distribution of rainfall in Weizhou Island is inhomogeneous. Therefore, this island has a freshwater shortage most of the year around despite high annual rainfall. Understanding the rainfall pattern may provide a scientific basis to help local decision-makers better manage water resources.

### 2.2. Data

A dataset of daily precipitation from 91 rain gauges in Guangxi province during the period 1961–2010 was obtained from the Meteorological Information Center of Guangxi. First, data quality and homogeneity were assessed. The purpose of data quality control was to identify errors in datasets of daily precipitation that might interfere with correct assessment of