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Spatiotemporal pattern of precipitation concentration and its possible causes in the Pearl River basin, China

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ABSTRACT

The spatiotemporal pattern of precipitation concentration is a key factor in a hydrological analysis. This study attempts to explore the spatiotemporal variations and the causes of the variations in precipitation concentration. Firstly, the Mann-Kendall statistical test and Sen's slope method are used to detect the temporal patterns of the annual precipitation concentration index (ACI), and the inverse distance weighted (IDW) interpolation method is used to analyze the spatial changes in the long period precipitation concentration index (LCI) as well as the temporal variation trend of the ACI based on daily precipitation at 42 sites during 1960–2012 in the Pearl River basin. Secondly, a possible link between precipitation concentration and elevation is investigated by calculating the correlation coefficient between LCI and elevation. Finally, the random forest algorithm (RF) is applied to identify the contributions of seven associated circulation influencing factors on the CI. The results show that: 1) The northwest of the Pearl River basin that is further from the sea and has a higher elevation, exhibits a lower LCI. The southeast part that is closer to the sea and has a lower elevation exhibits a higher LCI, indicating that extreme precipitation events will occur more frequently at lower elevations and closer to the sea areas. 2) The interannual variation of the ACI in the Pearl River basin is not obvious; the northwest part exhibits a decreasing trend while the southeast part has an increasing trend, and the spatial distribution of the ACI's change trend is likely affected by elevation and the distances from the sea. 3) The precipitation concentration is negatively correlated with elevation with a correlation coefficient of −0.92 at the 99% confidence level. 4) The significance analysis based on RF shows that the East Asian Summer Monsoon (EASM) is the most significant factor affecting the precipitation concentration of the Pearl River basin among seven associated circulation influencing factors.

1. Introduction

Extreme precipitation is of great concern since it exerts great impacts on floods, droughts, soil erosion and water utilization.(Xu, 2000; Xu and Singh, 2004; Scholz et al., 2008; Zhu et al., 2016), especially under the changing environment. In particular, the precipitation concentration can effectively identify extreme precipitation, which is mainly used to describe the heterogeneity of precipitation. The higher the precipitation concentration, the greater possibility of floods and droughts is, which can have great influences on socioeconomic losses. Due to their considerable scientific and practical merits, the spatiotemporal patterns, changing properties and implication of the precipitation concentration have been investigated by numerous researches to elevate the changing characteristic of regional or global extreme precipitation events. However, most of the research has focused on the changing characteristics, and the research about causes of the spatiotemporal distribution is still insufficient.

In previous studies, the Precipitation Concentration Index (CI), developed by Martin-Vide (2004) has been widely employed to analyze the precipitation concentration and associated spatiotemporal patterns in several countries such as Iran, China, Malaysia and Algeria (Alijani et al., 2008; Li et al., 2011; Suhaila and Jemain, 2012; Boucherf et al., 2014) as well as in Europe (Cortesi et al., 2012). Alijani et al. (2008) analyzed the spatial and temporal patterns of

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the CI and found that the daily precipitation tended to be irregular and intense across much of Iran. Li et al. (2011) found that higher and lower values of the CI were mainly observed in Southern and Northern Xinjiang. Suhaila and Jemain (2012) determined that the distribution of daily rainfall was more regular over the west, northwest and southwest regions compared to the east in Peninsular Malaysia. Boucherf et al. (2014) showed that the CI was lower in northern Algeria than in southern region and lower in the highlands than in the coastal regions. Cortesi et al. (2012) indicated that the CI increased from the northwest to the southeast in Europe, that no significant changes had occurred in the daily precipitation distribution across Europe during 1971–2010, and that the distance from the sea appeared to play a major role in the spatial distribution of the CI. On a global scale, the precipitation concentration has also been analyzed by using the CI. For example, Monjo and Martin-Vide (2016) found that a high precipitation concentration correlated with the rapid pace of physical processes such as convection in areas with a high degree of insolation and warm seas. It is important that previous studies investigated the spatiotemporal distribution of the regional or global CI and their changing trends, which contribute to regional flood prevention and water use management. However, research on the causes of the spatiotemporal distribution and changing property of the CI is still insufficient, especially under the changing environment.

The Pearl River basin (Fig. 1), the largest river basin in South China, includes the Pearl River Delta (PRD), a highly dense agglomeration of over 100 towns and cities, and occupies a crucial position in the socioeconomic development of China since the country adopted the 'open door and reform' policy in the late 1970s. Particularly in the PRD, a highly developed economy, dense population and low-lying terrain make this mega city group sensitive to floods caused by extreme precipitation. Therefore, it is necessary to conduct a thorough investigation of the precipitation CI, its changing property and even its possible causes across the Pearl River basin. A large amount of research on precipitation CI has been conducted in the Pearl River basin. Zhang et al. (2009) examined the spatial and temporal patterns of the CI and found that the CI values had increased in the south and decreased in the north of the Pearl River Basin based on daily precipitation data for 42 rain gauge stations during 1960–2005. Chen et al. (2011) investigated the changing characteristic of the seasonal precipitation in the Dongjiang River basin using monthly precipitation data covering 1956–2002 and determined that the intensity of the South-east Asian Monsoon carrying excess moisture was the main driving factor for precipitation changes in the Dongjiang River basin. Liu et al. (2015) explored the changes in precipitation, precipitation intensity and rainy days in the Pearl River Basin based on 24 climatic indices derived from daily precipitation data during 1959–2009. The authors found that the average annual precipitation of the entire basin did not exhibit obvious variation, while heavy and extremely heavy rains increased at most stations. In general, it can be concluded from these studies that the average annual precipitation in the whole basin reflected apparent regional characteristics and did not exhibit obvious variations. However, what causes such a complicated spatiotemporal pattern of the precipitation CI? Which is the dominant factor affecting its changing properties? In addition, the topography is considered an important factor that affects the variability of precipitation extremes. It has been shown that the generalized extreme value distribution over China is largely dependent on elevation (Yang et al., 2013). The correlation between precipitation extremes and elevation was also confirmed at the regional scale (Zhang et al., 2014). Is there any link between the CI of the Pearl River basin and its topography? These issues remain unknown. Further studies on the possible causes of the changing properties of the CI should be conducted, particularly on the contribution of different influencing factors and on the investigation of a possible link between the topography and the precipitation concentration. Therefore, using the Pearl River basin in China as a study area, the objectives of this paper are: (1) to analyze the spatial and temporal patterns of the precipitation CI in the Pearl River basin in China; (2) to determine, based on the calculation of the CI, the correlation between the topography and the precipitation concentration; (3) to identify the contributions of the associated circulation influencing factors on the changing properties of the CI in the Pearl River basin in China.

2. Study area and data

2.1. Study area

The Pearl River basin, located in the south of China (97°39′E–117°18′E; 3°41′N-29°15′N)(Fig. 1), is the third largest river basin in China with a drainage area of $4.42 \times 10^5 km^2$and has

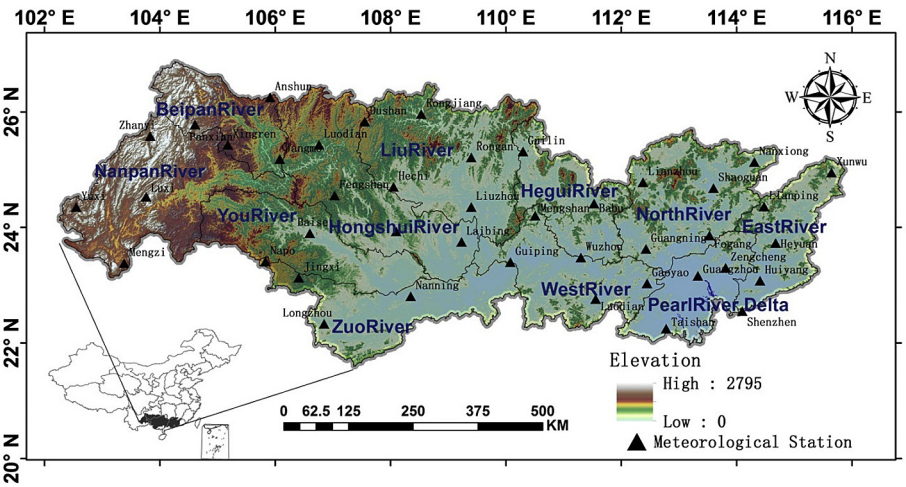

Fig. 1. Map of the Pearl River basin.

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