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Temporal and spatial distribution characteristics of water resources in Guangdong Province based on a cloud model

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Abstract

With a focus on the difficulty of quantitatively describing the degree of nonuniformity of temporal and spatial distributions of water resources, quantitative research was carried out on the temporal and spatial distribution characteristics of water resources in Guangdong Province from 1956 to 2000 based on a cloud model. The spatial variation of the temporal distribution characteristics and the temporal variation of the spatial distribution characteristics were both analyzed. In addition, the relationships between the numerical characteristics of the cloud model of temporal and spatial distributions of water resources and precipitation were also studied. The results show that, using a cloud model, it is possible to intuitively describe the temporal and spatial distribution characteristics of water resources in cloud images. Water resources in Guangdong Province and their temporal and spatial distribution characteristics are differentiated by their geographic locations. Downstream and coastal areas have a larger amount of water resources with greater uniformity and stronger stability in terms of temporal distribution. Regions with more precipitation possess larger amounts of water resources, and years with more precipitation show greater nonuniformity in the spatial distribution of water resources. The correlation between the nonuniformity of the temporal distribution and local precipitation is small, and no correlation is found between the stability of the nonuniformity of the temporal and spatial distributions of water resources and precipitation. The amount of water resources in Guangdong Province shows an increasing trend from 1956 to 2000, the nonuniformity of the spatial distribution of water resources declines, and the stability of the nonuniformity of the spatial distribution of water resources is enhanced.

Keywords: Water resources; Temporal and spatial distribution characteristics; Cloud model; Guangdong Province

1. Introduction

Water is one of the essential natural resources that sustain the existence and development of human society. However, the shortage of water resources has become a worldwide problem due to population growth and socio-economic development (Wei et al., 2004). Variation in climate and topography results in spatial and temporal variations of water resources over a region. The temporal and spatial distribution characteristics of water resources have impacts on the management of water resources, agriculture, and the aquatic ecosystem (Lilover et al., 1998; Petts et al., 1999; Hannah et al., 2000; Harris et al., 2000; Disalvo and Hart, 2002). Therefore, research on the regional temporal and spatial distribution characteristics of water resources is significant to any understanding the variation of regional water resources as well as their management and allocation.

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At present, methods for research on the temporal and spatial distribution characteristics of water resources involve analyzing the time domain and frequency domain of time sequences of water resources and studying the period and trend variations of water resources based on statistical theories (Conway et al., 2009; Ling et al., 2013). In some studies, simulations of the hydrological process have been carried out to describe the temporal and spatial variations of water resources and to forecast trends based on hydrological models (Xu et al., 2007; Zhang et al., 2013). In recent years, the chaos theory (Dai et al., 2007), information entropy (Zhang and Liu, 2000), wavelet analysis (Conway et al., 2009), and fractal theory (Lovejoy et al., 1987; Sivakumar, 2000) have also been used to study the temporal and spatial distribution characteristics of water resources. However, in these studies, most descriptions of the nonuniformity of temporal and spatial distributions of water resources are qualitative, and no quantitative description of the degree of nonuniformity of the distribution is provided. There have been few studies on the temporal variation of the spatial distribution characteristics and the spatial variation of the temporal distribution characteristics of water resources. In addition, only the temporal trend in water resources is analyzed in most of these studies (Lins and Slack, 1999, 2005; Milly et al., 2005). Based on the traditional fuzzy set theory and probability statistics, the cloud model was proposed by Li and Du (2005) and became a method for uncertain conversion between a qualitative concept and its quantitative description.

In this study, with a focus on the difficulty of describing the degree of nonuniformity of temporal and spatial distributions of water resources in a quantitative way, a cloud model was built for the temporal and spatial distribution characteristics of water resources in Guangdong Province. The spatial variation of temporal distribution characteristics and the temporal variation of spatial distribution characteristics of water resources were both analyzed.

2. Research area and data

2.1. Research area

As shown in Fig. 1, Guangdong Province ranges from 20°08′N to 25°32′N and from 109°40′E to 117°20′E at the southern end of China, with the Tropic of Cancer passing through its middle region. The overall topography of Guangdong Province is high in the north and low in the south, and the topographic pattern is complex. In addition to the river system in the Pearl River Basin, there are many medium and small rivers flowing into the sea in the province, such as the Hanjiang River. The Dongjiang, Xijiang, and Beijiang rivers in the Pearl River Basin converge at the border of Guangdong Province, running into the South China Sea through the Pearl River Delta. Guangdong Province is located in the downstream area of the Pearl River Basin and borders the South China Sea on the south, which enables moisture to enter from the Bay of Bengal in the Indian Ocean and the Pacific Ocean. The climate is warm and humid, with abundant precipitation, and the river runoff is completely recharged by precipitation. Compared with other provinces and districts in China, surface water resources are abundant in Guangdong Province. However, due to the large population, the amount of water resources per capita in Guangdong Province is only at the national average level, and the temporal and spatial

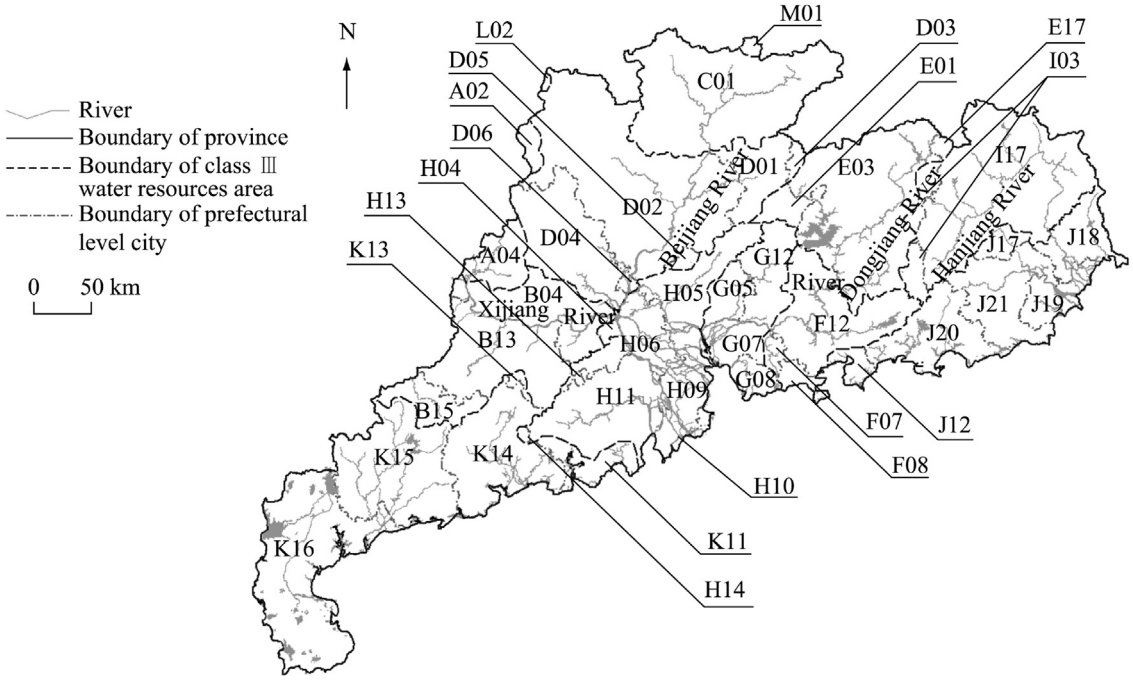

Fig. 1. Location of Guangdong Province and regional map of research areas.