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CHANGES IN CLIMATE SYSTEM

Responses of Hydrological Processes to Climate Change in the Zhujiang River Basin in the 21st Century

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Abstract

In this study, discharge at the outlet of Xijiang River, the biggest sub-basin of the Zhujiang River, was simulated and projected from 1961 to 2099 using the hydrological model HBV-D. The model uses precipitation and temperature data from CISRO/MK3_5, MPI/ECHAM5, and NCAR/CCSM3 under three greenhouse gas emission scenarios (SRES A2, A1B, B1). The results in water resources and flood frequency suggest that annual precipitation and annual runoff would increase after 2050 relative to the reference period of 1961–1990. In addition, increasing trends have been projected in area averaged monthly precipitation and runoff from May to October, while decreasing trends in those from December to February. More often and larger floods would occur in future. Potential increase in runoff during the low-flow season could ease the pressure of water demand until 2030, but the increase in runoff in the high-flow season, with more often and larger floods, more pressure on flood control after 2050 is expected.

Keywords: Zhujiang River Basin; hydrological model HBV-D; flood; low flow; projection

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1 Introduction

Under the background of global warming, air temperatures are rising and more heterogeneous precipitations occur in most basins in China, which cause floods and droughts. Water security, food security and eco-environment are threatened along with abrupt increasing in water demand. The Zhujiang River is located in southern China with annual runoff of 3,360 billion m^3. It is the second river in terms of water runoff next to the Yangtze River in China [*Yao*, 2004; *Tong*, 2007]. Recently, seasonal change of runoff becomes more significant due to climate change, which brings more often and large floods, and consecutive dry periods [*Tong*, 2007]. Especially since 2003, consecutive precipitation and below-normal runoff occurred more often in winter and spring. Analysis of changes in precipitation, temperature and runoff [*Yu and Xie*, 2007; *Dong*, 2006; *Shi et al.*, 2007; *Wang et al.*, 2006; *Liu and Chen*, 2007; *Dai et al.*, 2007], and impacting factors on runoff [*Peng et al.*, 2006; *You et al.*, 2005; 2006; *Qin et al.*, 2008] have been focused. Few researches are concerned with change in future climate and runoff in this region. With the increasing in temperature and precipitation [*Liu et al.*, 2009], hydrological processes will become more complicated. Research on trends in water resources and hydrological extremes in the future under climate change background is needed by

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flood control and drought relief sectors. In addition, it is the important scientific basis of designing strategies for climate change mitigation and adaptation.

Different climate models, climate change scenarios and hydrological models are used to study impacts of climate change on water resources and assessment of uncertainty impacts in different river basins [*Koutsoyiannis and Efstratiadis*, 2007; *Minville et al.*, 2008; *Preston and Jones*, 2008]. It is indicated that the largest uncertainty comes from the GCM structure, followed by the emission scenarios, and hydrological modeling [*Booij*, 2005; *Gosling et al.*, 2011; *Philips and Gleckler*, 2006]. So impacts studies based on results from only one GCM should be interpreted with caution [*Prudhommed et al.*, 2003]. In this study, the semi-distributed hydrological model HBV-D driven by output from three GCMs under SRES A2, A1B and B1 scenarios is used to simulate daily discharge from the Xijiang River, the largest tributary stream of the Zhujiang River. Based on the simulations, future changes in water resources and floods are analyzed.

2 Basin introduction

The Zhujiang River has its source in Yunnan province, China. It drains the provinces of Yunnan, Guizhou, Guangxi, Guangdong, Hunan, and Jiangxi in China, and a part of northeastern Vietnam, and flows into the South China Sea. The basin covers approximately 453,700 km^2 (excluding the Leizhou Peninsula), within which 442,100 km^2 are in China [*Dai et al.*, 2007]. It is characterized by mountainous area and Karst area in the northwest but mainly lower mountains and hills in the southeast [*Tong*, 2007; *Xie et al.*, 2002]. Due to the mountains, there are 48,000 km^2 cropland, and 126,000 km^2 forest [*Tong*, 2007]. The Zhujiang River consists of the Xijiang River, Beijiang River, Dongjiang River, and some smaller rivers within the Zhujiang River Delta. Xijiang River (Fig. 1a) is the largest tributary among them, with a length of 2,214 km and a drainage area of 353,100 km^2 [*Sun et al.*, 2006], with about 2,300 billion m^3 of water discharge every year [*Li and Zhang*, 2006].

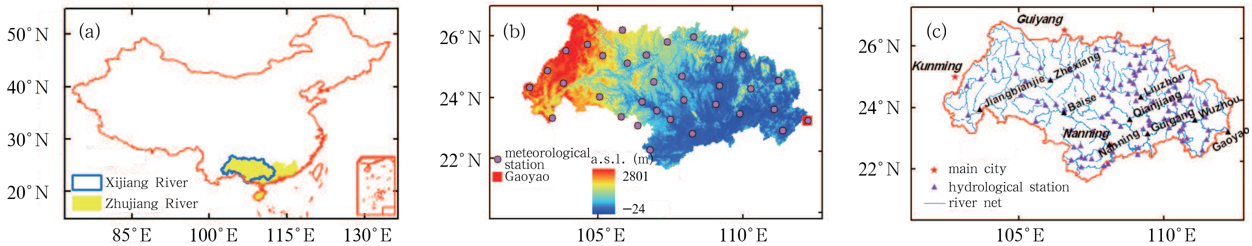

Figure 1 (a) Geographic location of the Zhujiang and Xijiang River Basins, (b) elevation and distribution of meteorological stations, (c) river systems and hydrological stations in the Xijiang River Basin

A tropical to sub-tropical climate prevails while the East Asian monsoon has strong influences on the basin [*Fischer et al.*, 2011]. The annual mean temperature varies from 14°C in the west to 22°C in the east, the relative humidity varies from 71% to 80% [*Tong*, 2007], and the annual average precipitation is 1,200 mm in the west and more than 2,000 mm around the coastline [*Gemmer et al.*, 2011]. The seasonal precipitation varies significantly, mainly due to the impact of the East Asian monsoon. Precipitation during flood season accounts for 72% of the annual amount. With significant inter-annual variability, the annual precipitation in wet years is 6–7 times as the amount in dry years. As a result, flood or drought disasters are likely to occur [*Liu and Chen*, 2007].

3 Available data

3.1 *Observations*

Daily temperature and precipitation records of 33 meteorological stations in the Xijiang River Basin during 1961–2006 are employed. The datasets are