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Recent changes of water discharge and sediment load in the Zhujiang (Pearl River) Basin, China

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Abstract

The paper is concerned with identifying changes in the time series of water and sediment discharge of the Zhujiang (Pearl River), China. The gradual trend test (Mann–Kendall test), and abrupt change test (Pettitt test), have been employed on annual water discharge and sediment load series (from the 1950s–2004) at nine stations in the main channels and main tributaries of the Zhujiang. Both the Mann–Kendall and Pettitt tests indicate that water discharge at all stations in the Zhujiang Basin showed no significant trend or abrupt shift. Annual water discharges are mainly influenced by precipitation variability, while the construction of reservoirs/dams in the Zhujiang Basin had little influence on water discharge. Sediment load, however, showed significant decreasing trends at some stations in the main channel of the Xijiang and Dongjiang. More stations have seen significantly decreasing trends since the 1990s. The decreasing sediment load in the Zhujiang reflects the impacts of reservoir construction in the basin. In contrast, the Liujiang, the second largest tributary of the Xijiang, has experienced a significant upward shift of sediment load around 1991 likely caused by exacerbated rock desertification in the karst regions. The annual sediment load from the Zhujiang (excluding the delta region) to the estuary has declined from 80.4×10^6 t averaged for the period 1957–1995 to 54.0×10^6 t for the period 1996–2004. More specifically, the sediment load declined steadily since the early 1990s so that in 2004 it was about one-third of the mean level of pre-90s. Water discharge and sediment load of the Zhujiang would be more affected by human activities in the future with the further reservoir developments, especially the completion of the Datengxia hydroelectric project, and an intensification of the afforestation policy in the drainage basin.

Keywords: gradual trend; abrupt change; water discharge; sediment load; the Zhujiang (Pearl River); time series analysis

1. Introduction

There is an increasing concern for water resource management in the international community due to the more dominant influence of anthropogenic forcing over natural drivers on river systems in the Anthropocene era (Crutzen and Stoermer, 2000; Meybeck, 2001; Varis and

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Vakkilainen, 2001; Meybeck, 2003). Many studies have been initiated to examine how river systems are affected by climate change and human activities. Detecting trends of long time series of water discharge and sediment load is a fundamental technique for understanding the relative importance of natural climate change and anthropogenic disturbances as well as their complex interactions on fluvial systems (Walling, 1995, 1997). It can also be helpful for better water resource management in the future (Walling and Fang, 2003; Kundzewicz, 2004).

It has been reported that changes of water discharge and sediment load can cause various effects on river system itself as well as the estuary and coastal shelf environment. Geomorphological evolution of river channels can be greatly affected by changes in water discharge and the relationship between sediment load and sediment-transport capacity of flow, such as the Rhone River in France (Petit et al., 1996; Arnaud-Fassetta, 2003), Wisloka River in southern Poland (Wyżga, 1997), Piave River in northeast Italy (Surian, 1999, 2006), and Cache Creek and Stony Creek in California, USA (Collins and Dunne, 1990; Kondolf, 1997). Yang et al. (2003) reported that the development of the Yangtze Delta has been, and will be, seriously influenced by the decline of sediment supply from the Yangtze River. Chen (2000) pointed out that changes of river inputs (mainly water flow, sediment load as well as nutrient flux) to the oceans caused by river basin development, notably the construction of dams, have more subtle effects which go far beyond the delta and estuaries including the transformation of the coastal shelf ecosystem and the starvation of fish populations. Hence, knowledge of riverine transports of water discharge and sediment load is of great significance not only for the river system itself but also for the delta and estuarine as well as coastal environments.

Water discharge and sediment load of most Chinese rivers have experienced great changes due to climate change and anthropogenic impacts in the drainage basin (Lu, 2004). Both water and sediment discharge of the Huanghe (Yellow River) have shown progressive decrease during the last 50 years, which is partly due to climate change (particularly, reduced precipitation) and more primarily, due to a series of human activities (particularly reservoir construction, water abstraction, and soil conservation) (Milliman, 1997; Yang et al., 1998; Xu, 2003; Walling, 2006; Wang et al., 2006). More studies have been carried out to examine the variations of water discharge and sediment load of part or the whole Changjiang (Yangtze River) Basin and possible influences of human activities were explored and discussed in these studies (Lu and Higgitt, 1998; Chen et al., 2001a,b; Yang et al., 2002; Lu et al., 2003; Zhang and Wen, 2004; Yang et al., 2005; Zhang et al., 2006). It has been reported that the completion of the Three Gorges Dam on the Yangtze River, the world largest dam, has already caused significant decrease in sediment discharge (Yang et al., 2003, 2006; Chu and Zhai, 2006), and primary production and fish catch in the East China Sea (ECS) (Chen, 2000; Gong et al., 2003).

The Zhujiang (Pearl River), is the second largest Chinese river in terms of annual water discharge, and plays a key role for fresh water supply to large cities in the Zhujiang Delta Region, such as Macau, Hong Kong, Zhuhai, and Zhongshan. The Zhujiang is the second largest river system contributing water discharge, sediment load and nutrient materials to the South China Sea (SCS) which is a major fishing ground. However, there are few reports in the international domain about current changes of water discharge and sediment load in this large drainage basin. Changes of water discharge and sediment load at Gaoyao hydrological station of the Xijiang in the Zhujiang Basin were briefly described by Walling (2006). Decreasing sediment load was reported to coincide with decreasing trends of some major ions and total dissolved solids (TDS) in the Dongjiang, one of the three main rivers in the Zhujiang Basin (Zhang et al., 2007). However, the above studies only showed and analyzed hydrological data from a few downstream stations in the main rivers rather than in the whole Zhujiang Basin. In this study, annual water discharge (WD) and sediment load (SL) during the past 50 years (the 1950s–2004) at nine stations in the Zhujiang Basin were investigated. Five stations are along the main channel of the Xijiang, two stations along the two largest tributaries of the Xijiang (namely Yujiang and Liujiang), one station along the Beijiang main channel, and one station along the Dongjiang main channel. The spatial distribution of these stations makes a full coverage of the Zhujiang Basin in the basin-wide scale.

The main objective of this study was to detect the recent changes, both gradual and abrupt, of water discharge and sediment load in the Zhujiang (Pearl River) Basin during the past 50 years. Also the possible causes for changes of water discharge and sediment load in the Zhujiang Basin, from both natural and anthropogenic aspects, were explored and discussed.

2. The Zhujiang (Pearl River) Basin

The Zhujiang (Pearl River) is the second largest Chinese river in terms of mean annual water discharge