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Sediment loads response to climate change: A preliminary study of eight large Chinese rivers

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Abstract

Climate change characterized by increasing temperature is able to affect precipitation regime and thus surface hydrology. However, the manner in which river sediment loads respond to climate change is not well understood, and related assessment regarding the effect of climate change on sediment loads is lacking. We present a quantitative estimate of changes in sediment loads (from 1.5 Gt yr^{-1} pre-1990 to 0.6 Gt yr^{-1} from 1991-2007) in response to climate change in eight large Chinese rivers. Over the past decades, precipitation change coupled with rising temperatures has played a significant role in influencing the sediment delivery dynamics, although human activities, such as reservoir construction, water diversion, sand mining and land cover change, are still the predominant forces. Lower precipitation coupled with rising temperatures has significantly reduced sediment loads delivered into the sea in semi-arid climates (4-61%). In contrast, increasingly warmer and wetter climates in subtropical zones has yielded more sediment (0.4-11%), although the increase was offset by human impact. Our results indicate that, compared with mechanical retention by reservoirs, water reduction caused by climate change or human withdrawals has contributed more sediment reduction for the rivers with abundant sediment supply but limited transport capacity (e.g., the Huanghe). Furthermore, our results indicate that every 1% change in precipitation has resulted in a 1.3% change in water discharge and a 2% change in sediment loads. In addition, every 1% change in water discharge caused by precipitation has led to a 1.6% change in sediment loads, but the same percentage of water discharge change caused largely by humans would only result in a 0.9% change in sediment loads. These figures can be used as a guideline for evaluating the responses of sediment loads to climate change in similar climate zones because future global warming will cause dramatic changes in water and sediment in river basins worldwide at rates previously unseen.

Key Words: Sediment load, Climate change, Human activity, Water withdrawal, Chinese rivers

1 Introduction

The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) concluded that global climate changes have been observed in recent decades and thus can be projected into the future (IPCC, 2007). These changes, particularly rises in temperature, are known to have effects on precipitation variability (Allen and Ingram, 2002; Trenberth et al., 2003; Barnett et al., 2005), surface runoff (Nijssen et al., 2001; Milliman et al., 2008), glacial and fluvial processes (Goudie, 2006), soil erosion (Michael et al., 2005) and sediment loads (Syvitski et al., 2003; Meade et al., 2010). However, little work has been done on the observed impacts of climate change on sediment loads in rivers and streams (IPCC, 2007; Syvitski et al., 2003; Knight and Harrison, 2009; Lu et al., 2010), especially in large river systems, due to a lack of data and difficulty in sediment modelling (Lu, 2004).

Although it has been accepted that anthropogenic influences are the cause of changes in terrestrial sediments entering the ocean (Walling and Fang, 2003; Walling, 2006; Syvitski et al., 2005; Hassan et al., 2008), the manner in which sediment loads responding to climate changes in large river basins needs investigation. In contrast to the paucity of integrated dataset facing rivers worldwide, continuous measurements of water discharge and sediment loads have been carried out for more than 50 years in many cases in China. We selected eight large Chinese rivers (the Songhuajiang, Laiohe, Haihe and Huanghe in the north and the Huaihe, Changjiang, Minjiang and Zhujiang in the south) (Figure 1) as a first attempt to evaluate the response of sediment loads to climate change. Although the runoff and sediment datasets have been systematically examined (Liu et al., 2008; Dai et al., 2009; Chu et al., 2009), and numerous studies on

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individual river basins have been conducted, e.g., the Huanghe (Hassan et al., 2008; Wang et al., 2007a), Changjiang (Yang et al., 2006b; Wang et al., 2007b), and the Zhujiang (Zhang et al., 2008), no attempt has been made to quantitatively link them with climate change. In essence, we used observed meteorological and hydrological records to track changes in temperature and precipitation and thus to quantify the changes in river sediment loads as influenced by climate change.

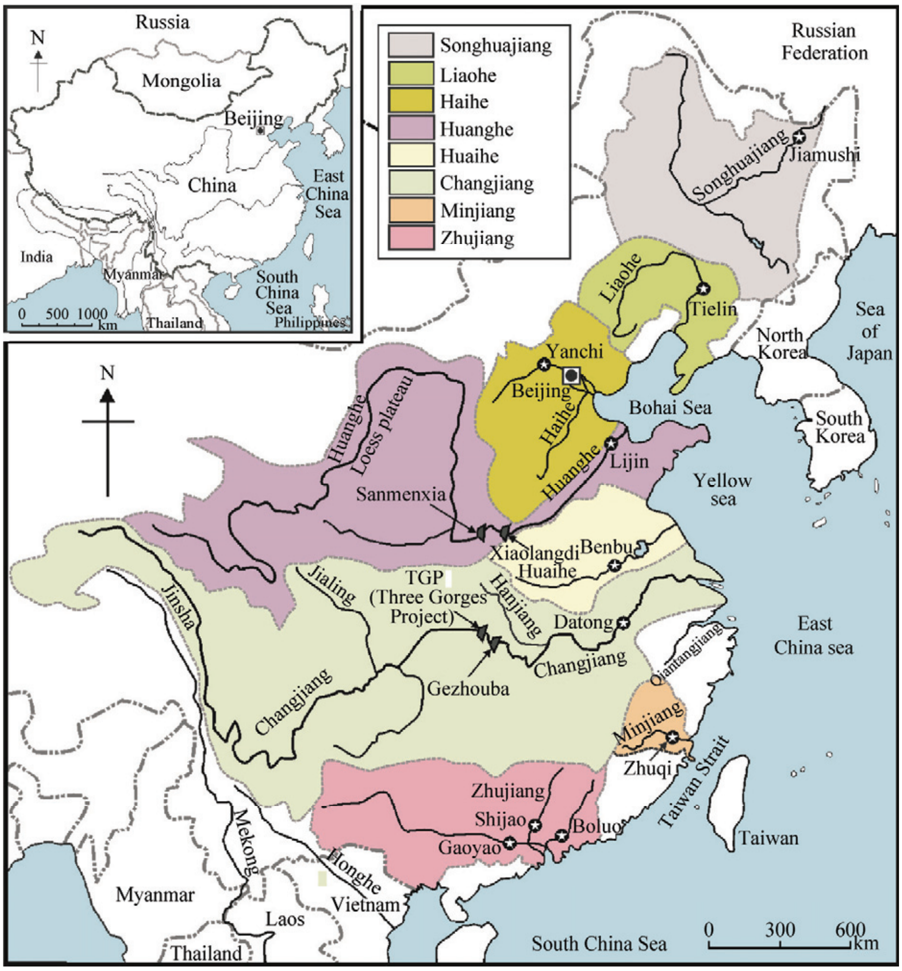

Fig. 1 Eight large Chinese rivers. Water discharge and sediment load records are obtained from ten hydrological stations on the eight rivers: Harbin for the Songhuajiang River. Tieling for the Liaohe River, Yanchi for the Haihe River, Lijin for the Huanghe (Yellow River). Bengbu for the Huaihe River, Datong for the Changjiang (Yaugtze River), Zhuqi for the Minjiang River and the combined Gaoyao, Shijiao and Boluo for the Zhujiang (Dearl River)

2 Materials and methods

2.1 Water discharge and sediment loads

Sediment loads refers to the suspended fraction only, whereas bedload was excluded due to its difficulty in field sampling. Measurement of the sediment loads was on the basis of standard procedures (Lu and Higgitt, 1999; Hassan et al., 2008). Errors in calculating sediment load were introduced through the low frequency of sampling, rather than continuous monitoring, which is likely to underestimate sediment load during peak hours. The measurements at these stations of the eight rivers represent the water discharge and sediment loads entering the ocean (Fig. 1). Except the data for the Haihe starting from 1963, all the other rivers have records for the years between the 1950s and 2007.

2.2 Climate data and spatial interpolation

Annual temperature and precipitation data from 1951 to 2007, provided by National Climate Centre, were used to interpolate a regular grid with 1-km resolution datasets for the eight rivers. There are 753 meteorological stations extensively covering the whole mainland China with international standard measurement of surface temperature and precipitation (Fig. 2). The objective of our work was to find an appropriate method for the spatial interpolation of mean annual temperature and mean annual precipitation into a regular grid with 1-km resolution from 1951 to 2007, for eight