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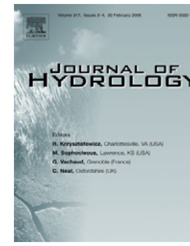

Characteristics of water isotopes and hydrograph separation during the wet season in the Heishui River, China

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Contribution

Summary Runoff generation and dynamics is an important issue in watershed and water resource management, but the mechanism in large scale is unclear and site-dependent. For this reason, spatial variations of δD and $\delta^{18}O$ of river water and their sources within large-area of the Heishui Valley of the upper Yangtze River in western China were investigated during the wet season. A total 117 river water samples were collected at 13 sampling sites located at the junction of the principal river course and its tributaries. The results showed no spatial variations of either δD or $\delta^{18}O$ values existed among tributary sampling sites A, B, E, F, H and I during the wet season, and significantly spatial variation occurred between tributary sampling sites A, B, E, F, H, I and site K; which indicated different proportions of rain entering river water should lead to spatial variation of water isotopes. The hydrograph separation analysis, based on the isotope data of river water, meltwater and rain water samples, showed the contribution of snow and glacier meltwater varied from 63.8% to 92.6%, and that of rain varied from 7.4% to 36.2%; which meant that snow and glacier meltwater was the main supplying water source of baseflow in the Heishui Valley. And the roles of glacier and snow meltwater should be significantly noticed in water resource management in this alpine valley at the rim of the Tibetan Plateau.

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Introduction

The water shortage and low use efficiency make china thirsty, and the loss of glacier and wetland in the western plateau will exaggerate this thirst in the future (Wang et al., 2006), while the same situation happens in other places of the world (e.g. Mark, 2002). Therefore, it is important to understand the runoff generation mechanism when studying headwater and river water dynamics, especially the seasonal changes, sources and composition of the baseflow.

Leopoldo et al. (1987) reported that the runoff mainly came from surface flow along perennial streams in humid zones in Brazil. McDonnell et al. (1991) found that stream water in New Zealand was supplied partially by subsurface flow in the humid zone. Cooper et al. (1991) found that runoff derived mainly from meltwater, because a similarity in δ^{18}O existed between the stream water at peak flow and the pre-melt snow pack in the tundra of Northern Alaska. Geyh and Gu (1991) found that groundwater was recharged by high-intensity and sporadic rain (up to 100 mm/h) in the Gurinai grassland in Inner Mongolia. Thus, all the results show that components of river water may include surface flow, subsurface water, meltwater and ground water and their contribution is site-dependent.

The stable isotope ratios of hydrogen and oxygen of water samples can provide essential information about water dynamics within a given watershed (Ruck et al., 2007); it is useful to identify water sources by tracers of stable isotope hydrogen or oxygen, since different water sources are acting within a river at different seasons. In hydrograph separation analysis, the two-component model was widely used to compute the contributions of different components of river water. Mortathi et al. (1997) reported that the average surface runoff and baseflow (pre-event) contributions were 30.3% and 69.7%, respectively, in the Amazon River. Kendall (1993) believed that surface water and subsurface water contributions were 38% and 62%, respectively, in northeastern China, based on stable isotope oxygen data. Laudon and Slaymaker (1997) detected a much larger prestorm water fraction (60–90%) existent in the alpine basin of the coastal mountains of British Columbia, according to both stable isotope hydrogen and oxygen analyses of those waters. But, a little information was reported on the components and the generation mechanism of baseflow in a large watershed.

In this study, the identification of water sources, hydrograph separation analysis of different tributaries, and spatial variations of stable isotopes hydrogen and oxygen were conducted on large catchments of 7240 km^2. We attempted to: (1) compute the contribution of different water sources to baseflow during the wet season; and (2) clarify the causes of temporal and spatial variation of water isotopes. And we expected that the results will provide an insight for water resource and watershed management in a large-area.

Study areas

The Yangtze River, the longest river in China, has an upper course of 4511 km long and an upper catchment area of 1.0×10^6 km^2 or so from the Geladandong snow-covered mountain in the Tibetan Plateau to the Yichang City in the Hubei Province (Chen, 2000). The Minjiang River is one of important tributaries in the upper course of Yangtze River and locates within the transition region between the Tibetan Plateau and the Sichuan Basin (Pu, 2000; Li et al., 2003). The Heishui River is the largest tributary of the Minjiang River and is 122 km long from the Maoergai Grassland to the Shaba village (Fig. 1).

According to the records of the Heishui precipitation station (32°03.00′N, 102°35.4′E; altitude of 2400 m above sea level (asl)), the average annual temperature is 9 °C and the average annual rain is 833 mm (Liu et al., 2008). The climate is described as a monsoon climate, affected by two atmospheric circulations. Western dry circulation from the Atlantic Ocean prevails during winter, and wet southwesterly monsoons enter from the Indian Ocean during summer (Zhang et al., 2002).

Monthly precipitation data from 1971 to 2000 were provided by the Heishui precipitation station, and monthly runoff data from 1988 to 2002 were provided by the local hydrology stations which located in the catchment (Fig. 1). The precipitation fluctuates monthly between 3 mm and 155 mm (Fig. 2a), and there was a wet season (May–October) and a dry season (November–April). The similar variation existed for runoff (Fig. 2b). The trend of average monthly runoff was consistent with that of average monthly precipitation, which indicated that precipitation was the main reason of runoff variation; especially the rain was one of the main supplying sources of river water during the wet season. The amounts of precipitation and runoff in June were the highest among the twelve months. Shaba station collected more runoff than the Heishui, while the seasonal runoff dynamics are similar.

Methods

Field sampling

There were 13 sampling sites chosen within the junction of the river's principal course and its tributaries. The sampling sites were named C, D, G, L and M along the principal course, and A, B, E, F, H, I, J and K along the outlet of seven tributaries (Fig. 1). At each sampling site, water samples were collected at 8:00 a.m., 12:00 noon and 4:00 p.m. each day, and this regime was repeated for a total of three collection days. A total of 117 samples from the river were collected during the wet season. All water samples were collected by water collectors and stored in 250 ml non-reactive plastic bottles with rubber-seal caps. The sampling window ran from May 21rd through June 17th in 2004, technically during the wet season. The direct effects of floodwater on the river were avoided during the sampling time, according to curves of runoff provided by the hydrology station for Heishui County. Meanwhile, four rain samples were collected at June 2, 13, 14 and 15, respectively.

Measurement of δD and δ^{18}O

The measurement and analysis of water samples was completed using the Thermal Finnigan MAT DelTaplus XP. Accuracy of the measurements was ±3‰ for δD, and ±0.3‰ for