



# A groundwater conceptual model and karst-related carbon sink for a glacierized alpine karst aquifer, Southwestern China



Cheng Zeng<sup>a</sup>, Zaihua Liu<sup>a,\*</sup>, Jianwen Yang<sup>b</sup>, Rui Yang<sup>a</sup>

<sup>a</sup> State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550002, China

<sup>b</sup> Department of Earth and Environmental Sciences, University of Windsor, Windsor, ON N9B 3P4, Canada

## ARTICLE INFO

### Article history:

Received 24 January 2015

Received in revised form 10 July 2015

Accepted 18 July 2015

Available online 23 July 2015

This manuscript was handled by Laurent Charlet, Editor-in-Chief, with the assistance of Nico Goldscheider, Associate Editor

### Keywords:

Jade Dragon Snow Mountain

Glacierized alpine karst aquifer

Conceptual hydrogeological model

Hydrochemistry

Stable isotopes

Karst-related atmospheric CO<sub>2</sub> sink

## SUMMARY

In the Jade Dragon Snow Mountain (JDSM) region, Yunnan Province, SW China, an extensive hydrochemical and stable isotopic study of a glacierized alpine karst aquifer was conducted during the period, 2011–2014. The objectives of the study were: first, to establish a conceptual hydrogeological model of the karst groundwater system; second, to estimate the proportion of extra glacier melt water infiltrating the karst aquifer that is being induced by the regional climate warming; third, to calculate the karst-related flux of carbon into the karst aquifer. Knowledge of the local hydrogeological background from previous work was the starting point of the hydrochemical and stable isotopic study. Some representative spring waters and recharge waters (i.e. glacier melt water and rainwater) were investigated both spatially and temporally by hydrochemical and isotopic techniques, including analysis of major and some minor ions and O and H stable isotopes. A conceptual hydrogeological model of a fracture-diffuse flow karst groundwater aquifer was proposed. The proportion of glacier melt water infiltrating into the karst aquifer was estimated by using the karst spring as a natural pluviometer, and with stable isotope analysis. Results show that (1) the JDSM karst aquifer is a diffuse flow system; (2) it has a number of discharge areas, and the Jinsha River is the karst drainage base level; (3) the proportion of the glacier melt water penetrating the karst aquifer is 29%; and (4) the karst-related carbon sink is  $26.67 \pm 3.44 \text{ t km}^{-2} \text{ a}^{-1}$  (as CO<sub>2</sub>), which is lower than that in non-glacierized karst aquifers but over ten times larger than the carbon sink flux from silicate weathering in non-karst areas, showing the control of both climate and lithology on the rock weathering-related carbon sink and the significance of carbonate weathering in the global carbon cycle.

© 2015 Elsevier B.V. All rights reserved.

## 1. Introduction

According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the globally averaged surface temperature data show a warming of 0.85 [0.65–1.06] °C over the period 1880–2012 due to the increase of the atmospheric concentration of CO<sub>2</sub> because of fossil fuel emissions and net land use change emissions. Study of the global carbon cycle has become the focus of much global climate change research as a consequence. Warming of the climate is producing many changes, such as warming of atmosphere and ocean, diminution of amounts of snow and ice, and rise of sea level. The average rate of ice loss from glaciers around the world shows a remarkable accelerating trend (IPCC, 2013). The cryosphere is sensitive to the climate change, especially in temperate glacier-covered mountainous regions. In the Alps and Central Asia, the areas of glacier

coverage have been showing strong diminishing trends (Kääb et al., 2002; Khromova et al., 2003; Paul et al., 2004a,b).

Lijiang is a famous international tourist city in NW Yunnan Province, China. However, a shortage of water has been more and more severe recently because of the rapid expansion of tourism. The temperate mountain glacier on the top of Jade Dragon Snow Mountain (JDSM), which is perhaps one of the most important water resources in the region, has been shrinking rapidly due to local climate change (He and Gu, 2003; He et al., 2003; Zeng et al., 2013). JDSM is located in a carbonate rock region. According to Hartmann et al. (2014), in many karst regions in the world, there will be an obvious decrease of precipitation and an increase in temperature over the next decades, and mountains are sentinels of climate change. As a result, the water supply problem is acute and getting worse in the JDSM region. Therefore, it is clearly essential to study the overall hydrogeological situation there.

The carbonate dissolution process, the global water cycle and the photosynthetic uptake of DIC (dissolved inorganic carbon)

\* Corresponding author. Tel.: +86 851 85895263.

E-mail address: [liuzaihua@vip.gyig.ac.cn](mailto:liuzaihua@vip.gyig.ac.cn) (Z. Liu).

constitute an important sink for atmospheric CO<sub>2</sub> (Liu et al., 2010). Freshwater storage in glaciers, ice caps and permanent snow is estimated to account for more than half (68.7%) of the total freshwater on the Earth (Gleick, 1996). The enhanced amounts of glacier melt water in karst regions released by climate warming participate in the water cycle and probably increase the karst-related carbon sink flux (Zeng et al., 2011, 2012). There are clear relationships between atmospheric CO<sub>2</sub>, chemical weathering and glaciers (Gibbs and Kump, 1994; Sharp et al., 1995; Anderson and Drever, 1997; Krawczyk and Bartoszewski, 2008; Maher and Chamberlain, 2014). However, most previous studies have been conducted in glacierized non-karst regions. Zeng et al. (2012) reported on the atmospheric CO<sub>2</sub> sink under climate warming at the Glarey spring in the Tsanfleuron glacierized karst area in the Swiss Alps. The Tsanfleuron alpine karst is a typical conduit-dominated karst aquifer system (Gremaud et al., 2009). It shows remarkable diurnal and seasonal hydrochemical variations chiefly controlled by air temperature which influences the aquifer recharge by ice and snowmelt (Zeng et al., 2012).

The Jade Dragon Snow Mountain (JDSM) glacier is a typical temperate mountain glacier. It has attracted much scientific attention, with previous studies being focused on stable isotopic variations in rainwater, snow and glacier meltwater, and river water, and on ionic compositions and  $\delta^{18}\text{O}$  in the shallow firn profile (He et al., 2002, 2006; Pang et al., 2005, 2006; Pang et al., 2007; Zhu et al., 2013). In particular, there is a primary study of the geochemistry and chemical exchange between groundwater and surface water in the Lijiang glacial basin by stable oxygen isotope and major ion analysis (Pu et al., 2013a). However, until now, little light has been shed on the hydrogeological conditions in this glacierized alpine karst aquifer, the groundwater conceptual model and the karst-related carbon sink in the aquifer.

Therefore, we conducted an extensive study of the JDSM alpine karst aquifer. The primary study objectives are: (1) to establish a conceptual groundwater model of the aquifer by use of hydrochemical and isotopic data; (2) to estimate the proportion of glacier meltwater stimulated by climate warming that is infiltrating into the underlying karst aquifer; (3) to calculate the karst-related carbon sink (flux) into the aquifer.

## 2. Description of Jade Dragon Snow Mountain (JDSM)

Jade Dragon Snow Mountain (JDSM) is located in Lijiang district, Yunnan Province, SW China (Fig. 1). It is a massif 35 km in length from north to south and 18 km in width from east to west, in the southeastern margin of the Qinghai-Tibet plateau and in the northwest of Lijiang Basin (Fig. 1). It belongs to the alpine – gorge land-form suite. Its highest peak is Shanzidou (5596 m a.s.l.).

JDSM is the southernmost glacierized mountain on the Eurasian continent. In 1957 there were 19 temperate mountain glaciers on its top with a total area of 11.6 km<sup>2</sup>. However, in 2009 there were just 13 glaciers remaining, with only a total area of 4.42 km<sup>2</sup>. Substantial glacier retreat was obvious (Du et al., 2013).

The study area is characterized by a monsoon climate with marked wet and dry seasons, (Fig. 2). More than 80% of the annual precipitation occurs during the wet season from June to September. The annual average precipitation is 957.2 mm, and the mean air temperature is 12.8 °C in Lijiang (Zeng et al., 2013). The annual mean air temperature near the Baishui No. 1 glacier tongue (4300 m in altitude) is 2.1 °C (Xin et al., 2013).

## 3. Hydrogeological background of the JDSM region

An extensive hydrogeological survey of the JDSM region was conducted after analysis of previous work (Figs. 3–5). The

hydrogeological investigation included spring and glacier surveys, precipitation and snow and ice sample collection. The investigated springs include Jinsha-Daju (1), Changshui (2), Baishui (3), Heishui (4), Yuzhuqingian (5) and Yushuizhai (6) Springs (Figs. 1, 3 and 5). Snow and ice specimens were collected from Baishui No. 1 Glacier (Fig. 3).

The principal bedrock of the snow mountain massif (Fig. 3) is carbonate, including marble and crystalline limestone of the upper Sanxiang Formation (middle Devonian  $D_2s^2$ ), marble and dolomitic marble of upper Devonian ( $D_3$ ), and Carboniferous and lower Permian ( $P_1$ ) crystalline limestone and marbles. These pure, intensively fractured carbonate rocks form an important aquifer for the water supply of Lijiang City. An undated sericite schist ( $M$ ) occurs to the west of the snow mountain and forms a western aquiclude. Other aquicludes are created by dense, massive amygdaloidal basalts and volcanic tuffs of Permian age ( $P_\beta$ ) on the southwest and northeast flanks of the mountain (Fig. 5A).

There is an active fault (the eastern JDSM Fault) along the eastern foothills that strikes approximately N–S and dips steeply eastwards. This fault presents a flow barrier because it is filled with fault gouge. There is a Quaternary moraine of carbonate gravel overlying the eastern basalt footwall of the fault, forming a porous aquifer in the unconsolidated sediment. The karst water in the JDSM alpine carbonate aquifer recharges this eastern morainic aquifer laterally in the form of subsurface flow.

The Jinsha River flows northeast through the northwestern part of the snow mountain, in Hutiaoxia Gorge (Leaping Tiger Gorge). Around 15 km in length, the gorge passes between Jade Dragon Snow Mountain and Haba Snow Mountain (Fig. 1). With a maximum depth of approximately 3790 m from mountain peak to river, the gorge is one of the deepest and most spectacular river canyons in the world.

Jade Dragon Snow Mountain and Haba Snow Mountain on the two sides of the Hutiaoxia Gorge belong to the same carbonate rock mass. There is no major fracture between the two Snow Mountains, so that the gorge is the result of an antecedent river which has been downcutting during tectonic uplift (Ming et al., 2007; Kong et al., 2010).

As mentioned, the lithology of the massif is dominated by marble which usually functions as an important aquifer. According to a tracer test in a nearby alpine-gorge area (Jinping District, western Sichuan Province), the marble aquifer is characterized by diffuse-flow in dense joints, sparse crannies and few karst conduits, and by a very thick unsaturated zone. The large difference in altitude between the recharge area and discharge area has caused the regional deep water flow system (Huang et al., 1995; Ma et al., 2006).

During our field hydrogeological survey, no karst caves were found in the JDSM area. There are a few dam foundation exploration adits in northwest part along the Jinsha River. Dripping water can be observed in a 150 m adit drilled in the carbonate unsaturated zone near Jinsha-Daju spring (Fig. 5G), showing the characteristics of diffuse flow. There are a great number of karst fractures (e.g., dissolutionally enlarged fractures and crushed rocks) in the carbonate bedrock underlying the JDSM glaciers (Fig. 5D and E). Most precipitation and glacier melt water recharges the alpine aquifer directly through them. Therefore, there are few surface streams in the study area.

The elevation of the northern Lijiang Basin is about 2700 m, and the Jinsha River at 1620 m in Hutiaoxia Gorge is the lowest modern karst drainage base level for the glacierized alpine karst aquifer. Karst development in the carbonate aquifer has always lagged behind the relatively rapid entrenchment of the Jinsha River because of the combination of isostatic rebound and fluvial entrenchment in the Jade-Dragon-Haba carbonate block since the

Download English Version:

<https://daneshyari.com/en/article/6410978>

Download Persian Version:

<https://daneshyari.com/article/6410978>

[Daneshyari.com](https://daneshyari.com)