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A tentative study of the relationship between annual $\delta^{18}O$ & δD variations of precipitation and atmospheric circulations—A case from Southwest China

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ABSTRACT

In this study, we present the 6-year $\delta^{18}O$ and δD records of precipitation from Chongqing, southwest China. Based on these data, the local meteoric water line (LMWL) has been set up as: $\delta D = 8.33\delta^{18}O + 19.42$. It is demonstrated that in El Niño scenarios, more vapor from closer moisture source (Western Pacific) was transported to south China, resulted in heavier stable isotopes of precipitation in southwest China, while in La Niña scenarios, the situations were just on the contrary. In addition, there is a positive correlation between the $\delta^{18}O$ of precipitation in southwest China and the Northern Atlantic Oscillation Index (NAOI) when the NAO is in the positive phase (typically in boreal winter-half year). At the interannual timescale, the $\delta^{18}O$ of precipitation in southwest China is more negative in strong NAO years than that in weak NAO years. We speculate that the north-south position migration of the westerlies and the route changes of vapor transport are correlated with the $\delta^{18}O$ changes of precipitation in southwest China under the climate change scenario around the North Atlantic.

1. Introduction

The stable isotope record of precipitation, reserved in ice cores, lacustrine sediments, tree-ring cellulose, speleothems, etc., is of great significance for the reconstruction of paleoclimate change. In recent years, the stalagmite $\delta^{18}O$ records have attracted considerable concern (Wang et al., 2001; Cheng et al., 2012; Duan et al., 2016), but the climatic significance of this proxy in Asian Monsoon regions is still contentious (Tan, 2016). The modern precipitation, as a crucial part in global water cycle, brings rich information on climate and environment. As the tracer of water cycle, the stable isotopic composition of precipitation, $\delta^{18}O$ and δD, is mainly controlled by the processes of evaporation and condensation, and influenced by many factors such as latitude, altitude, the distance from moisture source, temperature and rainfall. It is wildly accepted that at various time scales, the isotopic composition in precipitation can help us trace the origin of moisture source and the pathway of air mass transportation (Strong et al., 2007; Zhou et al., 2007; Coplen et al., 2008; Liu et al., 2010; Kebede and Travi, 2012; Stumpp et al., 2014; Wang et al., 2015). So, monitoring and analyzing the variation of precipitation isotopes in longer time scale (Eastoe and Dettman, 2016) and wider range (Lechler and Niemi, 2011) will be of benefit to the understanding of evolution process of general atmospheric circulation, and shed light on the value of paleoclimate reconstruction.

The relationship between δD and $\delta^{18}O$ in precipitation all over the world is called the Global Meteoric Water Line (GMWL), defined by Craig, revealing the internal relation between δD and $\delta^{18}O$ ($\delta D = 8\delta^{18}O + 10$) (Craig, 1961). The data from Global Network of Isotopes in Precipitation (GNIP), provided by the International Atomic Energy Agency (IAEA) confirm that the precipitation stable isotopic composition can be influenced by multiple factors. Before 1985, Hong Kong was the only monitoring station of GNIP in China; by 2015, there had been 33 stations in China. However, the data cannot be updated in time and are un-continuous except those collected in Hong Kong. It is particularly important to collect the original data in China considering the vast territory and the variety

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of natural environments. Inspired by the experience of GNIP, China set up the Chinese Network Isotopes in Precipitation (CHNIP) in 2004, based on the sites of Chinese Ecosystem Research Network (CERN) (Song et al., 2007). Southwest China is located to the east of the Tibet Plateau, influenced by the Indian Summer Monsoon (ISM), Eastern Asia Summer Monsoon (EASM), Asia Winter Monsoon (AWM), and the northern and southern branches of Westerlies (Fig. 1), which is even potentially influenced by the temperature changes in the southern hemisphere (Cheng et al., 2012; Li et al., 2014; Cai et al., 2015; Han et al., 2016; Zhang et al., 2017). But neither the GNIP nor CHNIP can provide data for this region. In this study, we collected monthly precipitation from January 2010 to December 2015 in Chongqing, southwest China, analyzed the stable isotopic composition of the precipitation, built the Local Meteoric Water Line (LMWL) and analyzed the seasonal and inter-annual variation of δD and $\delta^{18}O$ characteristics. Furthermore, we assessed the influence of circulation on the climate in southwest China by the integrated analysis of our data with the situations of El Niño, Southern Oscillation, North Atlantic Oscillation and the data of GNIP. Our work will make contribution to the defining of the climatic significance of Chinese stalagmite $\delta^{18}O$, which will promote both the reconstruction of paleoclimate in this region and the research on the evolution of the Asian monsoon.

2. Study area, data and method

2.1. Study area

Precipitation samples were collected in the campus of Southwest University (SWU), Beibei, Chongqing, southwest China (29°49′N, 106°25′E, altitude: 252 m) (Fig. 1). This region is dominated by typical subtropical, humid monsoon climate. The prevailing monsoons in summer are ISM and EASM, while in winter it is AWM. In the rainy season from May to October, the rainfall accounts for 70%–80% of the total precipitation throughout the year. During the period from 2010 to 2015, mean annual temperature is 18.5 °C, average annual rainfall is 1119 mm, and annual average humidity is about 77% in Beibei.

2.2. Data and analyzing method

Following the standard method for the collection of stable isotopic samples of precipitation (https://nucleus.iaea.org/wiser/index.php) presented in GNIP operated by IAEA, we set up our collecting equipment (a barrel) of precipitation on the building roof of the school of Geographical Sciences in SWU with 5 mm thick liquid paraffin to avoid the evaporation of rainfall. And the barrel was packed with tinfoil and bubble paper to eliminate the solar radiation-induced chemical effect. We collected the samples at regular intervals of single month, so each sample represents one-month's precipitation. All samples were stored in low-temperature condition at 5 °C, and 5 ml rain water was taken for test every month.

The stable isotopic analysis was performed on the liquid water isotope analyzer (LWIA DLT-100), Los Gatos Research Company, USA. For each sample, 1.5 ml volume water was analyzed for six times, and the last four data were used to calculate the average as the result of the sample. Accuracy of measurement is ±0.5‰ for δD and ±0.2‰ for $\delta^{18}O$ (2σ), respectively. Final results were expressed in permill by the relative to Vienna Standard Mean Ocean Water (V-

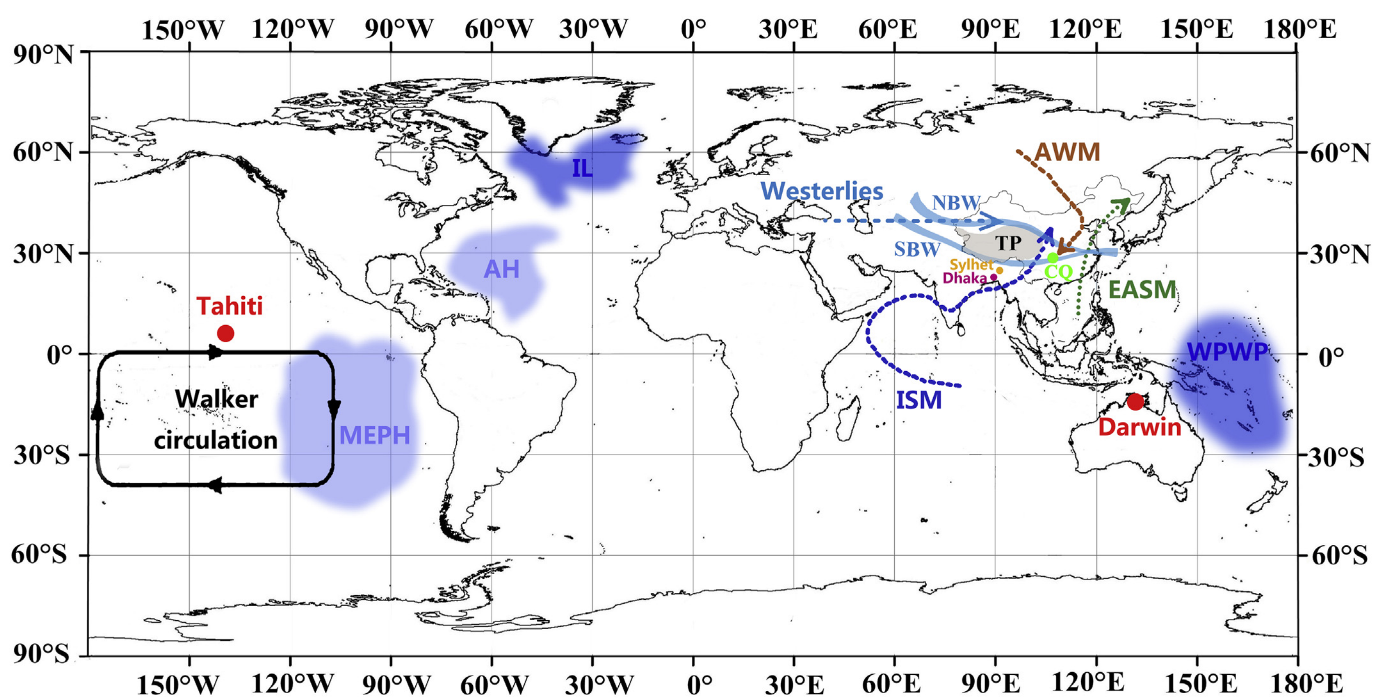

Fig. 1. (A) Location of the study site and the sketch map of the planetary circulations (After Cheng et al., 2012; Railsback et al., 2014). The gray area denotes the region of the Tibetan Plateau (TP). The light blue dashed line with arrow denotes the northern hemisphere westerlies. The light blue bands indicate the northern (NBW) and southern (SBW) branch of the westerlies around the Tibetan plateau. Dark blue dashed line with arrow indicates the Indian summer monsoon (ISM). Green dashed line with arrow denotes the East Asian Summer monsoon (EASM). Brown dashed line with arrow indicates the Asia Winter monsoon (AWM). The light blue areas present the Azores high (AH) and middle-east Pacific high (MEPH) and the blue areas denote the West Pacific warm pool (WPWP) and Icelandic low (IL) (after Marshall et al., 2001; Takahashi et al., 2009; Cane, 2005; Dvoryaninov et al., 2016). The coupled changes between these high and low cells result in the variation of North Atlantic oscillations (NAO) and El Niño-Southern Oscillations (ENSO). The light green solid circle presents the location of Chongqing (CQ), Southwest, China. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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