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Stable isotope in precipitation in China: A review

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ABSTRACT

The isotope ratios in precipitation are associated with various meteorological processes and display obvious spatial and temporal distributions, and thus can be used as important techniques in inversing atmospheric processes, tracing vapor sources, and reflecting the local weather and climate conditions. The composition and distribution of stable isotopes in precipitation in China are summarized and the factors that influence isotope ratios are elucidated. An overview of related research progress in China during the past several decades is presented and the prospects for future work in this subject area are described.

Keywords: precipitation; stable isotope; spatio-temporal distribution; China

1. Introduction

Stable isotopes are important components of natural water. The isotope fractionation effect in phase transition occurs in every aspect of the water cycle in nature, which is sensitive to environmental changes. The abundance of stable isotopes in precipitation, as important elements of the water cycle, closely relates to the meteorological conditions of rainfall formation and the initial conditions of the water vapor source (Zhang *et al.*, 2004a). Along with climate change, deuterium (^{2}H) and oxygen-18 (^{18}O) in precipitation can also change in different spatio-temporal backgrounds (Dansgaard, 1953, 1964; Zhang *et al.*, 2004a). Thus, the stable isotopes in precipitation can reflect the regional characteristics of climate and weather, and can serve as a natural tracer of its source (Zhang and Yao, 1994a). In addition, stable isotopes are widely applied in paleoclimate reconstruction (with ice cores, tree rings, lake sediments, and stalagmites), water resource investigation, and other research (Rozanski, 1985; Yao and Thompson, 1992; Dansgaard *et al.*, 1993; Thompson, 1995; Bryant *et al.*, 1996; Fricke *et al.*, 1998; Chamberlain and Poage, 2000; Dettman and Lohmann, 2000).

The earliest study of stable isotopes in precipitation began in the 1950s (Dansgaard, 1953). In order to investigate global isotopes, the International Atomic Energy Agency (IAEA) and the World Meteorological Organization (WMO) launched a program called the Global Network of Isotopes in Precipitation (GNIP) in 1961 (Dansgaard, 1964), and established more than 100 observation stations monitoring stable isotopic composition in precipitation. Currently there are more than 550 stations in this network.

In China the study of stable isotopes in the water cycle began with the scientific investigation of Mount Qomolangma in 1966, shortly after the establishment of the GNIP (Zhang *et al.*, 1973). Before 1983 China had only one station (Hong Kong) in the GNIP (Li and Zhang, 2004). Since the 1980s, more observation stations for monitoring stable isotopes were established in China, including in Qiqihar, Hotan, Yinchuan, Shijiazhuang, Tianjin, Lhasa, Kunming, Changsha, Guiyang, Nanjing, Fuzhou, Haikou, Guilin, Xi'an, Guangzhou, and other cities. To date more than 10 stations in China have been included in the GNIP network.

However, there is still very limited scientific research in such a large area. In 2004, based on the successful experiences such as the GNIP and the existing field stations of the Chinese Ecosystem Research Network (CERN), China established a national network named the Chinese Network Isotopes in Precipitation (CHNIP), and δD and δ^{18}O in precipitation began to be observed systematically (Song *et al.*, 2007). Utilizing this new network, China's scientists have done many researches on isotopes in precipitation (*e.g.*, Wei and Lin, 1994; Zhang and Yao, 1995a, 1998; Zhang *et al.*, 1996, 2004a, 2006; Liu *et al.*, 1997; Tian *et al.*, 2001e; Liu ZF *et al.*, 2009).

This paper summarizes the stable isotope composition distribution in precipitation and analyzes the influence of meteorological factors such as precipitation, temperature, winds, *etc*. Based on a comprehensive natural zoning method (Huang, 1959), the regional characteristics are evaluated in three different climatic zones in China (the Tibetan Plateau, the arid region in the northwest of China, and the monsoon region in East China).

2. Effect factors of δ^{18}O in precipitation

Utilizing data from 1961–1962, Dansgaard (1964) discussed the factors of seasonal and spatial distribution influencing δ^{18}O in precipitation, and described the latitude effect, temperature effect, altitude effect, amount effect, and continental effect. These effects were mainly based on the meteorological data and geographical factors at the sampling sites. Further study by Zhang *et al*. (2004a) showed that temperature is the main controlling factor at the high latitudes, especially at the poles (Zhang *et al.*, 1995), and that more significant positive correlations between temperature and isotope values can be found at the inland than at the coast (Zhang and Yao, 1998). In the tropics, rainfall is the main factor, while in the mid-latitudes the combined effect of temperature and precipitation influences the isotopic variation.

The temperature effect and amount effect in China have been widely researched using meteorological data (Zhang and Yao, 1994a; Wang *et al.*, 2001). Zhang *et al*. (2003b, 2005) argued that the condensing temperature in clouds, rather than the ground temperature, relates directly to the δ^{18}O values in precipitation, and the temperature effect dominates under an annual scale whatever the temperature effect or amount effect exists under a monthly scale. Liu ZF *et al*. (2009) established a negative correlation between δ^{18}O in precipitation and latitude or altitude by a Bowen-Wilkinson model.

However, the source and nature of the air mass can also influence the isotopic composition in precipitation (Wei and Lin, 1994). Water vapor in the atmosphere is the prerequisite of the rainfall, so the isotope composition in vapor can significantly affect that in precipitation (Hübner *et al.*, 1979; Schoch-Fischer *et al*., 1984). Additionally, vapor pressure is also a significant factor (Zhang and Yao, 1994b). Zhang and Yao (1995b) conducted related research on the original conditions and transportation of vapor, vapor saturation in clouds, and liquid water content in clouds. For example, it has been shown that the stable isotope ratios in raindrops increase as landing distance increases in a non-saturated atmosphere, and this is more significant with lower moisture (Zhang, 1997; Zhang *et al.*, 1998). By a dynamic fractionation model, Zhang *et al*. (2001) created a simulation of the isotope effect in mixed clouds. Their results showed that a negative correlation exists between the stable isotope ratios of condensation water and the maximum possible amount of condensation.

However, the stable isotope ratio in dropped rain is quite different, so the moisture effect is set, which means that the stable isotope ratio in precipitation correlates with temperature depression of the dew point in atmosphere (ΔT_d) (Zhang *et al.*, 2004b). Wang *et al.* (2009) built a differential equation model to simulate the changes of stable isotopic composition of rainfall.

Monsoon climate is widely distributed in China, especially in East China. Under the monsoon circulation, the spatial and seasonal distribution of precipitation is influenced by large-scale vapor transportation and budgets. Thus, the isotopic composition is affected, but not only by the temperature effect and latitude effect (Pang *et al.*, 2004a, b); Wei and Lin (1994) and Yamanaka *et al*. (2004) have shown that due to the impact of monsoon activity, δ^{18}O in precipitation in East China is obviously influenced by the amount effect. Pang *et al*. (2004a, b) concluded that the δ^{18}O in monsoon precipitation is also related to sunspots and ENSO (El Nino/Southern Oscillation), and the wind speed at high altitudes in the monsoon region exhibits a significant positive correlation with δ^{18}O of precipitation. Additionally, Pang *et al*. (2005) developed a new method for defining the origin of precipitation based on Rayleigh fractionation.

In summary, the two factors that affect the hydrogen and oxygen isotope composition in precipitation are, first, the environmental background of regional climate, that is, the source and nature of the water vapor and the hydrogen and oxygen isotope variation from vapor generating until the precipitation event; second, the local geographic factors, including the various meteorological elements in the precipitation process (especially the amount of precipitation, the temperature, and the humidity) and the latitude and altitude (Tian *et al.*, 1997). These factors affect each other, which determine the spatio-temporal distribution of stable isotopes in China.

Researches on China's stable isotope composition in precipitation can reveal the source and cycling of water vapor; the influence of monsoon, ENSO, and other climate events; and the significance of environments in different areas.

3. Spatial distribution of δ^{18}O in precipitation

Using GNIP data, Zhang *et al*. (1998) drew a spatial-temporal distribution of δ^{18}O values in China, which is higher in the southeast and northwest of China, and lower in the northeast of China and the southern Tibetan Plateau; then he and his colleagues found three vapor routes of precipitation in China (Zhang *et al.*, 2004a). Research by Liu *et al.* (1997) also found that the high-value areas of $\delta^{18}O$ in precipitation are in the southeast coast region year-round, but the low-value areas change with the seasons. The $\delta^{18}O$ values at middle-high latitude and middle-low latitude regions are different in summer and winter months in China. This difference is related with the temperature variation and the seasonality of air mass (Zhang and Yao, 1998; Zhang *et al.*, 2004b).

Seasonal distribution of stable isotopic ratios in precipitation can be classified into two types. First, in the inland region at middle-high latitude, the stable isotopic ratio correlates positively with the temperature, and the seasonal distribution of $\delta^{18}O$ values in precipitation is similar to that of temperature, so it displays as the temperature effect. Second, in the coastal region and monsoon region, the stable isotopic ratio and temperature have a significantly negative correlation, so it is attributed to the amount effect. Generally, the temperature effect appears north of 34°–36°N (Zhang *et al.*, 2008). Luo *et al.* (2008) found that the distribution of $\delta^{18}O$ is not parallel with latitude and shows a classic saddle shape. The values of $\delta^{18}O$ are higher in the southeast and northwest of China and lower in the northeast of China and the southern Tibetan Plateau. These results agree with earlier research but the regional characteristics are predominantly at small-scale, which is related to the local evaporation, monsoon, and water vapor source.

4. Study of $\delta^{18}O$ in precipitation in different regions

4.1. The Tibetan Plateau

Mountain glaciers are widely distributed in the Tibetan Plateau, which provides a platform for paleoclimate study. During the past two decades, many ice cores were drilled in the Tibetan Plateau (Yao *et al.*, 1991b, 1994, 1996; Hou and Zhang, 2003). The high-resolution ice core method is helpful for studying the stable isotopes in long-term precipitation. The unique topography in the Tibetan Plateau makes the moisture source of precipitation more complex. Due to the different sources of and the nature of the water vapor, it exhibits different features in the ratio of stable isotopes in different areas. Therefore, the Tibetan Plateau can be subdivided into monsoon areas, non-monsoon areas, and their transition areas.

At the beginning of the summer monsoon, the $\delta^{18}O$ values in precipitation suddenly decrease (Yao *et al.*, 1991a), reflecting the amount effect (Tian *et al.*, 1997). This may be related to the water vapor transportation at the low level of ocean (Tian *et al.*, 2001b). Studies have also indicated that the $\delta^{18}O$ values in precipitation show a relatively high level except in summer (Tian *et al.*, 2003, 2005, 2006), with no temperature effect. Tian *et al.* (2001c) found that the change of $\delta^{18}O$ in precipitation is related to the intensity of the monsoon; the relationship between water vapor transportation and the variation of $\delta^{18}O$ in precipitation were simulated, showing a strong amount effect. However, at the long-term scale, $\delta^{18}O$ in precipitation and temperature still have positive correlation (Yao *et al.*, 1996), and the temperature effect is evident in the ice cores (Thompson *et al.*, 2000). In addition, in high-altitude areas, the altitude effect of $\delta^{18}O$ in precipitation is obvious (Tian *et al.*, 1998) and the variation of $\delta^{18}O$ in precipitation with the elevation also affected by topography (Kang *et al.*, 2000).

In the central Tibetan Plateau, the Tanggula Mountains around 32°N–33°N are an important line of demarcation between monsoon areas and non-monsoon areas (Liu and Hou, 1999; Wang, 2006). Influenced by the southwest monsoon, the $\delta^{18}O$ values in summer precipitation trend downwards (Tian *et al.*, 2002; Yu *et al.*, 2006), but the trend is less significant than that in the southern Tibetan Plateau (Yu *et al.*, 2008). During the intermission between monsoons, relatively high $\delta^{18}O$ values still exist in precipitation, which may be caused by the recycling of local vapor (Yu *et al.*, 2009). In addition, the fluctuation of $\delta^{18}O$ in summer precipitation is controlled by the large-scale process rather than the local meteorological conditions (Tian *et al.*, 2001d).

In summary, the $\delta^{18}O$ in summer precipitation from southwest monsoon is low; the stronger the monsoon, the lower the isotopic values in the precipitation. However, the $\delta^{18}O$ in precipitation from the north or from local evaporation is high. At an annual scale, a positive correlation can be found between isotopes and temperature, and, before the monsoon occurs, the correlation is more significant (Yu *et al.*, 2006).

In the northern Tibetan Plateau, many studies have shown that $\delta^{18}O$ in precipitation is positively related with temperature, which is manifested as a temperature effect (Yao *et al.*, 1995; Zhang *et al.*, 1995; Yao *et al.*, 1996). Yao *et al.* (1995) quantitatively described the relationship between $\delta^{18}O$ in precipitation and temperature: as $\delta^{18}O$ in precipitation increases (or decreases) by 1‰, the temperature will rise (or fall) about 1.6 °C. This presents a negative relationship between $\delta^{18}O$ in precipitation and altitude, which also reflects the impact of temperature change (Yao *et al.*, 1994; Li *et al.*, 2006). There is an obviously positive correlation between $\delta^{18}O$ in precipitation and temperature in the northern Tibetan Plateau, so the $\delta^{18}O$ in ice cores is a reliable indicator for this area, which is important in paleoclimate reconstruction.

In summary, the stable isotopes in precipitation of different areas in the Tibetan Plateau have different characteristics, which are related to the local temperature, humidity, air pressure, air mass properties, elevation, and complex precipitation conditions, especially the properties of air mass. The positive correlation between temperature and the $\delta^{18}O$ values in precipitation becomes increasingly remarkable from south to north, as influenced by the monsoon (Zhang *et al.*, 2002), and the average $\delta^{18}O$ value in summer precipitation increases gradually from south to north (Tian *et al.*, 2001a).

4.2. The arid region of Northwest China

The arid region of Northwest China is located in the center of Eurasia, which is north of the Tibetan Plateau. The northwest wind prevails in winter, and wet air masses from the ocean in the summer are limited, so the precipitation is generally low (Yu *et al.*, 2003; Guo and Li, 2006). It is practical for studying the regional water circulation, according to the spatial and temporal distribution of the stable isotope composition.

Many reports show that the intercepts and slopes of the meteoric water line (MWL) in Northwest China are lower than the GMWL, and $\delta^{18}O$ in precipitation does not decrease with increasing precipitation at the annual scale. In other words, there is no amount effect. The $\delta^{18}O$ value in summer precipitation is high, which agrees with the dry season's values in the inland area (Zhang *et al.*, 2006). However, the annual temperature effect is very clear in the northwest of China, and the value of $\delta^{18}O$—the maximum and minimum of which appears in the summer and winter, respectively—increases with rising temperature. The temperature effect is mainly caused by the stable isotope fractionation in atmosphere and precipitation, and the stable isotopes are generally subjected to the temperature in the phase transition process (Zhang *et al.*, 2003a). We can reasonably explain and quantitatively recover climate information in the different sediments at the middle and high latitudes by determining the linear relation between the stable isotopic ratio and temperature, which is useful to reconstruct the local climate (Kang *et al.*, 2000).

In winter, the precipitation in the northwest of China mainly comes from the Arctic Ocean, with a route from northwestern Xinjiang to the East (Li and Zheng, 1992; Wang *et al.*, 2005; Wang *et al.*, 2006). The $\delta^{18}O$ values enrich gradually as the vapor is transported (Liu *et al.*, 2008). This is related to the isotopic fractionation of precipitation; before the water falls to the surface it experiences a second evaporation or is possibly mixed with a certain amount of water vapor from the local surface (Li and Zhou, 2007; Li *et al.*, 2009). These characteristics of $\delta^{18}O$ values are distinct from those in other regions.

In summer, the air masses that influence the northwest of China are very complex (He *et al.*, 2005; Zhao *et al.*, 2006), and the different regions also show different features. Through analyzing the distribution of $\delta^{18}O$ values in precipitation, Liu *et al*. (2008) revealed the precipitation moisture source and trajectory through the northwest of China in summer.

4.3. The monsoon region of East China

The monsoon region of East China is mostly bounded by 105°E, where it lies east of the line of the Da Hinggan Mountains, the Yinshan Mountains, the Helan Mountains, the Wushao Mountains, the Nyainqentanglha Mountains, and the Hengduan Mountains (Huang, 1959). From the Qinling Mountains–Huaihe River line (a traditional line between the subtropical zone and the temperate zone), we subdivided the monsoon region of East China into the southern area (henceforth, South China) and the northern area (henceforth, North China).

The meteorological factors affecting precipitation in South China are complex because of its water vapor sources, which include the western Pacific, the South China Sea, the Bengal Bay, the Arabian Sea, and others (Sun *et al.*, 2006). In addition, South China lies at the junction area of monsoons from East Asia, South Asia, and the Tibetan Plateau, so the distribution of stable isotopes in precipitation can indicate the transport path (Dansgaard, 1964; Cui *et al.*, 2005; Pang and He, 2005). Due to its location, South China is a hot spot in related research. For example, according to Pang and He (2005) the isotopic data from two typical stations, New Delhi and Hong Kong, exhibited the different vapor sources of monsoon rainfall, which coincided with the atmospheric circulation.

The isotope values in precipitation in South China show an obvious seasonal variation: close to negative in summer months and positive in winter months. The significant amount effect (Cai *et al.*, 2000; Zhang *et al.*, 2005; Xu *et al.*, 2008) implies that the precipitation in the rainy season in South China mainly originates from the water vapor of the low-latitude ocean. Influenced by the marine vapor, the heavy isotopes display a slight enrichment with rich precipitation and weak evaporation, so the ratio of stable isotopes in precipitation is low. However, in the dry season, affected by the continental air mass, the stable isotopes in precipitation show a high ratio, and the amount effect rather than the temperature effect. A significantly negative correlation is found between $\delta^{18}O$ and the local temperature, which is a special phenomenon of $\delta^{18}O$ changes in precipitation of the monsoon region at low latitudes (Wei and Lin, 1994; Zhang *et al.*, 2006; Zheng *et al.*, 2009).

However, some researchers have come to different conclusions. Pang *et al.*'s (2006) study in Lijiang at a weather scale showed a positive correlation between $\delta^{18}O$ and temperature. Regarding $\delta^{18}O$ in rainfall of Mengzi, Simao (now Pu'er), Tengchong in Yunnan Province, Zhang *et al.* (2006) found that there was a significantly negative correlation relationship between $\delta^{18}O$ and the daily temperature of atmosphere at different elevations.

Regarding spatial distribution, the $\delta^{18}O$ values are lower in the central part (Guangxi and Guizhou), and higher in the surroundings, especially along the east–west direction (Liu *et al.*, 2007). The lower values in the center may be caused by the southeast and southwest monsoons (Zheng *et al.*, 2009). In addition, South China is usually affected by typhoons and tropical low pressure, which are related to the seasonality of the $\delta^{18}O$ values in precipitation (Liu JR *et al.*, 2007, 2009). If the rainfall brought by a typhoon accounts for a large proportion of the monthly precipitation, the spatial distribution of isotopes can be a record of the movement path of the typhoon.

The spatial distribution characteristics in North China are different from those in South China. North China is located at mid-latitude in the Northern Hemisphere, where is controlled by Siberian High Pressure with frequent cold air masses and less precipitation in winter. However, in summer this area is also influenced by moisture from the Pacific Ocean (Song *et al.*, 1998). In North China, the mean temperature and precipitation generally decrease from south to north.

Many factors influence $\delta^{18}O$ in precipitation in North China, such as temperature (including surface temperature and dew point temperature), vapor pressure, and wind (including wind speed and direction) (Liu JR *et al.*, 2009). However, because the isotope fractionation effect mainly depends on the temperature of phase transition, with an extension from coastal land to the interior, the temperature becomes an increasingly major factor affecting the $\delta^{18}O$ values; from south to north, the temperature effect is gradually enhanced and the amount effect changes from year-round to the precipitation period (from June to September) (Liu ZF *et al.*, 2009). The temperature effect appears as follows: at the mid and low latitudes, the main geographical factor which controls $\delta^{18}O$ in precipitation is elevation, while the latitude is a major factor in inland areas far from the sea. In fact, they are both derived from the temperature effect (Liu JR *et al.*, 2009).

5. Meteoric water line and deuterium excess

Isotope fractionation occurs in the evaporation and condensation in the water cycle, so the hydrogen and oxygen isotopes in precipitation show a positive relationship. This rule can be generally expressed in terms of the equation $\delta D=8\delta^{18}O+10$, which is called the global meteoric water line (GMWL) equation, or the meteoric water line (MWL) of Craig (Craig, 1961).

The slope of the MWL indicates the type of isotope fractionation. When the slope equals 8, the formation of precipitation is isotopic equilibrium fractionation. If not, it indicates that the precipitation results from non-equilibrium fractionation. Under natural conditions, the factors that affect the stable isotope fractionation from vapor formation to raindrops are different, so the slope of the MWL is different from 8, either greater or less. Several scientists have conducted extensive studies of China's MWL. Zheng *et al*. (1983) calculated China's MWL ($\delta D=7.9\delta^{18}O+8.2$) at an earlier stage, after which related research was carried out all over China (Table 1).

In general, the precipitation in the arid and semi-arid regions is low and the evaporation is strong. Because of the isotope fractionation caused by imbalance evaporation during rainfall, the slope of the MWL equation is lower. With high temperature and low humidity, the slope of the MWL is lower and the intercept value decreases as the degree of deviation increases (Zhang and Yao, 1996). The slope and intercept in the monsoon region in East China are similar, reflecting the comparable climatic conditions and vapor sources. In areas close to the coast, the MWL coincides with the GMWL significantly, which may mean that the GMWL reflects the characteristics of hydrogen and oxygen isotopes in precipitation in the maritime climate (Cai *et al.*, 2000).

Table 1 Relations between δD and $\delta^{18}O$ at several stations in China

Station	MWL	Correlation coefficient	Reference
Heihe River	$\delta D=4.14\delta^{18}O-20.69‰$	0.99	Zhang and Wu, 2009
Xining	$\delta D=6.96\delta^{18}O-30.19‰$	0.66	Zhang and Yao, 1996
Delingha	$\delta D=5.86\delta^{18}O-27.28‰$	0.57	Zhang and Yao, 1996
Urumqi	$\delta D=7.21\delta^{18}O+4.50‰$	0.95	Li *et al*., 2009
Yichang	$\delta D=8.4\delta^{18}O+15‰$	0.97	Zhang and Yao, 1998
Nanjing	$\delta D=8.43\delta^{18}O+17.46‰$	0.98	Zhang and Yao, 1998
Changsha	$\delta D=8.47\delta^{18}O+15.46‰$	0.99	Zhang and Yao, 1998
Guiyang	$\delta D=8.83\delta^{18}O+22.15‰$	0.99	Zhang *et al*., 2005
Kunming	$\delta D=7.34\delta^{18}O+4.18‰$	0.98	Zhang and Yao, 1998
Tengchong	$\delta D=8.71\delta^{18}O+19.78‰$	0.99	Wei and Li, 1994
Guilin	$\delta D=8.42\delta^{18}O+16.28‰$	0.99	Tu *et al*., 2004
Fuzhou	$\delta D=8.84\delta^{18}O+16.49‰$	0.98	Zhang and Yao, 1998
Xiamen	$\delta D=8.16\delta^{18}O+10.68‰$	0.99	Cai *et al*., 2000
Hong Kong	$\delta D=8.13\delta^{18}O+11.39‰$	0.99	Zhang L *et al*., 2009
Haikou	$\delta D=7.89\delta^{18}O+11.04‰$	0.99	Zhang and Yao, 1998

Dansgaard (1953) defined deuterium excess ($d=\delta D-8\delta^{18}O$) based on the MWL, which is mainly influenced by the relative humidity in the source area, the sea surface temperature (SST), the wind speed, and other conditions. The deuterium excess can indicate environmental information, including the evaporation process with the equilibrium or non-equilibrium, evaporation rates, *etc.* (Wei and Lin, 1994). Thus, the deuterium excess is employed as an important parameter for tracing water vapor sources.

Related studies were carried out in China during recent years. Wei and Lin (1994), using deuterium excess, confirmed that there are different sources of precipitation mass during summer monsoon and winter. Based on the variation of *d* in southern and northern parts of the Tibetan Plateau, Tian *et al.* (2001c, 2005) found that the Tanggula Mountains is the demarcation line between monsoon areas and non-monsoon areas in the Tibetan Plateau, and they concluded that the middle Himalayas are not only affected by the southwest monsoon but also by the westerlies. Based on the relationship between *d* and relative humidity at the source region of water vapor, Pang *et al.* (2005) concluded that the monsoon vapor from the western Arabian Sea is the main vapor source of New Delhi. Recently, by studying the precipitation in the southwest of China, Zhang XP *et al.* (2009) found that the seasonal changes of the properties of air masses are an important factor controlling the seasonality of *d*.

6. Conclusions and prospects

Although stable isotopes comprise a small proportion in natural water, in precipitation they reflect the weather and climate characteristics, which is vital in the study of climate change and paleoclimate reconstruction. The factors that affect the distribution of stable isotopes in precipitation include the regional environment background and the local geographical features. However, for any specific study area, one certain factor may play a leading role.

According to international and domestic research of stable isotopes in precipitation, several methodological problems still exist in China as follows: (1) restricted by the current technology and equipment, research on stable hydrogen isotopes and excess deuterium is limited, compared with stable oxygen isotopes; (2) little attention has been paid to micro-cycle research of water vapor using stable isotopes, as compared with the large-scale vapor cycle; and (3) studies on stable isotopes in water vapor are rare and the scale of most of the research projects is still relatively small. Global change research by isotope techniques has become one of the frontiers of international geographical investigation. With a series of isotopes projects (*e.g.*, CHNIP), more monitoring sites are being established, which will play a significant role in the systematic research of hydrogen and oxygen isotopes in precipitation in China.

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