Quaternary International xxx (2016) 1–10

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Mid-late Holocene climate variations in southeast China inferred by the intermountain peat records from Fujian, China

Guoliang Lei [a, b], Yun Zhu [a, b], Binggui Cai [a, b, c, *], Zhizhong Li [a, b], Xiuyang Jiang [a, b], Jianqin Wu [d]

[a] State Key Laboratory of Subtropical Mountain Ecology (Funded by Ministry of Science and Technology and Fujian Province), Fujian Normal University, Fuzhou, 350007, China

[b] Institute of Geography, Fujian Normal University, Fuzhou, 350007, China

[c] Center for Water Research, Department of Geological Sciences, University of Texas at San Antonio, San Antonio, TX 78249-0663, USA

[d] Tianbaoyan National Nature Reserve, Yong'an, 366000, China

ARTICLE INFO

Article history:
Received 31 March 2016
Received in revised form
21 September 2016
Accepted 24 September 2016
Available online xxx

Keywords:
Peat
α-cellulose $\delta^{13}C$
Precipitation
Late Holocene
Fujian

ABSTRACT

The climate of southeastern China is strongly influenced by the EASM and TCs, which produce most of the precipitation in this area and sustain large-scale industrial and agriculture activities. However, proxy climate records from this area are sparse because of the dense population and intensive human activities. In this study, a total of ten well-dated peat cores collected from the intermountain basins in Fujian Province were evaluated to explore the initiation histories of the peat bogs, and $\delta^{13}C_{\alpha c}$ of α-cellulose extracted from four cores were further analyzed to investigate the precipitation history over the last thousand years. Lithological characteristics of the peat sections show that coarse gravel and sands occur at the bottom of each core, which implies that erosion may be the constraint for the initiation of these peat bogs. The formation of intermountain peatlands indicates rapidly weakening erosion, which in turn suggests a decline in intensive rainfall and (or) total rainfall. Based on AMS ages, three cores show consistent basal ages of approximately 4.2 ka BP, whereas five cores exhibit consistent basal ages centered at approximately 1.2 ka BP. This staged increasing trend of peat bogs distribution since the mid-Holocene coincides with the gradual decline in the intensity of the EASM intensity suggested by the Chinese stalagmite $\delta^{18}O$ records, which indicates that intensive rainfall in the Fujian area has decreased as the EASM has weakened during the late Holocene. This long term change on insolation scale may be connected to insolation and SST of the western North Pacific Ocean. The $\delta^{13}C_{\alpha c}$ exhibits large variability in amplitude from −27.5‰ to −11.3‰, and the periods of heavier $\delta^{13}C_{\alpha c}$ and lighter $\delta^{13}C_{\alpha c}$ corresponded to the layers of gray muddy silt and black peat respectively. We interpret the large amplitude variability in $\delta^{13}C_{\alpha c}$ as a reflection of changes in the proportions of submerged plant matter, which is rich in $\delta^{13}C$. Heavier $\delta^{13}C_{\alpha c}$ indicates a higher proportion of submerged plants with more detritus input, and suggests wetter hydrological conditions with higher precipitation. The changes in $\delta^{13}C_{\alpha c}$ over time show that there was a rapid decreasing trend of $\delta^{13}C_{\alpha c}$ around 800 yr BP, which indicated that precipitation decreased since 800 yr BP. This decrease in precipitation was consistent with the decrease in temperature from the MWP to the LIA, which implies that there was a wetter climate during the MWP and a less wet during the LIA in southeastern China.

1. Introduction

The precipitation history of the late Holocene, especially of the past 1000 years (including the Middle Warm Period (MWP) and the Little Ice Age (LIA)), is essential to our understanding of the processes and dynamic mechanisms of climate systems in the context of global warming. The stalagmite isotope record indicates a gradual decline in the intensity of the East Asian Summer monsoon (EASM) since the mid-Holocene that follows a decreasing trend in insolation (Wang et al., 2005). However, proxy records derived from lacustrine deposits (An et al., 2000; He et al., 2004) show an

* Corresponding author. State Key Laboratory of Subtropical Mountain Ecology (Funded by Ministry of Science and Technology and Fujian Province), Fujian Normal University, Fuzhou, 350007, China.

E-mail address: Bingguicai@qq.com (B. Cai).

http://dx.doi.org/10.1016/j.quaint.2016.09.051
1040-6182/

asynchronous pattern of Holocene monsoon precipitation across eastern China. Some peat records even suggested an anti-phase relationship between southwestern and northeastern China (Hong et al., 2005).

The regional pattern of monsoon precipitation and its corresponding EASM intensity over the last 1000 years are highly debated. For example, modeling results indicate that precipitation will increase when warming is caused by increased solar radiation (Liu et al., 2013). This result is consistent with changes in EASM intensity at the decade-to-century scale over the past 1 ka, as recorded by high-resolution stalagmite oxygen isotopes (Hu et al., 2008; Zhang et al., 2008). However, the precipitation distribution pattern reconstructed based on literature demonstrates that patterns of warm periods differ from those of cold episodes (Zheng et al., 2014). There is a zonal pattern of precipitation distribution from east to west during the cold period, whereas zonal distribution is oriented from south to north during the warm period (Zheng et al., 2014). The diatom record from the southern Okinawa Trough shows that this region was relatively wet during the LIA (Li et al., 2011). The geochemistry of Lake Huguangyan on the Leizhou Peninsula also suggests that the climate in southern China was dry during the MWP and wet during the LIA (Chu et al., 2002). The opposite climate pattern occurred in northern China, where it was wet during the MWP and dry during the LIA. As these patterns transitioned in the area between the middle and lower reaches of the Yangtze River and southern China, the climate in southeastern China was a unit component of EASM because its summer precipitation is also influenced by typhoons. Therefore, the proxy climate records from this area are important for investigating the nature of the EASM and typhoons over the Holocene. In addition, this mountainous terrain is a densely populated economic center of China. A strong understanding of its climate background over the Holocene could improve our capabilities for water management and climate hazard prevention under the ongoing global warming. However, for eastern and central China, such as the middle and lower reaches of the Yangtze River and the Huang-Huai Plain, up-to-date proxy records are primarily derived from historical documents (Ge et al., 2013). High-resolution natural records (e.g., stalagmite or tree-ring records) are mainly obtained from northern and western China. Relatively few paleoclimate records are available from the subtropical region of southeast China (Ge et al., 2013). Recently, some studies had focused on this region (Wang and Ye, 2009; Liu et al., 2011; Wang et al., 2011, 2012a, 2012b, 2014b; Yue et al., 2012; Li et al., 2013; Zhu et al., 2013), but robust records from this area remain limited partly because of a lack of the appropriate materials.

A peat deposit is an accumulation of partially decomposed and thermally immature organic matter (Blackford, 2000; Chambers et al., 2012). Regional climate change can affect peatland formation, bog vegetation and its preservation in peat deposits via hydrological processes (Barber, 1985; Gorham, 1991; Chambers et al., 2012; Langdon et al., 2012; Zhang et al., 2014, 2015, 2016; Kalnina et al., 2015). Fujian, located in southeastern China, generally has warm–wet summers and relatively dry winters, and peat bogs have developed in parts of the intermountain basins with elevations typically above 1000 m. These peat deposits are very sensitive to local vegetation recorded by pollen analysis (Yue et al., 2012; Xu et al., 2013). Because of heavy rainfall and the high rates of erosion of the landscape, the development and expansion of undisturbed natural peat in these mountain ranges of this region are sensitive to variations in precipitation (Zhu et al., 2013). In this study, we have integrated ten well-dated peat cores, including six previously published cores and four new cores, to reveal temporal distribution patterns of peat bogs in the highland of central Fujian. The regional precipitation features since the mid-Holocene are also discussed. Furthermore, the $\delta^{13}C_{ac}$ values in α-cellulose extracted from the four new cores were determined to reconstruct a high-resolution regional precipitation history for the past 1 ka. The precipitation patterns during the MWP and the LIA in southeastern China are then explored.

2. Materials and methods

2.1. Study area and climatology

Fujian Province is located in southeastern China, close to the Tropic of Cancer at the southern boundary of the subtropical zone with the South China Sea to the southeast (Fig. 1). The mountains and hills cover more than 80% of the total area of this province. Vegetation typically covers more than 60% of Fujian province. The current natural local vegetation is primarily subtropical evergreen broadleaved forest, which is known for its high species diversity (Wu, 1980). Because the terrain is mountainous, there is distinct vertical zonation of vegetation, which can be divided into four belts: the shrub-meadow belt (>1500 m), the pine forest belt (1500–1200 m), the evergreen broadleaved forest belt (1200–500 m), and the second forest (<500 m).

This area has a subtropical climate influenced by the EASM and tropical cyclones (TCs, such as typhoons) that originate from the Western North Pacific Ocean (WNP). The mean temperature during January, the coldest month, is about 5 °C in the northwest and 12 °C in the southeast of the province. In the warmest month, July, the average temperature is 25–30 °C. Fujian has abundant rainfall, with an average annual precipitation of 800–1900 mm. Seasonal variations in precipitation are characterized by relatively dry and wet seasons (Fig. 2). Most of the annual precipitation falls between March and September, with a peak during May and June (Fig. 2) when the southeast (summer) monsoon brings large amounts of moisture from the ocean into this region, where it encounters cold fronts and yields heavy frontal rain. The typhoons contribute most of the rainfall from July to October to this region; torrential rains typically occur around the coast. In contrast, the winter is relatively mild and dry; the region is dominated by high pressure and frequent outbreaks of cold air associated with the northwest (winter) monsoon during the winter months.

The peat bogs evaluated in this study, including those from which the four new cores and the six previously published cores were collected, developed in intermountain basins of central Fujian. The four new cores were collected near Jiufeng Mountain and Daimao Mountain, whereas the published cores were collected around Jiufeng Mountain and Daiyun Mountain (Fig. 1). All of these mountains have many hills higher than 1000 m, and the peat bogs were found in valleys near the tops of these hills. These valleys have flat bottoms and are poorly drained. The resulting marshy environments allow peat bogs to develop. The present vegetation surrounding these peat bogs includes pine forests and evergreen broadleaved forest (Wu, 1980), which are dominated by *Pinus taiwanensis, Schima* spp., *Quercus* spp., *Rhapniolepis indica, Castanopsis* spp., Lauraceae and Hamamelidaceae.

2.2. Peat core collection and sample preparation

From September 2011 to December 2013, a thorough investigation was conducted on Jiufeng Mountain and Daiyun Mountain in central Fujian Province to ascertain the distribution of modern peat bogs in the intermountain basin. Four well-preserved peat bogs were found and studied (Table 1, Fig. 1). A deposit core was collected using a peat corer at the center of each of these peat bogs. The longest core, 358 cm, was obtained from Jiufeng Mountain (Table 1). Subsamples for laboratory analysis were separated at 2-