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THEMATIC ISSUE

Characteristics of climate change in southwest China karst region and their potential environmental impacts

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Abstract Global warming, due to the enhanced greenhouse effect, is likely to have significant effect on the hydrological cycle, which would result in more evaporation, more precipitation, and uneven distribution of precipitation around the globe. Some parts of the world may see significant reduction in precipitation, or major alterations in the timing of wet and dry seasons, and increases in both floods and droughts. In China, a warming trend has been observed across the mainland region during the past 50 years, with an increasing temperature of about 0.2–0.3 °C/10 year in northern and less than 0.1 °C/10 year in southern China. To understand the characteristics of climate change, this study has conducted statistical analysis on climate parameters from 12 representative meteorological stations in southwest China karst region. The non-parametric Mann–Kendall rank statistic method and the Pettitt–Mann–Whitney change point statistics were used, respectively, for the change trend and change point analyses of daily temperature and precipitation at each station. The 5-year moving averages of 11 climate parameters showed a clear increase in the maximum and minimum annual average temperature in southwest China, however, no consistent increase for precipitation. In addition to temperature and precipitation, changes in the atmospheric pressure, wind speed, and cloud cover were also observed from this study. Changes in climate characteristics will or have altered the hydrologic cycle in the region, which would induce more frequent drought and flood, redistribution of water resources, rocky desertification, and carbon balance, and will ultimately have great impacts on the social, economic, and environmental life in the region.

Keywords Climate change · Change trend · Environmental impact · Southwest China · Karst

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Background

Global warming, due to the enhanced greenhouse effect, is likely to have significant effect on the hydrological cycle, which would result in more evaporation, more precipitation, and uneven distribution of precipitation around the globe. Some parts of the world may see significant reduction in precipitation, or major alterations in the timing of wet and dry seasons, and increases in both floods and droughts. In China, a warming trend has been observed across the mainland region during the past 50 years, with an increasing temperature of about 0.2–0.3 °C/10 year in northern and less than 0.1 °C/10 year in southern China. 'A study by Zhang et al. (2013) indicated that the extreme drought frequency has significantly increased in the past 50 years in the southwestern Sichuan Basin, southern Hengduan Mountains, the coast area of southern Guangxi, and northern Guizhou. Wang and Zhang (2011) showed that the average temperature in China has risen by 1.1 °C from 1908 to 2007 and the annual precipitation decreased gradually since the 1950s, with an average decline of 2.9 mm per decade, except for a slight increase from 1991 to 2000. Because of climate change, water distribution pattern has changed in China over the past 50 years, especially in major river basins such as the Yangtze and Pearl River basins, where runoff has increased, while in other basins there was a decline. Studies (Liu and Hou 1998; Shrestha et al. 1999; Liu and Chen 2000; IPCC 2007; Nogues-Bravo et al. 2007) showed that warming at high elevations was already occurring at approximately three times the global average. The Intergovernmental Panel on Climate Change (IPCC) has projected that average annual mean warming will be about 3 °C by the 2050s and about 5 °C in the 2080s over the Asian land mass, with temperature on the Tibetan Plateau rising substantially more (IPCC 2007).

Rapid changes of temperature in various regions were detected by the multiple timescale *t* test method. The year 1969 was a rapid change point from a high temperature to a low temperature along the Yangtze River and South China. In the years 1977–1979, temperature significantly increased from a lower level to a higher level in many places, except for regions in North China and the Yangtze River. Another rapid increasing temperature trend was observed in 1987. In the years 1976–1979, a positive rapid change of summer temperature occurred in northwestern China and southwestern China, while a decreasing temperature was found between the Yellow River and the Yangtze River. A rapid increase of winter temperature was found for 1977–1979 and 1985–1986 in many places.

In this study, the non-parametric Mann–Kendall rank statistic method and the Pettitt–Mann–Whitney change point statistics were adopted, respectively, to analyze the change trends and change points of all climate parameters at the 12 representative meteorological gauging stations in southwest China karst region. The 5-year moving averages of mean atmospheric pressure, air temperature, wind speed, cloud cover, hours of sunshine, and the annual total evaporation and precipitation were analyzed. Further studies will be conducted on the spatial distribution and classification of rainfall and temperature, and the change characteristics of climate conditions such as the frequency and magnitude of precipitation in the region.

Study area and data

The geographical region of southwest China includes Guangxi, Sichuan, Chongqing, Tibet, Yunnan, and Guizhou provinces and autonomous regions. However, the southwest karst region (Fig. 1) often refers to Guizhou, Yunnan, Hunan, Sichuan, Chongqing, Hubei, and Guangdong, and Guangxi, which have a total of 0.54 million km^2 of karst areas. The population in the southwest karst area is estimated to be around 100 million. Geomorphological features in southwest China are characterized by multiple mountains and plateaus, widely distributed karst and red clay hills, deep canyons, and gorges. Carbonate rocks are widely distributed in Yunnan and Guizhou. Karst landforms result in uneven distribution of water resources and diverse ecological environment. Geological hazards such as collapses, landslides, and mudslides happen often in the region.

Plateau monsoon, East Asia and southwest monsoons are important sources of water vapor in the region. The Qinba Mountain blocks cold air from north to south, which keeps the southwest areas fairly warm in the winter with annual average temperature between 14 and 24 °C. In general, precipitation decreases from southeast to northwest and from south to north, and precipitation distribution varies with altitudes and mountain slopes as well. Annual rainfall is around 1,000–2,500 mm in south Yunnan, 1,100–1,400 mm in most of the Guizhou province, and 1,000–1,300 mm in Sichuan Basin. The Yangtze and Pearl River drainage basins account for 81.28 % of the southwest area. Runoff is about 40–60 % in the summer, 25–40 % in the fall, 10–20 % in the spring, and 8–12 % in the winter. With abundant precipitation and warm weather, plants and vegetation types are abundant in southwest China.

The dominant soil types are tropical and subtropical zone soils, with red soil, dry red soil, and yellow soil typically in the Yunnan–Guizhou plateau, and yellow and yellow-brown soils in Chongqing. The soil structure in karst areas often lacks the C layer, which easily leads to soil erosion. Karst systems in southwest China are typical of a dual- or three-phase structure with pores, fractures, and conduits combined to form unique surface and subsurface flow systems, calcium-rich geochemical environments, and special types of cretaceous soils.

Figure 1 shows the available weather stations in southwest China. Twelve out of 134 stations were selected for this study. Each station has daily data for average atmospheric pressure; average, maximum, and minimum temperatures at 2 m above ground; average vapor pressure; relative humidity; average cloud cover; average cloud cover at low altitude; average wind speed; average ground temperature; daily precipitation; sunshine hours; and daily evaporation rate from the 1950s to 2006.

Change trend and change point analysis

The change trends of precipitation and temperature in southwest China karst region were analyzed using the modified version of the non-parametric Mann–Kendall rank statistic method. To perform the test, Kendall's S_k has to be calculated in all pairs (x_i, x_j) of observation data. S_k is computed from:

Fig. 1 All available climate stations in some of the southwest karst areas including Guangxi, Guizhou, Yunnan, Chongqing, and Sichuan

$$S_k = \sum_{i=1}^{k} r_i \quad (1)$$

where $k = (2,3, \ldots,n)$, n is the data set record length, and r_i is

$$r_i = \begin{cases} 1 & \text{if } x_i > x_j \\ 0 & \text{if } x_i \leq x_j \end{cases} \quad (j = 1, 2, \cdots, i)$$

The test is based on the statistic τ that is computed from:

$$\tau = \frac{4 \sum S_k}{n(n-1)} - 1 \quad (2)$$

The variable t, associated with τ normally distributed and of zero mean, has a variance of:

$$\sigma_t = \frac{2(2n+5)}{9n(n-1)}. \quad (3)$$

The significance test is based upon the formula:

$$Z_t = \pm\tau\sqrt{\frac{9n(n-1)}{2(2n+5)}}, \quad (4)$$

in which τ is the value of t at the probability point in the Gaussian distribution appropriate to the two-tailed test. At a specified level of significance of α, the standard Z_α value can be obtained from the Z table for the standard normal distribution, with $Z_{\alpha/2}$ being the critical value. In the case of a positive trend, the auxiliary variable Z_t is greater than the threshold value $Z_{\alpha/2}(Z_t > Z_{\alpha/2})$. Z_t is less than $Z_{\alpha/2}$ in the case of a statistically significant negative trend ($Z_t < -Z_{\alpha/2}$).

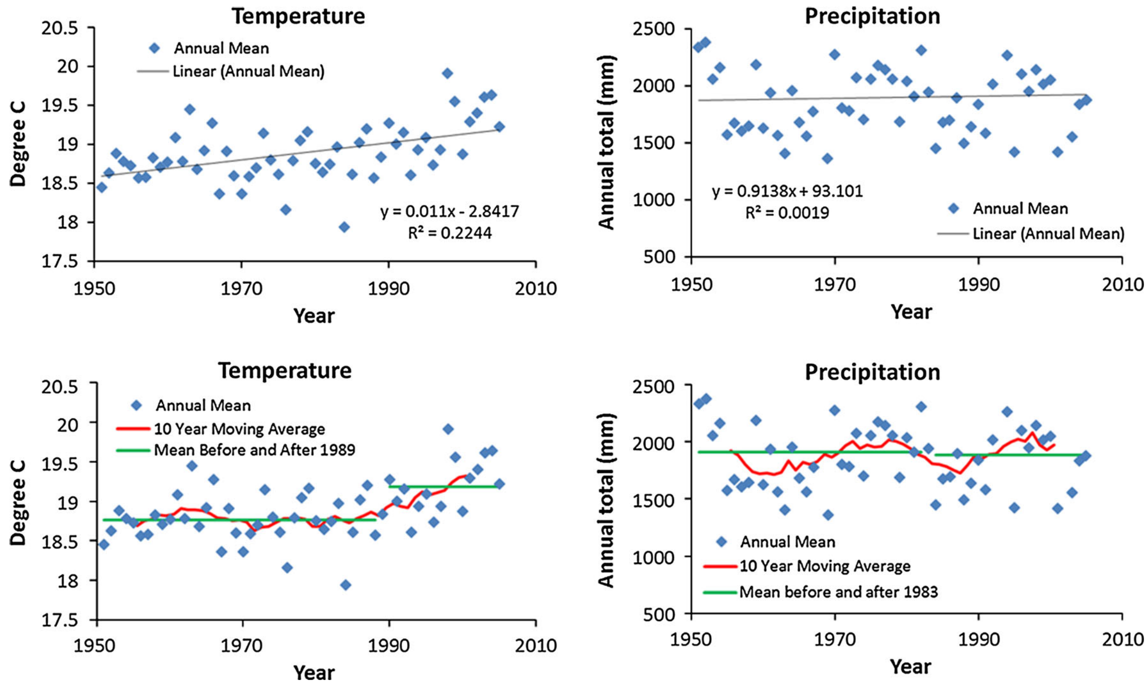

Fig. 2 The annual and 10-year moving average of mean temperature and mean rainfall depth at Guilin gauging station

The change point analysis was based on the Pettitt–Mann–Whitney change point statistics. Let n be the length of the time series and t be the time of the most likely change point. A time series of n years of flow or stage can be divided by the time t into two sample groups, $\{X_1, X_2, \ldots, X_t\}$ and $\{X_{t+1}, X_{t+2}, \ldots, X_n\}$. Define the test statistic index, U_t, as:

$$U_{t,\mathrm{n}} = U_{t-1,\mathrm{n}} + V_{t,\mathrm{n}} \quad \text{for } t = 2, \ldots, \mathrm{T} \tag{5}$$

where $V_{t,n} = \sum_{j=1}^{n} \mathrm{sgn}(X_i - X_j)$, $\mathrm{sgn}(X_i - X_j) = 1$ for $(X_i - X_j) > 1$, $\mathrm{sgn}(X_i - X_j) = 0$ for $(X_i - X_j) = 0$, and $\mathrm{sgn}(X_i - X_j) = -1$ for $(X_i - X_j) < 1$.

Pettitt (1979) developed the following procedure to determine whether the change point was statistically significant. First, the test statistic K_t and the probability that a change point associated with maximal $|U_t|$ can be approximated by:

$$K_t = \mathrm{Max}_{1 \le x \le n} |U_t| \tag{6}$$

$$P = 2 \exp\left[\frac{-6K_t^2}{n^3 + n^2}\right]. \tag{7}$$

Equations (5–7) yield the change point with an estimated probability of P. If P is less than 0.05, the change point is statistically significant.

In addition, all analyses for this study were conducted using Matlab. The trend and change point analyses were based on the monthly data. Identification of change points is not only based on the statistical significance but also carefully checked by examining the plots of annual average data. The multi-year moving average of annual data has often been used to understand the long-term change trend of time series data.

Results and discussion

Shown in Fig. 2 are examples of the annual mean temperature and annual total precipitation, the 10-year moving average, and the means before and after the change point for temperature and precipitation at Guilin station. The change trend and its statistical significance, and their corresponding change points for temperature, vapor pressure, cloud cover, time of sunshine, average wind speed, evaporation, precipitation, and relative humidity at each station are listed in Table 1, with 1 indicating positive/increase trend (highlighted in red), −1 for negative/decrease trend (highlighted in green), 0 for no significant change trend but with fluctuations. Next to the trend index in the table is the significance level of change trend with 1 being significant and 0 insignificant.

Table 1 shows that precipitation had a decreasing trend at most of the selected locations over the past 60-year period and 1978–1984 was identified as the period when significant change happened for precipitation at these gauging locations. On top of fluctuations, precipitation in Liuzhou, Guilin, Shapingba, and Kunming had an increase trend.

On the average, the sunshine time had a decreasing trend at all other locations but Lancang, Simao, and Dali in

Table 1 Change trend of climate parameters at various gauging stations in southwest China

Climate Parameter	Guangxi						Guizhou						Yunnan										Chongqing	
	Wuzho		Liuzhou		Guilin		Guiyan		Weining		Bijie		Mengzi		Lancang		Simao		Kunming		Dali		Shapingba	
	Trend	Significance	Trend	Significance	Trend	Significance	Trend	Significance	Trend	Significance	Trend	Significance	Trend	Significance	Trend	Significance	Trend	Significance	Trend	Significance	Trend	Significance	Trend	Significance
Maximum T	1	0	1	0	1	0	-1	0	-1	0	1	0	-1	0	1	0	1	0	1	0	1	0	1	0
	1998		1998		1998		1973		1954		1998		1988		1993		1978		1992		1994		1984	
Minimum T	1	0	1	1	1	0	1	0	1	0	1	0	1	1	1	1	1	1	1	1	1	0	1	0
	1998		1985		1988		1977		1996		1988		1993		1979		1980		1987		1988		1994	
Average T	1	0	1	0	1	0	-1	0	1	0	1	0	1	0	1	1	1	1	1	1	1	0	1	0
	1998		1985		1989		1999		1998		1998		1980		1979		1980		1992		1998		1997	
Ground T	1	0	1	0	1	0	-1	0	1	0	1	0	1	0	1	0	1	1	1	0	1	0	1	0
	1998		1985		1978		1973		1997		1998		1979		1990		1994		1997		1998		1966	
Vapor pressure	1	0	1	0	1	0	-1	0	1	0	1	1	1	0	1	0	1	0	1	0	1	1	1	0
	1959		1959		1957		1954		1958		1961		1993		1980		1980		1980		1960		1988	
Low Cloud	1	1	1	0	-1	0	1	1	-1	0	1	1	-1	0	-1	0	-1	0	1	0	1	1	1	1
	1977		1989		1988		1981		1973		1956		1977		1968		1968		1994		1989		1979	
Sunshine (hrs)	-1	1	-1	0	-1	1	-1	1	-1	1	-1	1	-1	1	1	0	1	0	-1	1	1	0	-1	1
	1980		1974		1978		1978		1988		1979		1987		1993		1988		1979		1958		1981	
Wind Speed	-1	1	-1	1	-1	0	1	1	-1	1	-1	1	-1	1	1	0	-1	1	-1	1	-1	1	1	1
	1965		1965		1977		1988		2002		1967		1996		1988		1985		1988		1985		1992	
Evaporation	-1	0	-1	0	1	1	-1	0	-1	1	-1	1	-1	0	-1	1	1	1	-1	0	-1	1	-1	0
	1975		1963		1988		1993		1981		1979		1991		1965		1972		1988		1986		1963	
Precipitation	0		1	0	1	0	-1	1	-1	1	-1	1	0		-1	1	-1	1	1	1	-1	1	1	0
			1984		1983		1984		1979		1984				1978		1979		1990		1978		1995	
Relative Humidity	-1	0	-1	1	-1	0	1	0	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1	1	0	1	0
	1998		1979		1983		1998		1997		2001		1997		1978		1978		1992		1970		1955	

Yunnan. The negative trend in sunshine duration may be resulted from the negative radiative forcing of the enhanced aerosols (Kaiser and Qian 2002). An increasing trend of low-altitude cloud cover was observed at all stations except for Guilin, Weining, Mengzi, Lancang, and Simao. Unfortunately, the change trend of low-altitude cloud cover shown from this study does not fall into the conclusion drawn in a paper published in science by Clement et al. (2009), in which they concluded that global warming has a tendency to dissipate clouds, thus to reduce cloud cover. The discrepancy could be due to the unique characteristics of climate condition in the high-altitude southwest China region, which is entirely different from the northeast pacific region where Clement et al. (2009) study was based upon.

Other than Guiyang, Lancang, and Shapingba, wind speed was seen as a decreasing trend at every other location. However, no consistent change points for wind speed could be identified for the 1960s–2000s period. Xu et al. (2006) attributed the decline of wind speed in southwest China to the weakening of impact from the East Asian monsoon in both winter and summer seasons for the recent three decades.

As expected, affected by global warming, the minimum temperature had shown a consistent increasing trend at all stations with change points from the 1980s to 1990s, while maximum temperature had a moderate increase at all locations, but interestingly some decrease at Guiyang, Weining, and Mengzi. The ground temperature showed an increasing trend at all but Guiyang station. Coincidently,

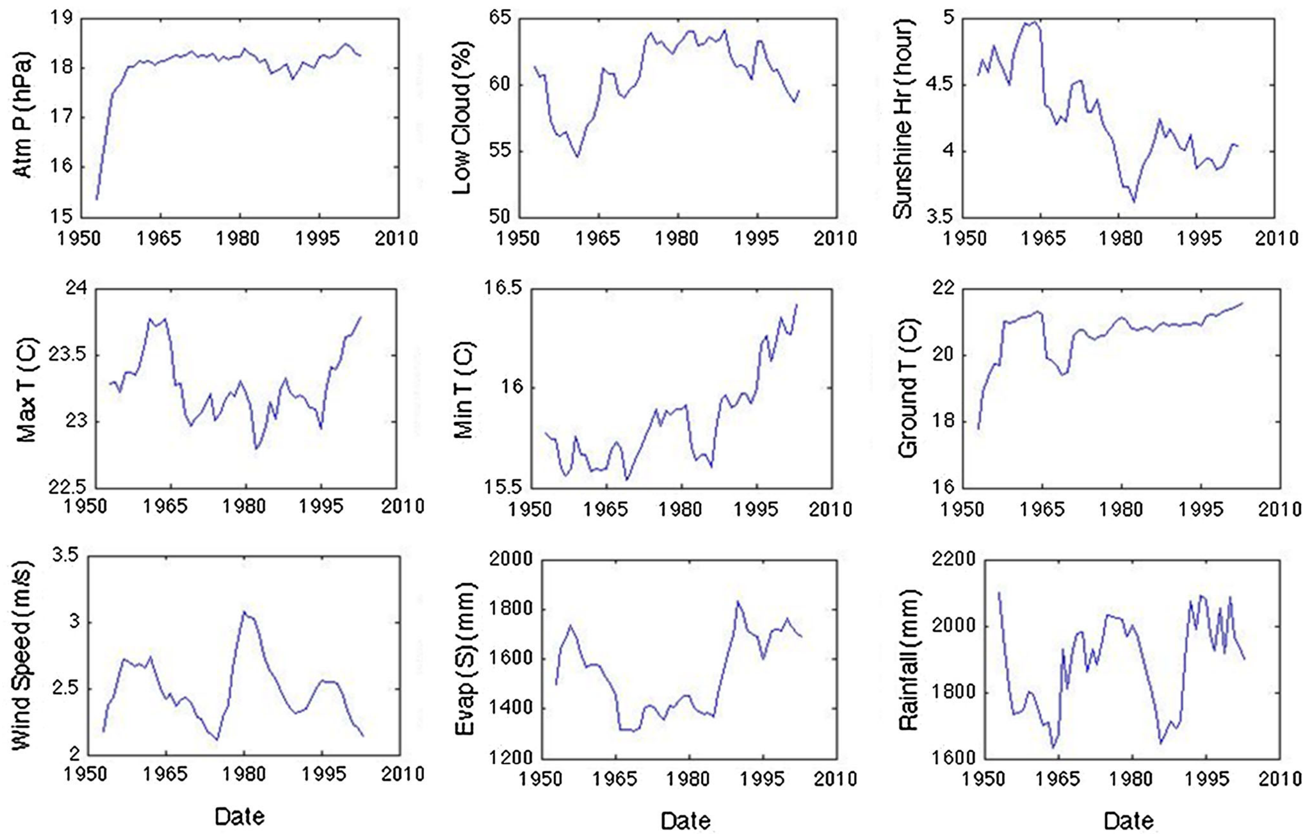

Fig. 3 Five-year moving average of climate parameters at Guilin station in Guangxi

the relative humidity showed a decrease trend for every location except for Guiyang, Dali, and Shapingba. The decrease in humidity could be a combined effect of increasing vapor pressure and air temperature.

Shown in Figs. 3 and 4 are the 5-year moving averages of major climate parameters at Guilin and Mengzi stations, respectively. The vapor pressure in Guilin had a steady increase from the 1950s. The low-altitude cloud cover increased around the 1960s before it started to decrease around 1990. The average sunshine hours at Guilin station had a consistent overall drop. The average vapor pressure, low-altitude cloud cover, and sunshine hours at Mengzi station in Fig. 4 almost had opposite change pattern, which implies different climate conditions at both locations. The minimum and the ground temperatures had consistent increase at both locations with change points for the minimum temperature in 1988. However, the maximum temperature in Guilin had a low period from 1968 to 1995 before it started to rise, while in Mengzi it started to decline after reaching the highest around 1980. The average wind speed in Guilin had more fluctuations, whereas in Mengzi it stayed between 3.2 and 3.5 m/s from 1955 to 1983 before a decline to about 2.3 m/s. Evaporation rate at both locations had almost opposite patterns. Precipitations did not show consistent increase or decrease trends rather than fluctuations at both stations.

Climate variation has resulted in changes of precipitation, temperature, and other climate parameters, which subsequently affected the hydrologic cycle, water resources, and the ecologic environment. More frequent floods and droughts have been observed in southwest karst areas. In the spring of 2010, Southwest China experienced the worst drought in a century (http://www.asianews.it/news-en/Worst-drought-in-a-century-wipes-out-harvests-in-southwestern-China17947.html). A study by Zhang et al. (2013) showed that the extreme drought frequency had significantly increased in the past 50 years in southwestern Sichuan Basin, southern Hengduan Mountains, the coast area of southern Guangxi, and northern Guizhou. During the summer monsoon period, the extreme drought frequency is growing, which generally occurs in the high mountains around the Sichuan Basin, most parts of Guangxi, and "the broom-shaped mountains" in Yunnan. Climate change will affect agricultural production. Gao (2012) showed that the crop yield is negatively related to temperature and predicted that the crop yield in 2030 will be 7 % less under the current climate change trend.

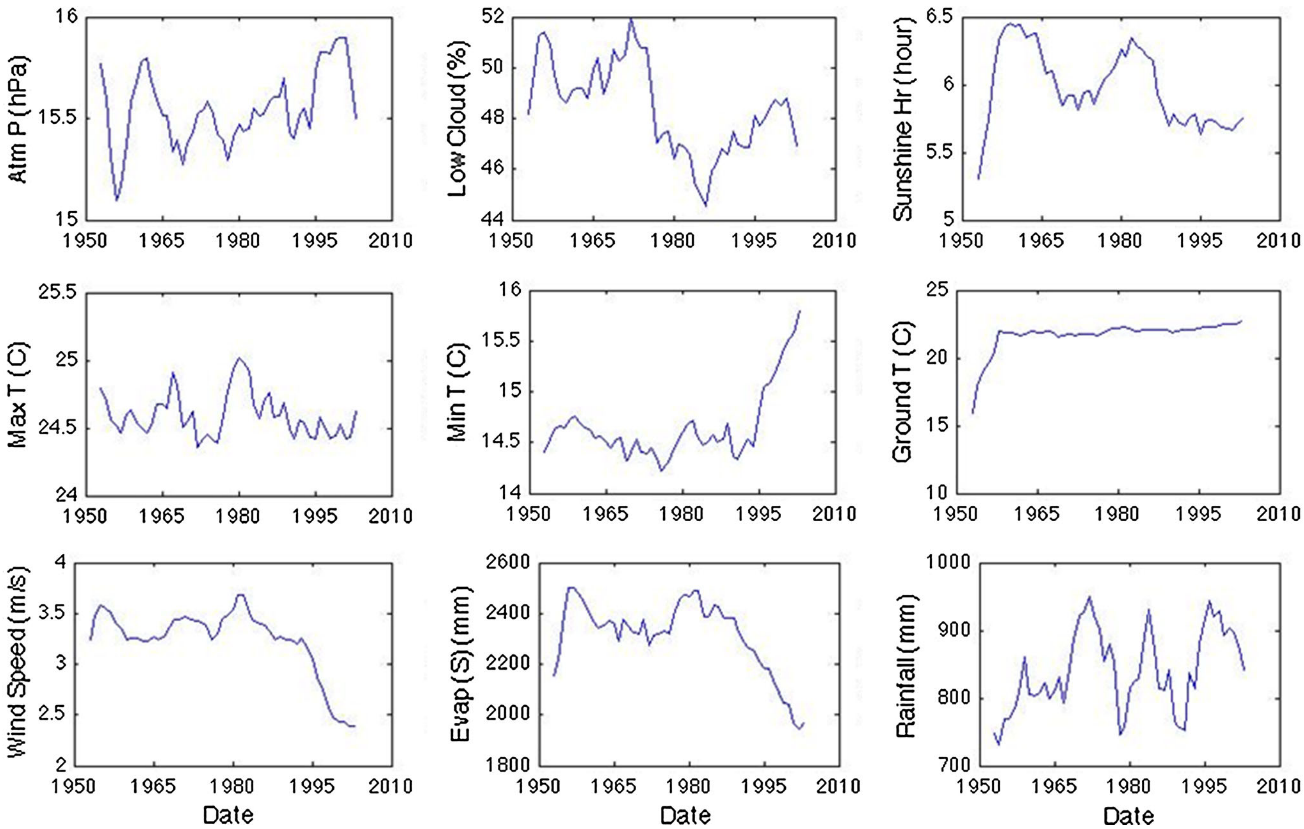

Fig. 4 Five-year moving average of climate parameters at Mengzi station in Yunnan

Impact of climate change on hydrologic cycle and water resources has been observed in southwest China. Other than the increased frequency of floods and droughts, runoff characteristics have been modified by changing climate conditions. Studies by Costa-Cabral et al. (2008) and Nijssen et al. (2001) indicated that Mekong had observed an increase in precipitation during early monsoon and increased runoff, and predicted future increase in precipitation and extreme floods. Studies by Su et al. (2005), Wang et al. (2005) and Zhang et al. (2006) had seen an increase in precipitation, extreme rainfall, and more frequent floods, but no significant change in runoff. They predicted an 11.6 % decrease of glacier areas in the upper Yangtze River but 10 % glacier discharge increase for up to 28.5 % by 2050, which will significantly change the hydrologic characteristics within the river basin.

This study has shown that even though the climate conditions can be quite different, it is common that the minimum temperature has increased at all studied locations. Other than Guiyang, the ground has warmed up at all other 11 locations over the last 60 years. A review by Davidson and Janssens (2006) on nature indicated that soil carbon decomposition is sensitive to temperature, particularly ground temperature, thus to have positive or negative impact on climate change. Jiang et al. (2013) showed that the carbon cycle in southern China is active due to moderately warm climate conditions. Global warming may accelerate carbon cycle thus to reduce the carbon storage in soils, although this remains to be studied.

Conclusions

Analyses from this study showed that the daily maximum, minimum, average, and ground temperature, and the vapor pressure had an increasing trend in the past 60 years in southwest China. The minimum and ground temperatures have seen consistent increase in the area. However, the sunshine duration, evaporation rate, precipitation, the relative humidity, and even the low-altitude cloud cover had a decreasing trend in the region. The change points were identified through statistical analysis and confirmed by visually examining the 5-year moving average plots. Other than precipitation which had a change point around 1978–1984, change points for other climate parameters at other locations were not consistent. Comparison of climate parameters at Guilin and Mengzi gauging locations showed that characteristics of climate conditions can be significantly different; however, the increase trends of minimum temperature and even ground temperature were similar at all locations.

The focus of this study is on the change trend and change pattern of major climatic parameters at some representative gauging stations. Causes on some of these changes might be due to global climate change or more to a combination of climate change and human activities. Impacts of climate change on the hydrologic cycle, water resources, and eco-environment in southwest China karst region have been observed. Some major researches such as climate change on soil carbon decomposition and carbon storage in soils, climate change to the ecosystems, and climate change to desertification in southwest karst region remain to be conducted.

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References

Clement AC, Burgman R, Norris JR (2009) Observational and model evidence for positive low-level cloud feedback. Science 325:460

Costa-Cabral MC, Richey JE, Goteti G, Lettenmaier DP, Feldkötter C, Snidvongs A (2008) Landscape structure and use, climate, and water movement in the Mekong River Basin. Hydrol Process 22:1731–1746

Davidson Eric A, Janssens Ivan A (2006) Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. Nature 440(7081):165–173

Gao C (2012) The impact of climate change on China's crop production: a CMIP5 ensemble assessment, Agro-Geoinformatics (Agro-Geoinformatics). In 2012 First international conference on Agro-Geoinformatics, pp 1–5. doi:10.1109/Agro-Geoinformatics.2012.6311641

IPCC (Intergovernmental Panel on Climate Change) (2007) Climate change 2007: the physical science basis. In: Solomon S et al (eds) Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 235–336

Jiang Z, Lian Y, Qin X (2013) Carbon cycle in the epikarst systems and its ecological effects in South china. Environ Earth Sci 68(1):151–158

Kaiser DP, Qian Y (2002) Decreasing trends in sunshine duration over China for 1954–1998: indication of increased haze pollution? Geophys Res Lett 29(21):2042. doi:10.1029/2002GL016057

Liu X, Chen B (2000) Climatic warming in the Tibetan Plateau during recent decades. Int J Climatol 20:1729–1742

Liu XD, Hou P (1998) Relationship between the climatic warming over the Qinghai-Xizang Plateau and its surrounding areas in recent 30 years. Plateau Meteorol 17:245–249 (in Chinese)

Nijssen B, O'Donnell GM, Hamlet A, Letternmaier DP (2001) Hydrological sensitivity of global rivers to climate change. Clim Change 50:143–175

Nogues-Bravo D, Araujo MB, Errea MP, Martinez-Rica JP (2007) Exposure of global mountain systems to climate warming during the 21st century. Global Environ Chang 17:420–428

Pettitt AN (1979) A non-parametric approach to the change point problem. J R Stat Soc Ser C Star 28:126–135

Shrestha AB, Wake CP, Mayewski PA, Dibb JE (1999) Maximum temperature trends in the Himalaya and its vicinity: an analysis based on temperature records from Nepal for the period 1971–94. J Climate 12:2775–2787

Su BD, Xiao B, Zhu DM, Jiang T (2005) Trends in frequency of precipitation extremes in the Yangtze River basin, China: 1960–2003. Hydrol Sci J 50:479–492

Wang S, Zhang Z (2011) Effects of climate change on water resources in China. Climate Res 47:77–82. doi:10.3354/cr00965

Wang X, Xie ZX, Feng QH, Yang YL, Yang MQ, Lin J (2005) Response of glaciers to climate change in the source region of the Yangtze River. J Glaciol Geocryol. 27:498–502

Xu M, Chang CP, Fu C, Qi Y, Robock A, Robinson D, Zhang H (2006) Steady decline of East Asian monsoon winds, 1969–2000: evidence from direct ground measurements of wind speed. J Geophys Res 111:D24111. doi:10.1029/2006JD007337

Zhang Q, Xu CY, Becker S, Jiang T (2006) Sediment and runoff changes in the Yangtze River basin during past 50 years. J Hydrol 331:511–523

Zhang M, Ji He, Wang B, Wang S, Li S, Liu W, Ma X (2013) Extreme drought changes in Southwest China from 1960 to 2009. J Geogr Sci 23(1):3–16. doi:10.1007/s11442-013-0989-7