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Variability and trend analysis of precipitation during 1961-2015 in Southwest Guizhou Autonomous Prefecture (SGAP), China

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ABSTRACT

Information on variability and trends of precipitation over a region is useful in the agricultural production management. The linear regression analysis, 5-year moving average, accumulated anomaly and Mann-Kendall trend detection were used to assess the variability and trends in precipitation over Southwest Guizhou Autonomous Prefecture (SGAP) region of China. The results revealed that the annual precipitation showed an increasing trend at Wangmo and Xingren and decreasing trends at Anlong, Ceheng, Pu'an, Qinglong, Xingyiand Zhenfeng stations. The UF(k) and UB(k) curves of each region have intersections, except in Ceheng and Xingren, and this indicated that the precipitation has seen a abrupt change in six stations. The results of this study will provide theoretical guidance for agricultural water management in Southwest Guizhou Autonomous Prefecture of China.

Key words: Precipitation, accumulated anomaly, Mann–Kendalltrend detection test, SGAP

Precipitation is one of the most important meteorological variables which can impact the occurrence of drought or flood. Changes in precipitation, and the amount of precipitation is an important indicator to determine the severity of drought (Dang *et al*., 2011). Analysis of precipitation and drought data yields important information which can be used to improve water management strategies, plan agricultural production or in general, impact economic development of a certain region (Gocic *et al*., 2013). Mann-Kendall test statistics and other non-parametric tests have been used to detect the abrupt change in precipitation over different parts of India (Chakraborty *et al.* 2017; Waghaye *et al.* 2018).

Southwest Guizhou Autonomous Prefecture (SGAP) of China belongs to the Panjiang river basin of the Pearl River. SGAP has an agro-based economy and most of the states fall in the seasonal drought area. SGAP is a major flue-cured tobacco producing area of China, and the economic value of flue-cured tobacco production plays an important role in agricultural production in the whole state (Shao *et al*., 2009). In recent years, due to the uneven distribution of rainfall resources, different degrees of water supply and demand in SGAP's major tobacco areas, especially in the transition period (spring) of flue-cured tobacco, caused a huge impact on the growth of flue-cured tobacco and obstructed the normal growth and development of flue-cured tobacco.

Therefore, the aim of the present study was to analyse the variability and trends of precipitation over SGAP region of China, and to elucidate the abrupt changes of spring precipitation.

MATERIALS AND METHODS

Study area

Southwest Guizhou Autonomous Prefecture (SGAP) of China is located in the southwest of Guizhou Province (104°35'E–106°32'182 E; 24°38'N–26°11'N), and it has eight counties, which are Anlong, Ceheng, Pu'an, Qinglong,Wangmo, Xingren, Xingyi and Zhenfeng. The state belongs to the Panjiang river basin of the Pearl River, which is a typical low-latitude and high-altitude mountain area and most of the altitude is between 1000 and 2000 m. The SGAP is located in the sub-tropical climate zone with the annual mean temperature ranging between 13.8~19.4°C, the average annual precipitation of 1352.8 mm mainly concentrated during May to September.

Data sources

Fifty five years (1961-2015) daily rainfall data of spring season (March to May) for eight meteorological stations (Anlong, Ceheng, Pu'an, Qinglong, Wangmo,

Table 1: Variations of annual precipitation by the linear trend and 5-year moving averages in SGAP (1961-2015).

Station	Average precipitation (mm)	Linear trend (mm ·year^{-1})	Trend
Anlong	1184.1	-2.4	↓
Ceheng	1251.0	-1.9	↓
Pu'an	1345.7	-3.7	↓
Qinglong	1508.2	-3.8	↓
Wangmo	1088.5	8.3	↑
Xingren	980.7	20.3	↑
Xingyi	1438.9	-1.8	↓
Zhenfeng	1318.1	-1.8	↓

"↑" indicate an increasing trend, and "↓" indicate a decreasing trend.

Table 2: The variation of precipitation by the accumulated anomaly curve in SGAP (1961-2015).

Station	Positive				Negative			
	No. of years	Percentage (%)	Largest anomaly year	Accumulated anomaly (mm)	No. of Years	Percentage (%)	Smallest anomaly year	Accumulated anomaly (mm)
Anlong	46	83.6	2001	1414.2	9	16.4	1964	-417.0
Ceheng	44	80.0	1997	1502.4	11	20.0	1964	-603.8
Pu'an	51	92.7	2001	1957.6	4	7.3	2013	-109.6
Qinglong	51	92.7	1983	1962.2	4	7.3	2013	-215.1
Wangmo	5	9.1	1962	99.8	50	90.9	1981	-4323.9
Xingren	0	0.0	—	—	55	100	1981	-10629.6
Xingyi	34	61.8	2003	1803.7	21	38.2	1966	-781.2
Zhenfeng	43	78.2	1986	1312.5	12	21.8	2013	-545.9

Xingren, Xingyi and Zhenfeng) were obtained from Meteorologic Bureau of SGAP, and the partially missing data were downloaded from National Meteorological Information Center, China Meteorological Administration (http://data.cma.cn).

The linear regression equation were developed to find the linear trend. Five years moving average, and accumulated anomaly were calculated following He *et al*. (2013). The Mann–Kendall test statistic (S) are calculated following Mann (1945), Kendall (1975) and Haktanir *et al*. (2013).

Abrupt change test

For time series X_n (n is the length of the data set), the order series (S_k) is given as follows:

$$S_k = \sum_{i=1}^{k} r_i, (k = 2,3,4,\ldots,n) \quad (1)$$

$$r_i = \begin{cases} +1, x_i > x_j \\ 0, x_i \le x_j \end{cases}, (j = 1,2,3\ldots,i) \quad (2)$$

Where x_j and x_i are the sequential data values.

The statistic (UF_k) is defined as:

$$UF_k = \frac{[S_k - E(S_k)]}{\sqrt{Var(S_k)}}, (k = 1,2,3,\ldots,n) \quad (3)$$

Where UF_1=0, $E(S_k)$ and $Var(S_k)$ are the average value and variance of S_k, which can be calculated by following equations:

$$E(S_k) = \frac{n(n+1)}{4} \quad (4)$$

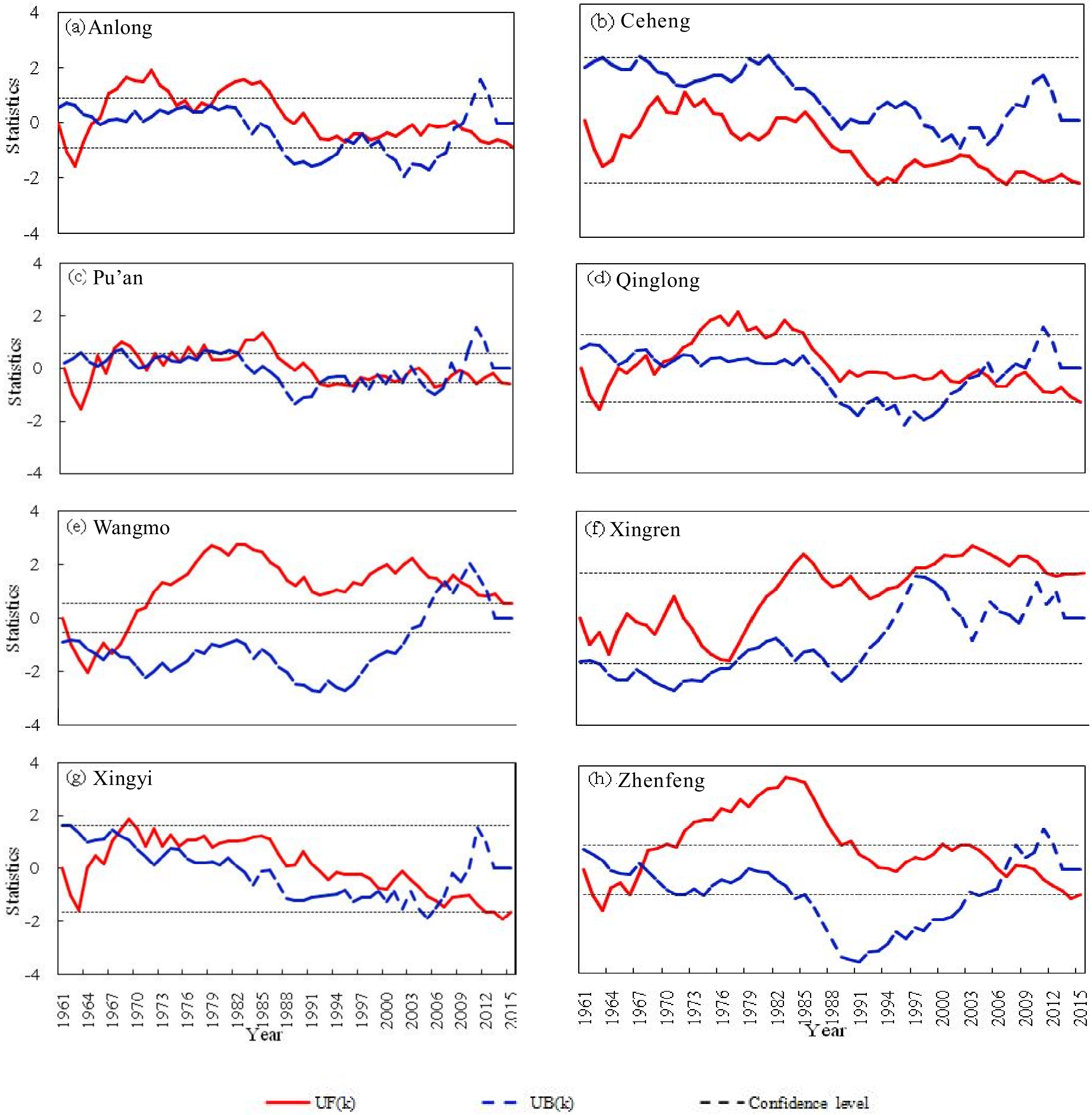

Fig 1: Abrupt change of precipitation by MK in spring of SGAP

$$Var(S_k) = \frac{n(n-1)(2n+5)}{72} \qquad (5)$$

Then, the UB_k is calculated by repeating the above process in the order $X_n, X_{n-1}, \ldots, X_3, X_2, X_1$ of the time series which makes $UB_k = UF_k$ ($UB_1 = 0$, $k = n, n-1, \ldots, 3, 2, 1$). The significance level is $p = 0.05$ in this study.

RESULTS AND DISCUSSION

Temporal variation of precipitation

The annual precipitation variation by the accumulated anomaly, 5-year moving averages and the linear trend is shown in Table 1. From the aspect of interannual variation, the annual precipitation over the SGAP varied between 980.7 mm at Xingren to 1508.2 mm at Qinglong. The annual

Table 3: Years of increasing / decreasing trend and abrupt change of precipitation (1961-2015).

Station	Increasing trend	Decreasing trend	Intersections	Abrupt changes piont
Anlong	1965-1991 and 2007-2008	1961-1965, 1991-2007 and 2008-2015	6	1965, 1977, 1979, 1995, 1997 and 2008
Ceheng	1967-1977 and 1982-1986	1961-1967, 1977-1982 and 1986-2015	0	0
Pu'an	1964-1965, 1966-1970, 1971-1988 and 1989-1990	1961-1964, 1965-1966, 1970-1971, 1988-1989 and 1990-2015	20	1964-1965, 1967, 1970-1973, 1975, 1978, 1982,1991, 1995, 1998, 2000-2003 and 2007-2009
Qinglong	1966-1968 and 1969-1988	1961-1966, 1968-1969 and 1988-2015	2	1969 and 2004
Wangmo	1969-2015	1961-1969	8	1961, 1965, 1966, 1967, 2006, 2007, 2008 and 2012
Xingren	1965-1966, 1970-1972 and 1979-2015	1961-1965, 1966-1970 and1972-1979	0	0
Xingyi	1964-1991	1961-1964 and 1991-2015	2	1967 and 2006
Zhenfeng	1967-2006 and 2007-2010	1961-1967, 2006-2007 and 2010-2015	2	1967 and 2006

precipitation showed an increasing trend at Wangmo and Xingren stations at the rate of 8.3 and 20.3 mm year^{-1} respectively (Table 1),while the decreasing trends were observed at Anlong, Ceheng, Pu'an, Qinglong, Xingyi and Zhenfeng stations, at the rate of-2.4, -1.9, -3.7, -3.8, -1.8 and -1.8 mm year^{-1} respectively (Table 1).

The positive anomaly was highest (92.7%) at Pu'an and Qinglong with accumulated anomaly of 1957.6 and 1962.2 mm respectively followed by Anlong (83.6%) with accumulated anomaly of 1414.2 mm and Ceheng (80%) with accumulated anomaly of 1502.4 mm (Table 2). There was not a single year of positive anomaly at Xingren, while the lowest positive accumulated anomaly of 99.8 mm was observed at Wangmo in 5 years, having 50 years of negative anomaly with accumulated anomaly of -4323.9 mm. The highest accumulated negative anomaly of -10629.6 was observed at Xingren. It may be noted that the year of largest positive anomaly were different at different stations, while the shortest negative anomaly were commonly observed in 1964, 1981 and 2013 (Tabel 2). This indicated that heavy rains may be localised phenomena while droughts may be occurring over larger regions.

Mann-Kendall trend test and abrupt change test

The abrupt change of precipitation during spring season in SGAP (1961-2015) is shown in Table 3. The UF(k) curves in each region all exceeded the critical value, which indicated that the precipitation has obvious changes in each region with a significant increasing or decreasing trend. What's more, the UF(k) and UB(k) curves in each region had intersections at all stations, except Ceheng and Xingren, which indicated that the precipitation has seen an abrupt change in the six regions (Fig. 1).

Pu'an station had highest (20) intersections, indicating that the precipitation over Pu'an was highly fluctuating over the years, as a result abrupt changes occurred on 20 occasions. On the other hand Qinglong, Xingren and Zhenfeng had two intersections each, the abrupt changes occurred in 1967 and 2006 at Xingyi and Zhenfeng . While at Qinglong it occurred in 1969 and 2004 (Table 3). The significant increasing and decreasing trends shown in Fig.1 depicts the temporal processes of the statistics UF(k) and UB(k) curves obtained from the Mann-Kendall test for sub-regions at the confidence interval of 90 per cent. The UF(k) curves in each region exceed the critical value, the precipitation has obvious changes in each region and has a significant increasing or decreasing trend. The result is also consistent with Mo *et al.*(2012),they found that there was and ecrease of precipitation in the region from 1958-2010.Li nad yang (2013) also reported that the precipitation in SGAP has many time-scale characteristics, the 30a time-scale periodic oscillation was obvious.

CONCLUSIONS

It can be concluded that the annual precipitation showed an increasing trend at Wangmo and Xingren stations and a decreasing trend at Anlong, Ceheng, Pu'an, Qinglong, Xingyiand Zhenfeng stations.The UF(k) and UB(k) curves of each region have intersections, except Ceheng and Xingren, and this indicated that the precipitation has seen a abrupt change in six regions. The analysis have elucidated the variability and trend of annual precipitation and the abrupt changes of spring precipitation, which will provide theoretical guidance for agricultural water management in Southwest Guizhou Autonomous Prefecture of China.

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