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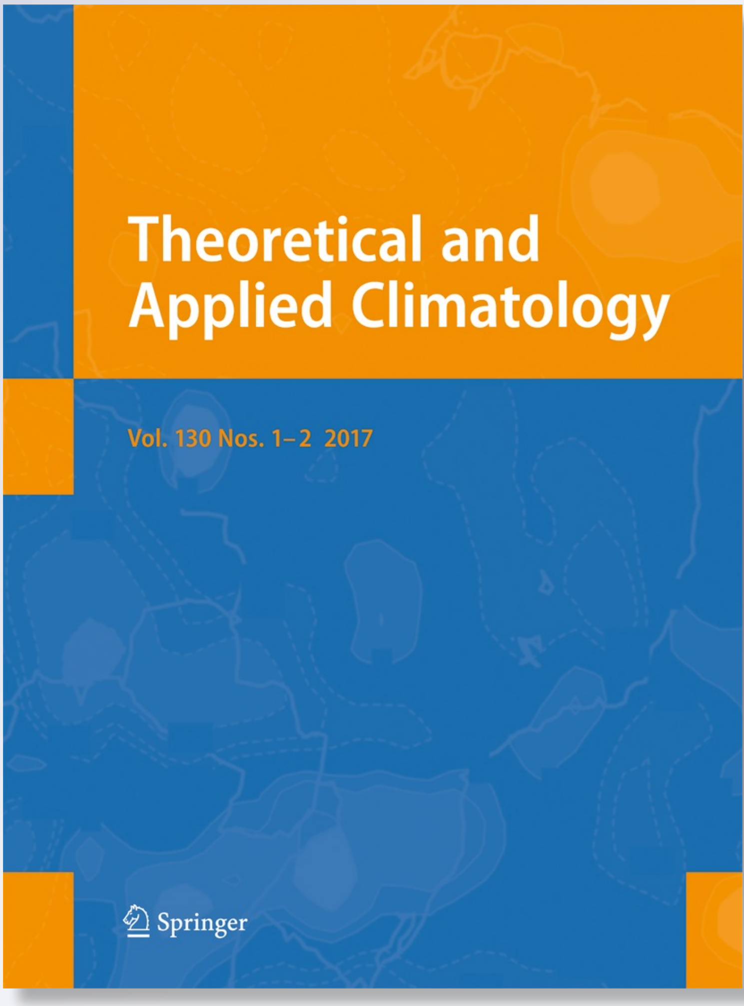

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ORIGINAL PAPER

Out-phased decadal precipitation regime shift in China and the United States

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Abstract In order to understand the changes in precipitation variability associated with the climate shift around mid-1970s, the precipitation regime changes have been analyzed over both China and the USA. Specifically, a new variable is designed based on Benford's Law (BL) to detect precipitation regime shift by using only the first digit information of the datasets. This new variable describes the decadal precipitation regime shift more directly and clearly than the traditional variables, such mean or trend of yearly precipitation amount. It is found that there is an obvious out-phased relation for precipitation regime shift over China and the USA, i.e., a significant shift from the lower to the higher BL's goodness of fit (weaker to stronger precipitation intensity) in the Southern China occurred in 1979, and a significant shift from the higher to the lower BL's goodness of fit (stronger to weaker precipitation intensity) in the USA occurred around 1978.

1 Introduction

Observation studies have shown that the decadal and interdecadal variability plays an important role in global climate system. It has been observed that the climate experienced a significant interdecadal shift in mid-1970s, such as atmosphere circulation and ocean temperature in the Pacific Ocean (Lee et al., 2012; Guilderson & Schrag, 1998). The climate shift, which is one of the most important and mysterious events in climate history, involves many regions of the world (Graham, 1994). Monitoring of Southern Oscillation Index (SOI) has shown that El Niño-Southern Oscillation (ENSO) underwent a regime transition in the late 1970s (Power & Smith, 2007). The Pacific Decadal Oscillation (PDO) index shifted from dominantly negative values to dominantly positive values in 1976. In 1976, the North Pacific region, including much of North America, saw great increases in winter and spring temperatures (Hartmann & Wendler, 2005).The Asian summer monsoon, which plays a major role in weather system in East Asia, experienced a weakening trend in the late 1970s (Huang et al., 1999; Ding et al., 2008).

Against the background of climate shift in many regions around the world, precipitation regime shift has been detected in the late 1970s in China. Some studies have shown that there is an increasing trend in summer precipitation covering central China and the Korean peninsula and a decreasing trend covering Northern China after the 1970s' climate shift (Huang et al., 1999; Ding et al., 2008). The "Southern Flood-Northern Drought" pattern was raised since then. It has been proposed that the transition point of increasing summer precipitation in lower Yangtze River is closely around 1979 (Qian & Qin, 2008). In winter, precipitation decreases significantly in the area of Northern part of Eastern China and increases in the Southern parts (Zhai et al., 2005).

Apart from China, precipitation in USA experienced some changes as well in late 1970s (Hartmann & Wendler, 2005; Sellars et al., 2015). China and the USA are two of the largest countries, located across the Pacific Ocean. The climate features of the two countries are different due to the differences in geographic features and land-sea thermal contrast. Previous studies have demonstrated a tele-connection pattern exists between China and the USA, especially in the aspect of hydroclimate. Some studies showed correlation in the field of total and extreme precipitation and atmospheric tele-connection pattern linking these two countries (Wang et al., 2014; Lau

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& Weng, 2002). However, few people studied interdecadal precipitation variability in terms of precipitation intensity and compared it with China in details, and the precipitation regime shift in the late 1970s over the USA has not caused a great discussion, either.

In recent years, some new methods on abrupt climate change detection have been proposed. For example, He et al.(He et al., 2015; He et al., 2012; Jin et al., 2016) proposed three new methods to detect abrupt dynamic change. These new methods are based on moving cut data-rescaled range analysis, moving cut data-DFA (MC-DFA), and moving cut data-approximate entropy (MC-ApEn). Feng and his coauthors (Feng et al., 2005) applied heuristic segmentation algorithm to detect the abrupt changes of nonlinear time series which fits the climate system well. Still, more related methods can see more reviewed and cited references in their papers.

So, the motivation of our work is to study the precipitation regime shift on the aspect of precipitation intensity and try to find the out-phased shift happening in late 1970s between China and the USA. Meanwhile, in order to present the decadal shift directly and clearly, a ***new variable*** based on Benford's Law (BL) which only uses the first digit information to accomplish shift detection is introduced here (see section 2 for details). For the first time, we applied BL to the precipitation data sets, and found that the information related to the first digit distribution is enough to detect precipitation regime shift. The precipitation regime shift in the Southern and central Eastern China and the whole USA in the late 1970s can be detected using the BL's goodness of fit more easily than applying traditional variables. The shift happening in each season is analyzed as well. Seasonality is accounted for four non-overlapping seasons [Winter: December–February (DJF), Spring: March–May (MAM), Summer: June–August (JJA), Autumn: September–November (SON)]. We found the precipitation shifts occurring in China and the USA in the late 1970s are linked to each other and exhibit opposite phase.

2 Data and methods

2.1 Data

In our study, we have studied daily precipitation records from 550 rain gauge stations all over China. The locations are displayed in Fig. 1 (filled dot). In order to analyze subregional features, we refer to Guo et al. (Guo et al., 2007) and divide the whole nation into six sub-regions (from region a to region f), and the basis of the dividing China into six domains is the annual total precipitation amount and clustering analysis, see Fig. 1. The precipitation dataset was provided by the National Climate Center (NCC) of the China Meteorological Administration (CMA). The 550 original time series cover a period from 1961 to 2005. We also studied USA's daily unified grid precipitation datasets from the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center (CPC), covering the year from 1948 to 2005. The USA dataset is of 0.25 * 0.25 spatial resolution. There are no missing data in the dataset considered in the study. Similarly, we divided the USA into two domains, the western USA and eastern USA, and the dividing line is along 90° W which is in line with the longitude of The Mississippi River. Actually, similar divisions have been adopted widely in the literature (e.g., Findell et al. 2011).

2.2 Benford law and new variable for precipitation regime shift detection

In 1881, Simon Newcomb found that the initial pages of the logarithmic tables were more worn out than the latter ones. It was obvious that people looked more often for numbers with smaller non-zero first digits than larger ones, which in turn revealed the fact that the first digit distribution is not uniform in nature but shows higher probability for the smaller digits. In 1938, Frank Albert Benford investigated some 20 tables of 20,229 numbers ranging from the area of lakes and the length of rivers to the weights of molecules and atoms. He published a paper entitled "The Law of Anomalous Numbers" (Benford, 1938) and drew the conclusion that the first digit probability distribution is

$$P_D = \log\left[(D+1)\middle/D\right] \tag{1}$$

in many data sets, where $D = 1; \ldots 9$ is the first digit. For example, the numbers 123.0 and 0.015 both have $D = 1$. According to Eq.(1), numbers beginning with the first digit 1, occurs almost 30.1 %, while numbers beginning with the first digit 2, occurs 17.6 %, and so on down to first digit of 9 which appears less than 5 %. Since then the law was noticed by the scientific community and was called in the name of Benford.

Increasing number of data sets from different sources have been tested to conform with this law: the area of lakes, the length of rivers, the molecular weights of molecular compounds (Benford, 1938), some pulsar quantities (Shao & Ma, 2010), decay width of hadrons (Shao & Ma, 2009), and so on. Although many tables of data follow the logarithmic distribution of first digits, there are likewise many examples that do not (Ausloos et al., 2015; Bormashenko et al., 2016). Despite a strict explanation is still lacking, the law has been widely utilized. The law is used to detect fraud in election (Mebane, 2004), to ascertain frauds in taxing and accounting (Nigrini, 1996), to examine earthquake records in seismology (Sambridge et al., 2010), to study the country-wise adherent distribution of major world religions (Mir, 2012), to

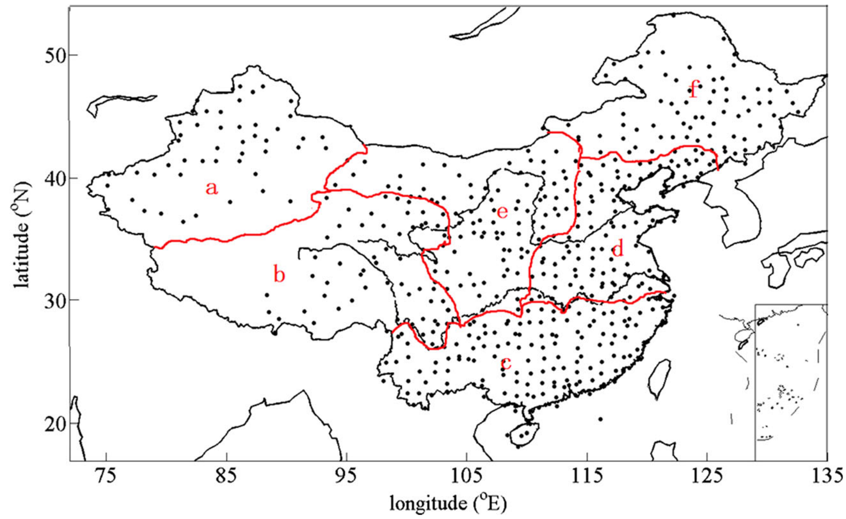


Fig. 1 The location of the 550 rain stations over China and the sub-regions of China

detect quantum phase transitions (Sen & Sen, 2011), to distinguish noise from chaos (Li et al., 2015), to quantify non-stationarity effects on organization of atmospheric turbulent eddy motion (Li & Fu, 2016), and so on. It has also been suggested that BL may provide a novel way of testing realism in mathematical models of physical processes (Hill, 1998).

A goodness of fit measure to BL was calculated as follows (Sambridge et al., 2010):

$$\phi = \left[1 - \left(\sum_{D=1}^{9} \frac{(n_D - nP_D)^2}{nP_D}\right)^{1/2}\right] \times 100 \tag{2}$$

where n_D is the number of observed data with first digit D, P_D is the proportion of data expected with first digit D from (1) and n is the total number of data. If $\phi \geq 90$, we say the dataset conform to BL well, and if $\phi = 100$, the result is completely Benford's distributed. The smaller the goodness of fit ϕ is, the worse the conformity with BL. Then, goodness of fit can be taken as an index for precipitation regime shift detection.

3 Results

3.1 Precipitation regime shift quantified by annual precipitation intensity anomalies

First of all, we use traditional variables (TV), which are mainly based on mean or trend of some variables during certain period, to show that precipitation regime shift exists in late 1970s across China. We define the annual precipitation intensity as the annual total precipitation amount divided by the number of annual total rainy days. Rainy days are defined as the days when daily precipitation amount is larger than 1 mm per day. Using the annual precipitation intensity, we can find there are precipitation regime shifts over the whole region and some specific regions of China.

Figure 2a displays the interdecadal variation of precipitation intensity anomalies in the whole nation. Two different precipitation regime patterns have been identified, from the beginning to the end of 1970s, the negative annual precipitation anomalies are dominated; however, since the ending of 1970s, they switched to the dominant positive annual precipitation intensity anomalies. Though the shift pattern which switches from negative anomaly to positive anomaly can be found in this traditional variable analysis, and the result is also consistent with previous studies, we can't determine the change point time directly. To determine the exact shift year, we must use some tests to further locate the transition point. Here, we employ moving T test to detect change point and find that the shift happened in the year of 1979. The 95 % confidence level is used to appraise the significance of shift point in our study. In other words, in the precipitation intensity field, the anomaly is negative during 1961–1979 and positive during 1980–2005.

In fact, for the precipitation intensity field, the conclusion found over the whole region does not hold over all of the specific regions. Figure 2b shows the sub-regional details in the four domains of China. After the change point detection, we found no significant shift existing in late 1970s in region a and region b (region e and region f show the similar features as region a and region b, for brevity detailed results have not been shown here). However, the region c and region d present a significant shift in 1979, which has passed statistical test at 95 % confidence level.

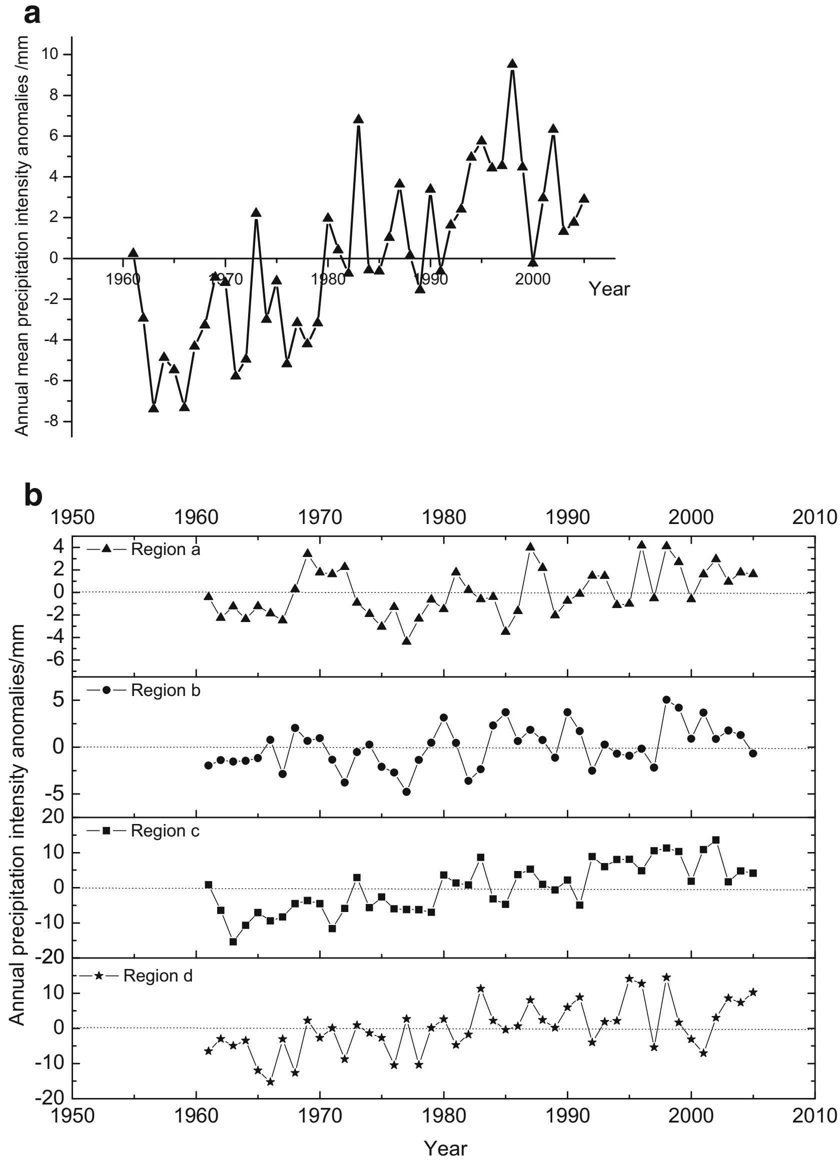
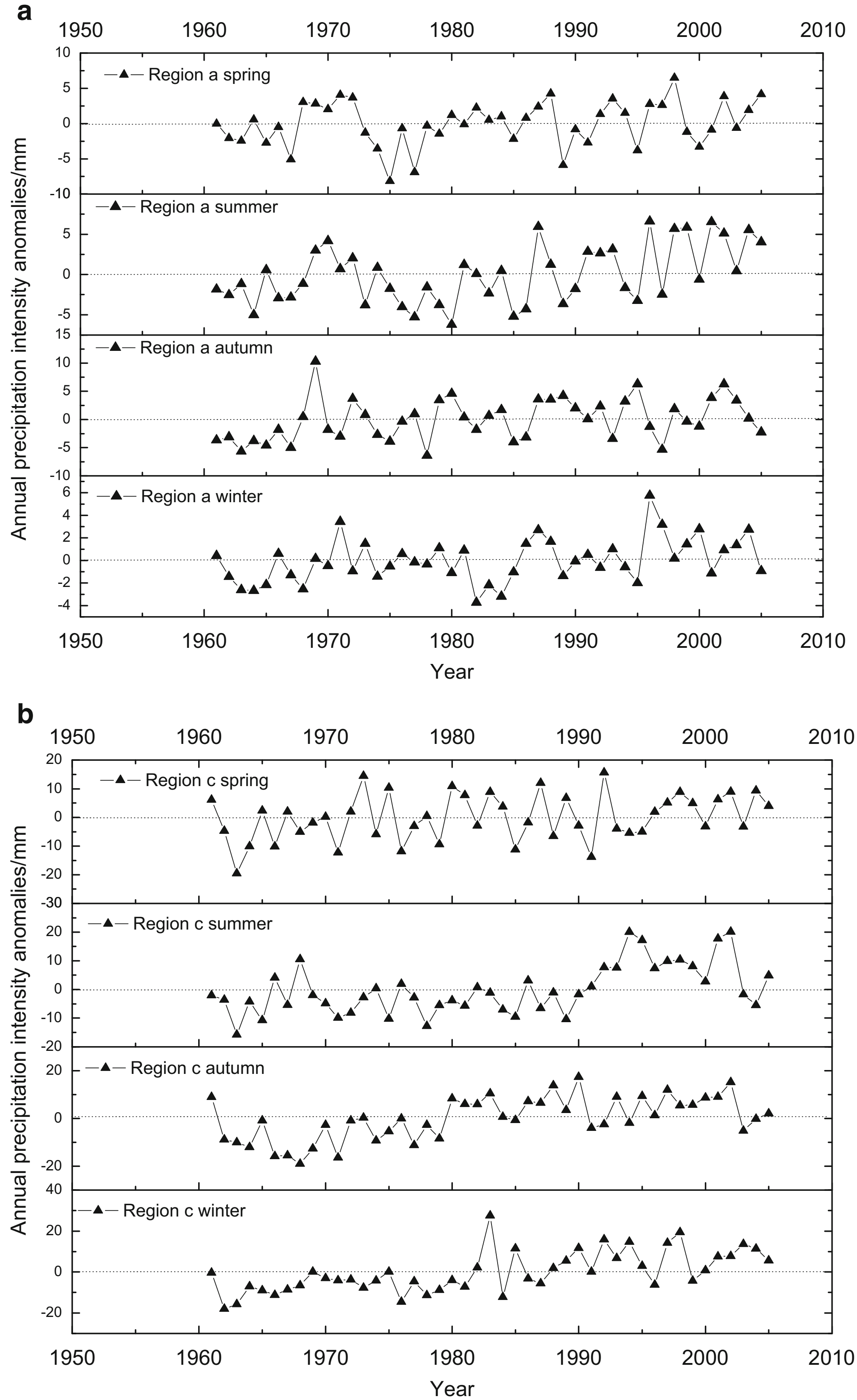


Fig. 2 Annual mean precipitation intensity anomalies over **a** whole nation and **b** sub-regions of China

Apart from the regional features, seasonality is another important factor which must be considered. In order to learn which season plays a more important contribution to the interdecadal variations, the analysis on seasonal variations is essential. We chose two typical regions to analyze seasonal contribution to interdecadal shift. Figure 3 shows the seasonal features of precipitation regime shift over region a and region c. In region a where no significant shift has been detected in interdecadal variation, there is also no significant shift in each season either. In region c, marked precipitation regime shift has been found. However, here, we can see that precipitation regime shift can not be detected in all seasons, and there are marked precipitation regime shifts only in autumn and winter; and the shift year of 1979 has significantly passed the test at 95 % confidence level. Therefore, the above results indicate that in the region a, no shift in each season leads to no shift in annual variation. In the region c, the marked shift happening in autumn and winter contributes greatly to the shift happening in late 1970s and the precipitation regime shift is closely linked with the detailed seasonal variations.

Previous studies have found there are close relations in hydro-climate changes over China and the USA. Does precipitation regime shift occur in the USA? We calculate the intensity anomalies across the USA from 1948 to 2005. More marked decadal regime shift can be discovered, see Fig. 4. It is obvious that the shift exists in both of the two parts, and the shift in the western USA is more clearly than the eastern USA, though there are much bigger fluctuations in the annual precipitation intensity variation in the eastern USA. After the change

Fig. 3 Seasonal variation of annual mean precipitation intensity anomalies over **a** region a of China and **b** region c of China



point detection, the shift year is determined as 1978 in the western USA and 1979 in the eastern USA, which have passed the 95 % confidence level. This illustrates that the precipitation regime shift is not only a nationwide phenomenon, but also a local change in the USA, which is different from what has been found in China.

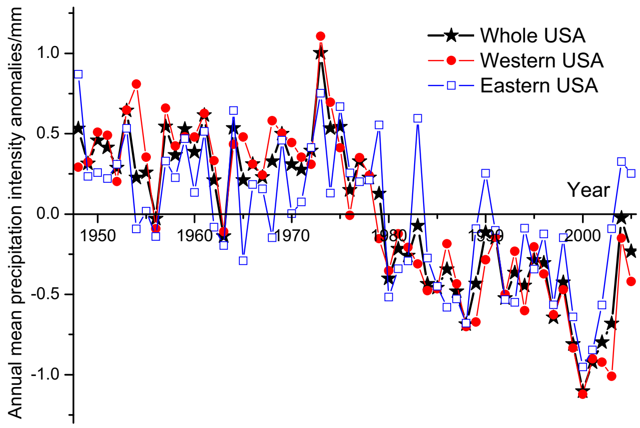


Fig. 4 Annual mean precipitation intensity anomalies over the USA

3.2 Precipitation regime shift using goodness of fit to Benford's law

Although the precipitation regime shift pattern and shift year can be detected by means of precipitation intensity anomalies, the shift year can not be identified directly at the first sight. A change-point test is required which is complicated and inaccurate sometimes. In this case, a new variable based on BL which presents the shift pattern and shift year more directly and clearly is introduced here.

For comparison, for all the 550 precipitation stations in China, we first use the daily precipitation amount series to calculate the first digit distribution of the dataset for each year and derive yearly value for the goodness of fit ϕ. Figure 5a shows us the annual variation of goodness of fit from the precipitation variation over 550 China stations to the BL. It is obvious that there are two states before and after 1979. Before 1979, the mean goodness of fit is about 87 %, afterwards, the mean goodness is about 92 %. Here, it can be easily found that it is the year of 1979 that the precipitation regime shift happens. We have found that the higher goodness of fit corresponds to positive precipitation intensity anomalies, while the lower goodness of fit corresponds to negative precipitation intensity anomalies. Obviously, BL displays precipitation regime shift more clearly and directly. Even though the shift year can be easily identified, we still need a more rigorous statistical significant test to confirm our eye-observed result. For the annual variation of goodness of fit ϕ, moving T test is applied to determine the transition point. The fact that 1979 is the changing point, derived from BL, exceeds 99.5 % significant confidence level, which is higher than those for the precipitation intensity anomalies.

The BL's goodness of fit presents well not only across the whole China, it can also work well at a regional spatial scale. Figure 5b displays BL's goodness of fit features for precipitation series from stations over four domains of China. In the region a, the goodness of fit is around 86 % and keeps oscillating around just one state especially after the year of 1970.

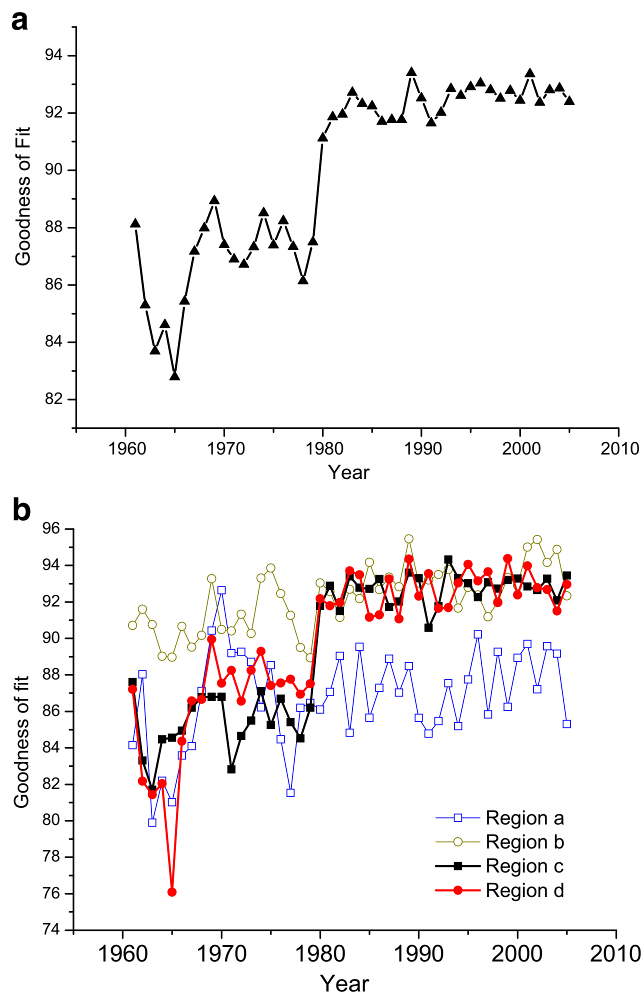


Fig. 5 BL's Goodness of fit over **a** whole nation and **b** sub-regions of China

So, there is no precipitation regime shift over this local region. In the region b, in spite of the fact that the goodness of fit presents a rising trend, no shift can be found during whole period. While in the region c and region d, there are two marked states for the goodness of fit, and a distinct abrupt jump from one state to the other state has been found. So, there are precipitation regime shifts over these two local regions. The goodness of fit rises around from 85 to 92 % and 87 to 92 % in 1979, respectively. The shift year is determined as 1979, which exceeds 99.5 % significant confidence level.

Therefore, we have a reason to believe that the BL's goodness of fit can be used as a new variable to detect precipitation regime which presents the shift more directly and clearly. We can get the exact shift year at the first sight which passes statistical test at a higher confidence level, and the shift pattern is obvious and accurately determined compared to traditional variables used to detect the decadal precipitation regime shift. Another advantage of the BL's goodness of fit is that the shift year determined by this variable is insensitive to the number of the sliding points chosen in moving T test, while it may not in the traditional variable, such as the annual precipitation intensity anomalies, see Fig. 6. Due to this fact, we choose the number of the sliding points as 5 for all moving T test in this paper.

Next, we will present the seasonal contributions to the BL goodness of fit. Similarly, we show the results from two contrasted typical regions. In the region a, no significant change point has been found in late 1970s for each season (Fig. 7a), just the same as the previous conclusion given by TV (Fig. 3a). In the region c, we find a shift in goodness of fit exist in autumn and winter. In autumn, the goodness of fit is about 82 % during 1961–1980 and 92 % during 1983–2005. The winter shift is more marked and there are two distinct states, and the goodness of fit switches from 77 to 92 % in 1980 (Fig. 7b). The precipitation regime shift can be identified easily and directly in autumn and winter. BL's goodness of fit can present the shift very well, even under the condition of less rainy seasons. From these results, we can make a conclusion that autumn and winter precipitation plays a more important role on the interdecadal variation in the region c.

For the USA, we can see that there is a definitely determined precipitation regime shift, and the goodness of fit oscillates within a much narrower ranges around two different states before and after shift point; and it decreases from 98.2 to 96.7 % in 1978. Even though it decreases only 1 %, it is definitely determined as a shift between two states at the first sight (Fig. 8), which has passed the 99 % confidence level. While with the precipitation intensity anomaly calculation, the change point can only be determined with the help of further statistical test. Almost the same shift year has been detected using the two distinct methods; so, we conclude that our method is suitable not only in China, but also in the USA.

Figure 8 also shows the results over the western and eastern USA. Goodness of fit all oscillates around different states before and after shift happening, and it decreases from 97.3 to 96.5 % and 98.9 to 97.1 % in the western USA and eastern USA from 1978 to 1979. In spite of the fact that goodness of fit decreases a bit more in the eastern USA than the western USA, the precipitation intensity anomaly shift happened in the

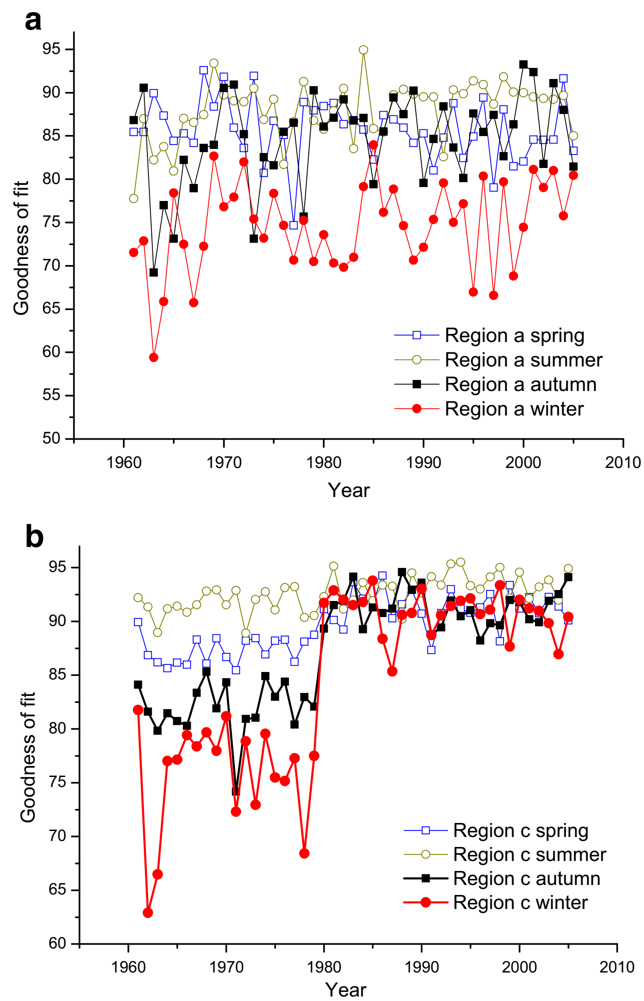


Fig. 7 Seasonal variations of goodness of fit over **a** region a of China and **b** region c of China

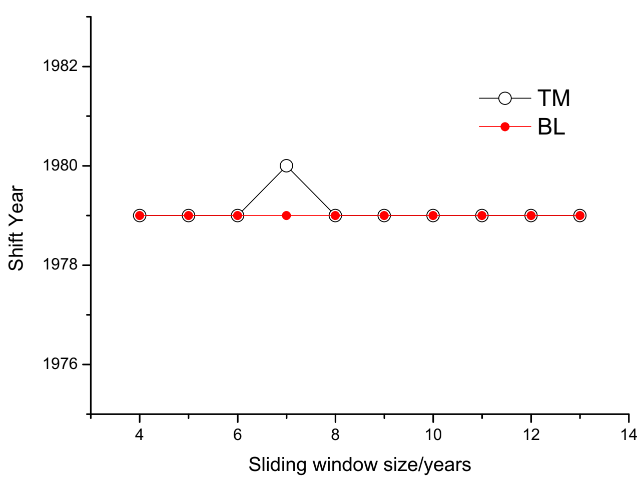


Fig. 6 Shift year vs. sliding window size in moving T test for annual mean precipitation intensity anomalies and BL's Goodness of fit over China

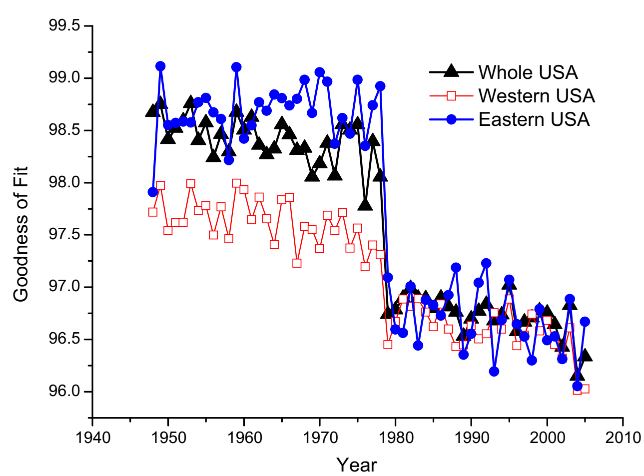


Fig. 8 BL's Goodness of fit over the USA

western USA is much more obvious than the western USA in 1978 (Fig. 4). Both the shifts have passed moving *T* test at 99 % confidence level successfully. In other words, we can confirm the transition year by both method but different shift patterns will be presented by TV and BL.

At last, we compare results from the traditional and the new variable based on BL in both China and the USA and come to a conclusion that all of precipitation regime shifts detected from TV can be easily detected by BL as well. Moreover, the shift year presented from BL can be easily identified at the first sight which holds at a higher significant confidence level. Without complicated calculation and further statistical test, the new variable presents the shift pattern and shift year more directly and clearly.

3.3 Out-phased precipitation regime shift across China and the USA

The results presented in previous two sections indicate that there are out-phased decadal precipitation variations over China and the USA.

Table 1 Correlation coefficient of precipitation variation between China and the USA from BL and TV calculations

	All year	Spring	Summer	Autumn	Winter
BL	−0.8910	−0.7114	−0.7267	−0.7857	−0.6656
TV	−0.5334	−0.0128	−0.5462	−0.4173	−0.2374

Especially, the annual precipitation intensity anomalies before and after the shift point are different over China and the USA. There is a significant shift from the negative precipitation intensity anomalies to the positive precipitation intensity anomalies over China in 1979. However, a significant shift from the positive precipitation intensity anomalies to the negative precipitation intensity anomalies occurred in the USA around 1979, see Fig. 9a. Although there are still some much bigger annual fluctuations, the out-phased decadal regime shift can be determined between China and the USA.

In fact, the out-phased decadal precipitation regime shift between China and the USA can be presented more directly and clearly with the help of BL calculations, see Fig. 9b, where two marked states exist in BL goodness of fit in

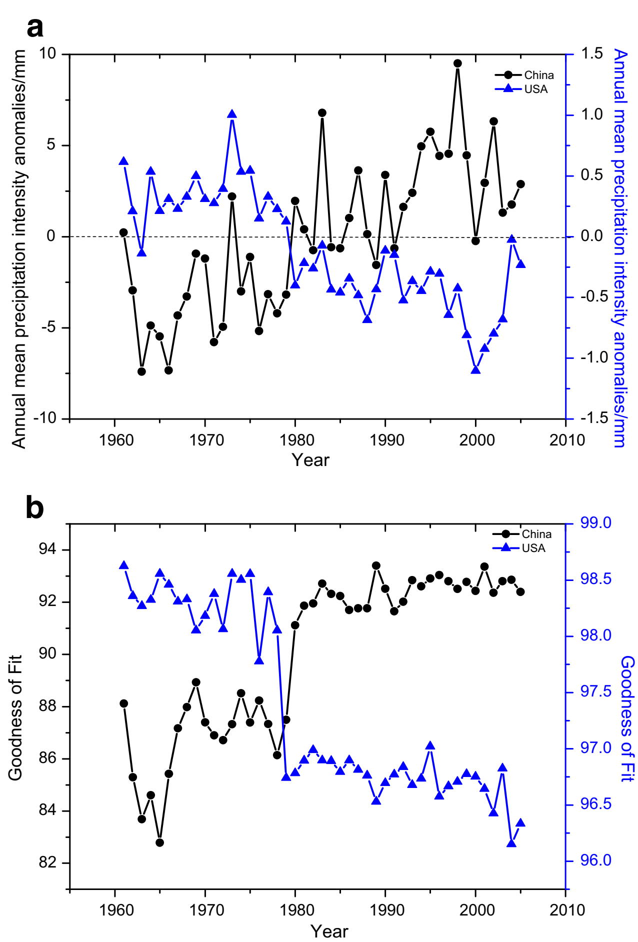


Fig. 9 Out-phased precipitation shift presented by **a** TV and **b** BL measures between China and the USA

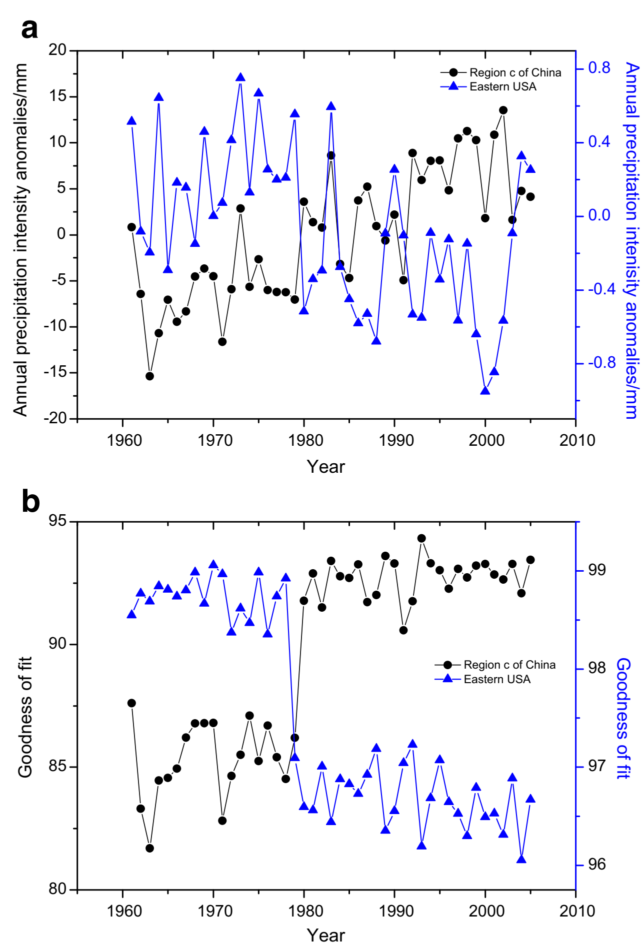


Fig. 10 Out-phased precipitation shift presented by **a** TV and **b** BL measures between specific typical regions over China and the USA

Table 2 Correlation coefficient of precipitation variation between region c of China and the Eastern USA from BL and TV calculations

	All year	Spring	Summer	Autumn	Winter
BL	−0.9322	−0.5941	−0.2678	−0.6784	−0.5675
TV	−0.5572	−0.1099	−0.4927	−0.0935	−0.2742

precipitation variations over China and the USA; and there is a significant shift from the lower value state to the higher value state over China in 1979. However, a significant shift from the higher value state to the lower value state occurred in the USA around 1979. At the same time, we can see that the transition from one state to the other state is abrupt and marked.

In order to determine quantitatively which method exhibits the out-phased regime shift between China and the USA more apparent, the correlation coefficient is calculated. The results of all year and four seasons are displayed in Table 1. The correlation coefficient calculated using BL (−0.8910) is larger than TV (−0.5334). This indicates BL can present the out-phased pattern better, and this feature can be recovered in the seasonal variations of precipitation intensity. Especially in spring season, the correlation coefficient derived from BL is at least an order of magnitude greater than that from the traditional variable.

The out-phased behaviors in precipitation regime shift over China and the USA exist not only in the area of whole nation, but also in some specific sub-regions. The localized correlation of this kind of out-phased behaviors in precipitation regime shift over China and the USA can be even more significant. For example, Fig. 10a and b present the out-phased behaviors in precipitation regime shift over region c in China and the eastern USA. From the BL result, the out-phased behaviors in precipitation regime shift are even more marked. Table 2 summarizes the correlation coefficient between region c in China and the Eastern USA from two methods. The correlation coefficient of all years from BL (−0.9272) is much close to −1. The out-phased decadal shift behavior between China and the USA is doubtless.

4 Discussions and conclusions

To understand why the first digit information can be used as a tool for regime shift detection is of great importance. Many scientists in different fields have tried to explain the underlying reason of Benford's law, but a successful explanation of BL has remained elusive (Berger & Hill, 2011). Among them was Feller, who gives a simple explanation that large spread for a random variable x to be likely Benford's distributed (Feller, 1957). While Hill has theoretically demonstrated that large spread (or large spread on a logarithmic scale) does not imply that a random variable was approximately Benford's distribution, for any reasonable definition of "spread" or measure of dispersion (Berger & Hill, 2010). Although many aspects of BL now have been discussed, there is no satisfying approach that simultaneously explains its presence in dynamical systems, number theory, statistics, and real-world data. In that sense, most experts seem to agree with Fewster (Fewster, 2009) that the ubiquity of BL, especially in real-life data, remains mysterious.

A question that "What types of distribution can follow Benford's Law well?" is raised then. Formann tested seven types of common distributions such as uniform distribution, exponential distribution to find the interrelation of BL and the distribution of the variable. The result shows that long right-tailed distribution of a random variable is much easily compatible with BL (Formann, 2010). It is no wonder that precipitation time series conform to BL so well, since the precipitation time series admits a typical long-tailed distribution.

The second issue related the results shown in this article is why there are different BL conformations for the positive and the negative precipitation intensity variations, and BL's goodness of fit can be used to detect precipitation regime shift. Sambridge et al. suggested that BL will be a natural feature of data sets with sufficient dynamic range (Sambridge et al., 2010). We may assume that a wider dynamic range corresponds to a higher goodness of fit. Set precipitation dataset from the 550 precipitation stations over China is an example; the highest positive anomaly (HPA) is 9.5128 and the lowest positive anomaly (LPA) is 0.132, while the highest negative anomaly (HNA) is 7.3982 and the lowest negative anomaly (LNA) is 0.934. After calculation, the dynamic range of the positive anomaly (DRPA) is about 72.07; while the dynamic range of the negative anomaly (DRNA) is about 7.921. The DRPA is about ten times larger than DRNA. Table 3 shows the dynamic range of precipitation anomalies over sub-regions of China and the USA.

Our results show that in most sub-regions, the DRPA is much larger than DRNA. It supports that dataset which

Table 3 Dynamic range of precipitation anomalies

	HPA	LPA	HNA	LNA	DRPA	DRNA
Region a of China	4.1706	0.2038	−4.3756	−0.4276	20.4642	10.2329
Region c of China	13.5461	0.7771	−15.3723	−2.6669	17.4316	5.7641
Western USA	1.1071	0.2019	−1.1218	−0.1235	5.483	9.0834
Eastern USA	0.8701	0.0028	−0.9519	−0.0915	310.750	10.403

contains a wider and sufficient dynamic range is more easily to conform to BL and gets a higher goodness of fit. Therefore, the higher goodness of fit to BL corresponds to the positive anomaly, and the lower goodness of fit corresponds to the negative anomaly. Just because of this fact, BL can be used to detect precipitation regime shift. Meanwhile, the dynamic ranges from region c in China and the Eastern USA are much larger than other sub-regions and they are the two places where shifts present more clearly. It indicates that a bigger difference in dynamic range means a bigger jump in goodness of fit that the shift shows more directly and clearly.

The third issue is why there is out-phased decadal precipitation pattern and shift. Lots of studies are trying to give an explanation about the out-phased precipitation pattern. For example, Zhao has found that the inter-decadal hydro-climate between Asia and the North America are bridged by the Asian-Pacific Oscillation (APO)-related circulations from Eastern Asia to central North Pacific Ocean in the upper troposphere (Zhao et al., 2007; Zhao et al., 2011). The APO-related circulations often result in out-phase hydro-climate changes over China and the USA, and this is closely linked to the inter-decadal teleconnections (Fang et al., 2015; Mao et al., 2011). When the APO was high, tropospheric temperature was higher over Asia and lower over the North America. If this happens, upper-tropospheric high and lower-tropospheric low pressure systems strengthen over Asian and weaken over the North America, meaning stronger moisture transport over Asia. So, precipitation generally enhanced over China and decreased over the USA (Zhao et al., 2011).

In summary, we focus on the precipitation regime shift of China and the USA in late 1970s and use two kinds of variables to detect the shift patterns and shift year. Through the traditional variable, we can't determine the shift year at the first sight and the shift pattern is not clear enough. On this occasion, we introduce a new variable based on BL to help us detect the shift more explicitly. BL offers us a faster and clearer way to detect the transition year using just only the first digit information, where the precipitation regime shift reflects more directly and clearly, and a statistical change point test is not required as well. It fits well not only in geographical divisions but also in seasonal divisions. Using the goodness of fit to precipitation variations instead of precipitation intensity anomaly, the out-phased decadal variation between China and the USA presents better embodiment in both the whole year and four seasons. These results may be used as a new tool for prediction as well. After calculating the annual goodness of fit to precipitation time series directly, the time when the goodness jumped to a higher value state or a lower value state is the transition year. When the goodness jumped higher, it means a stronger rain intensity period has come.

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