Analysis on Periodic Change of Small Pan Evaporation in Xinjiang

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Abstract: This paper selects ten national reference climatologic stations and two national basic stations in Xinjiang, respectively Urumqi Station, Turpan Station, Qitai Station, Usu Station, Altay Station, Ili Station, Hami Station, Khotan Station, Minfeng Station, Aksu Station, Ruoqiang Station and Yanqi Station. According to the surface observation data of the stations during 1961-2019, complete $E_{20}$ sequence for the period 1961-2019 is acquired. This paper analyzes spectral characteristics and periodic changes of annual $E_{20}$ in each station. Results show: (1) The complete daily $E_{20}$ sequence during 1961-2019 after run-in in 12 stations experiences typical changes on a yearly basis, and at present, the entire Xinjiang enters a new high evaporation period; (2) The main period of annual $E_{20}$ in the 12 stations shows 23~32a periodic oscillation, and the evaporation level in each station is the most active on that dimension; secondly, Yanqi Station, Aksu Station, Khotan Station, Minfeng Station and Hami Station have obvious and universal periodic oscillation on the longer scale of 14~22a; Altay Station, Usu Station, Qitai Station, Urumqi Station and Ruoqiang Station show obvious periodic oscillation on the scale of 10a; this study sufficiently confirms the larger periodic change trend of evaporation sequence in Xinjiang during 1961-2019.

1. Introduction

Pan evaporation is an important index of atmospheric evaporation capacity used to estimate land evaporation, hydrologic cycle and crop water requirement [1]. The pan evaporation may be acquired by different ways, such as establishing estimate model based on meteorological observation data [2-3] or observing with instruments [4]. Domestic and overseas scholars made analysis on pan evaporation and acquired many outputs for reference. For instance, LINACRE [5] established PENPAN physical model to estimate pan evaporation; ROTSTAYN et al. [6] integrated aerodynamic researches of LINACRE and THOM et al. [7] to establish PENPAN model. Based on PENPAN model, RODERICK et al. [2], JOHNSON and SHARMA [8] respectively proved the model was used successfully to estimate Type A pan evaporation in different stations in Australia. MALIK and KUMAR, based on artificial neural network and cooperative neural fuzzy inference system, adopted multiple linear regression (MLR) to simulate daily pan evaporation in certain place at the foot of the Himalayas in India [9]. ZHANG et al. compared pan evaporation in Qinghai-Tibet Plateau during 1966-2003, and by referring to the trend of
crop evapotranspiration and actual evaporation, found opposite change trend of pan evaporation and actual evaporation; the former is reducing while the latter is increasing, showing the evaporation paradox in Qinghai-Tibetan Plateau [10]. YANG [11] et al. analyzed inconsistence of solar radiation data in China caused by instrument change based on observation data of pan evaporation. MCMHON et al. [12] offered guidance to estimate daily and monthly actual evaporation, potential evapotranspiration, reference evapotranspiration and pan evaporation in three parts. Zeng Yan et al. [13] analyzed 20cm diameter (Φ20 cm) pan data in 664 metrological stations in China during 1960-2000, and found pan evaporation in China showing obvious reduction trend. They believed the total solar radiation is reduced due to smaller percentage of sunshine. Qi Tianyao et al. [14], through analysis on pan evaporation in China during 1960-2005, believed relative humidity is the key factor affecting changes of pan evaporation in China. However, Liu Min et al. [15] carried out trend analysis based on monthly observation data of Φ20 cm pan evaporation and meteorological elements in 671 meteorological stations in China, and results show the reduction of daily temperature range and average wind velocity is the influencing factor for lower pan evaporation. Other scholars studied pan evaporation in upstream of Yangtze River [16], Yellow River catchment [17], Huaihe River catchment [18], Dongjiang River catchment [19], Lancang River catchment [20], Qinghai Lake catchment [21] and Shiyang River catchment [22].

2. Data and methods
2.1 Meteorological station distribution and data period

The commonly used pan evaporation observation instrument in foreign countries is Type A pan, while scholars in China once used Φ20 cm, Φ80 cm and E601 pans successively in recent 60 years. This paper analyzed data in 12 metrological stations in Xinjiang with outstanding typical pan evaporation, long data sequence and continuous data. The longitude and latitude variation range of the stations are respectively 85.8~94.7° and 36.9~44.3°; altitude height variation range is 30~ 3095 m. The variation scope of perennial average temperature, wind speed, relative humidity and daylight hours in the research area are respectively 0.7~14.5 °C, 0.8~4.0 m/s, 39.4~67.4% and 7.1~9.1 h [24]. The geographical location and DEM of evaporation stations can be seen in Fig.1.
3. Results and analysis

3.1 Annual growth rate in each station

The annual change of E20 evaporation in each station is large, and shows a rising trend in recent 59a largely. The annual growth rate can be seen in Table 1. According to Table 1, the average annual growth rate in Xinjiang is 0.002%; the annual growth rate in 12 stations shows the annual-scale E20 in stations in South Xinjiang is obviously high, and growth rates are of little difference; it only shows reduction trend in Aksu Station; the growth rate in stations in North Xinjiang are uneven, and trends are obviously different; while in East Xinjiang, Turpan Station and Hami Station show the trend of reduction. The reduction trend is remarkable particularly in Turpan Station. The average growth rate in stations in South Xinjiang is 0.002%, in stations in North Xinjiang is 0.004% and in the two stations in East Xinjiang is 0.001%. This result almost overturns the former judgment that South Xinjiang has larger evaporation ability due to dry weather, large wind speed, low humidity, little precipitation, high temperature and sufficient sunlight. Meanwhile, the damaged exploration environment on observation site of Turpan Station in East Xinjiang affected the value of metrological elements measured for a long time from 2004, and particularly affected the irradiance a lot [26]. Thus, it also affected evaporation greatly (the station was relocated in 2015); although the sunlight is sufficient, and the weather is dry with little rain in Hami Station, the evaporation is affected to certain degree since effective wind speed isolation is formed by forests around the observation site; similarly, Aksu Station (relocated in 2016) in Tarim River catchment in South Xinjiang shows the trend of less evaporation in recent years as affected by detection environment, which is reasonable. Whereas the growth rate in stations in North Xinjiang is obviously larger than that in South Xinjiang, the growth rate in Yining Station, Usu Station and Urumqi Station is particularly remarkable. Through comparison of relevant data, the precipitation in the region is lowering, and accordingly the humidity is lower and average maximum temperature is higher; while in South Xinjiang, the precipitation is increasing obviously with higher humidity, and the sand wind weather is reducing greatly. Therefore, it is reasonable that the annual growth rate in South Xinjiang is smaller than that in North Xinjiang.

Table 1 Annual evaporation change trend in 12 stations (%)

| Growth rate/Station name | Atlay Station | Usu Station | Qitai Station | Yining Station | Urumqi Station | Hami Station | Turpan Station | Minfeng Station | Khotan Station | Ruoqiang Station | Yanqi Station | Aksu Station | Annual |
|--------------------------|--------------|-------------|---------------|----------------|----------------|--------------|----------------|----------------|----------------|----------------|-------------|-------------|--------|
| Annual rate              | 0.001        | 0.006       | 0.0001        | 0.008          | 0.003          | -0.0002      | -0.002         | 0.003          | 0.003          | 0.001           | 0.001       | -0.001     | 0.002  |

3.2 Periodic change characteristics in each station

Fig.2 is the Morlet wavelet transform coefficient graph of 10 national reference stations and two national basic stations of Urumqi Station and Turpan Station in Xinjiang after annual average evaporation sequence during 1961-2019 is standardized. The warm-toned area refers to the period with higher annual average evaporation while the cold-toned area refers to the period with lower evaporation. According to Fig.2, the yearly-based average evaporation in each station has periodic oscillation on different time scales, in which the periodic oscillation on the scale of 23~32a is universal, and the evaporation level of each station is the most active on the scale; the annual average evaporation experiences cycling alternation of high-low-high. In the meantime, it is obvious that at present Xinjiang has entered a new high evaporation period. Next, Yanqi Station, Aksu Station, Khotan Station, Minfeng Station and Hami Station show obvious and universal periodic oscillation on the longer scale of 14~22a; the evaporation in each station experienced five cycling alternations from high to low. Atlay Station, Usu Station, Qitai Station, Urumqi Station and Ruoqiang Station show obvious periodic oscillation on the scale of 10a; however, the oscillation center is gradually moving up to 17a with the increase of time scale. Moreover, Atlay Station, Usu Station, Qitai Station, Urumqi Station, Ruoqiang Station, Khotan Station, Minfeng Station and Hami Station experience different periodic changes on the shorter scale of 5~10a; however, the periodic change on that scale is excessively fast, and oscillation center is shifted frequently and split, i.e., the stability of periodic oscillation is weak. The analysis results also show that the potential evaporation in Xinjiang show main periodic change of 26~28a, and Hami Station and Turpan Station have secondary periodic
change of 15~17a; Yanqi Station and Aksu Station in South Xinjiang have 18~19a secondary periodic changes; moreover, the secondary cyclic change in aforesaid South and North Xinjiang is obvious, and prominent in the entire study and analysis.

Fig. 2 Annual-scale E20 wavelet graph in 12 reference stations and Urumqi Basic Station

Based on aforesaid analysis, Xinjiang has fully entered high evaporation period, and the high degrees are different. That is because meteorological elements are changing greatly in surface layer with change of height and other elements. In the same period, the influences of different heights and different element change valve on evaporation measured are different. The wind speed distribution plays the main role. The larger the wind speed is, the higher the evaporation will be. Moreover, different distributions of humidity, temperature, precipitation and daylight also affect evaporation greatly.
4. Conclusion

(1) The daily E20 sequence of 12 stations during 1961-2019 after run-in shows yearly-based typical changes. At present, the entire Xingjiang has entered a new high evaporation period.

(2) The main period of annual E20 in 12 stations is the periodic oscillation on the scale of 23–32a; moreover the evaporation level of each station on the scale is the most active; secondly, Yanqi Station, Aksu Station, Khotan Station, Minfeng Station and Hami Station show obvious and universal periodic oscillation on the longer scale of 14–22a, and Atlay Station, Usu Station, Qitai Station, Urumqi Station and Ruoqiang Station show obvious periodic oscillation on the scale of 10a;

(3) The annual change rate of the 12 stations sufficiently confirms the increasing trend of evaporation sequence periodic changes in Xinjiang during 1961-2019.

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