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# 1961 -2016 年新疆哈密参考作物蒸散量变化与成因分析

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**摘 要:** 5 1961 -2016 Penman-Monteith Mann-Kendall 56 -20.57 mm/10a 4 -65.94 mm/10a -32.77 mm/10a -11.94 mm/10a -4.99 mm/10a 12.79 mm/10a 20 80 2009 2003 1996 1986 56

**关键词:** Penman-Monteith Mann-Kendall
**中图分类号:**S161; X43 **文献标志码:**A

# Variation of reference crop evapotranspiration and climate influence factors in Hami of Xinjiang during 1961 -2016

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**Abstract** Based on the long-term climatic data from 5 typical weather stations in Hami Xinjiang during 1961 to 2016 several methods such as Penman-Monteith model trend analysis cumulative anomaly and Mann-Kendall test were used to analyze the characteristics of reference crop evapotranspiration $ET_0$ change and climate influence factors in Hami since the last 56 years. The results show that the average annual $ET_0$ in Hami showed a decreasing trend during the latest 56 years and the tendency rate was -20.57mm/10a. The annual $ET_0$ in Hami Chuomaohu Yiwu and Hongliuhe showed the decreasing trend and the tendency rates were -65.94 mm/10a

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– 32.77 mm/10a – 11.94 mm/10a – 4.99 mm/10a respectively. The annual $ET_0$ in Balikun showed an increasing trend and the increasing rates was – 12.79 mm/10a. The annual $ET_0$ in Hami is the largest in summer followed by spring and autumn and the least in winter. The annual $ET_0$ in Hami had changed abruptly since the 1980s but there were obvious differences among the meteorological stations. The mutation points of Hongliuhe Balikun Chuomaohu and Yiwu were 2009 2003 1996 and 1986 respectively. Correlation analysis showed that the annual $ET_0$ in Hami was mainly affected by wind speed relative humidity and precipitation decreased mean wind speed increased relative humidity and precipitation together led to a decrease trend in annual $ET_0$ over the past 56 years in Hami.

**Key words** reference crop evapotranspiration Penman-Monteith model influence factors Mann-Kendall test Hami City

20 IPCC AR5 1880 – 2012 0.85℃ 1951 – 2012 0.12℃/10a [1] 1960 – 2009 1.38℃ [2] 0.22℃/10a [3] Evapotranspiration $ET$ Evapotranspiration $ET_0$ [4] [5 – 7] [8 – 10] [11] [12] $ET_0$ [13] [14] [15 – 16] $ET_0$ $ET_0$ 40°52′ – 45°05′N 91°06′ – 96°23′E [17 – 18] 1961 – 2016 5 $ET_0$

# 1 材料与方法

## 1.1 数据来源

http //cdc. cma. gov 5 1 1961 1 2016 12 3 – 5 6 – 8 9 – 11 12 – 2

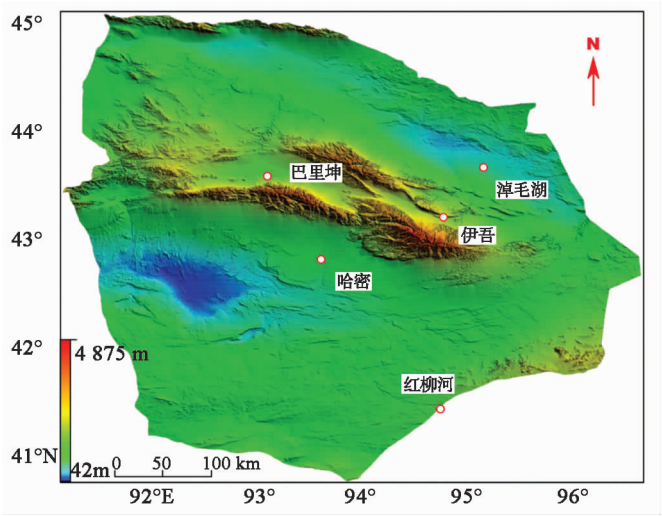


图 1 哈密气象站点分布

Fig. 1 Distribution of meteorological stations in Hami

## 1.2 $ET_0$ 计算方法

Penman – Monteith

$$ET_0 = \frac{0.408\Delta\ (R_n - G) + \gamma \frac{900}{T+273} u_2\ (e_s - e_a)}{\Delta + \gamma\ (1 + 0.34u_2)}. \quad (1)$$

$ET_0$ mm/d $R_n$ MJ/ $m^2 \cdot d$ G MJ/ $m^2 \cdot d$ $u_2$ 2m m/s $e_s$ kPa $e_a$ kPa $\Delta$ kPa/℃ kPa/℃

### 1.3 分析方法

$ET_0$ 10 $ET_0$ $ET_0$ Mann-Kendall $ET_0$ SPSS $ET_0$

## 2 结果与分析

### 2.1 哈密地区参考作物蒸散量的年变化特征

Penman-Monteith 5 1961 – 2016 $ET_0$ 1 2 1961 – 2016 $ET_0$ 1 205.89 mm/a 1998 1 085.63 mm/a

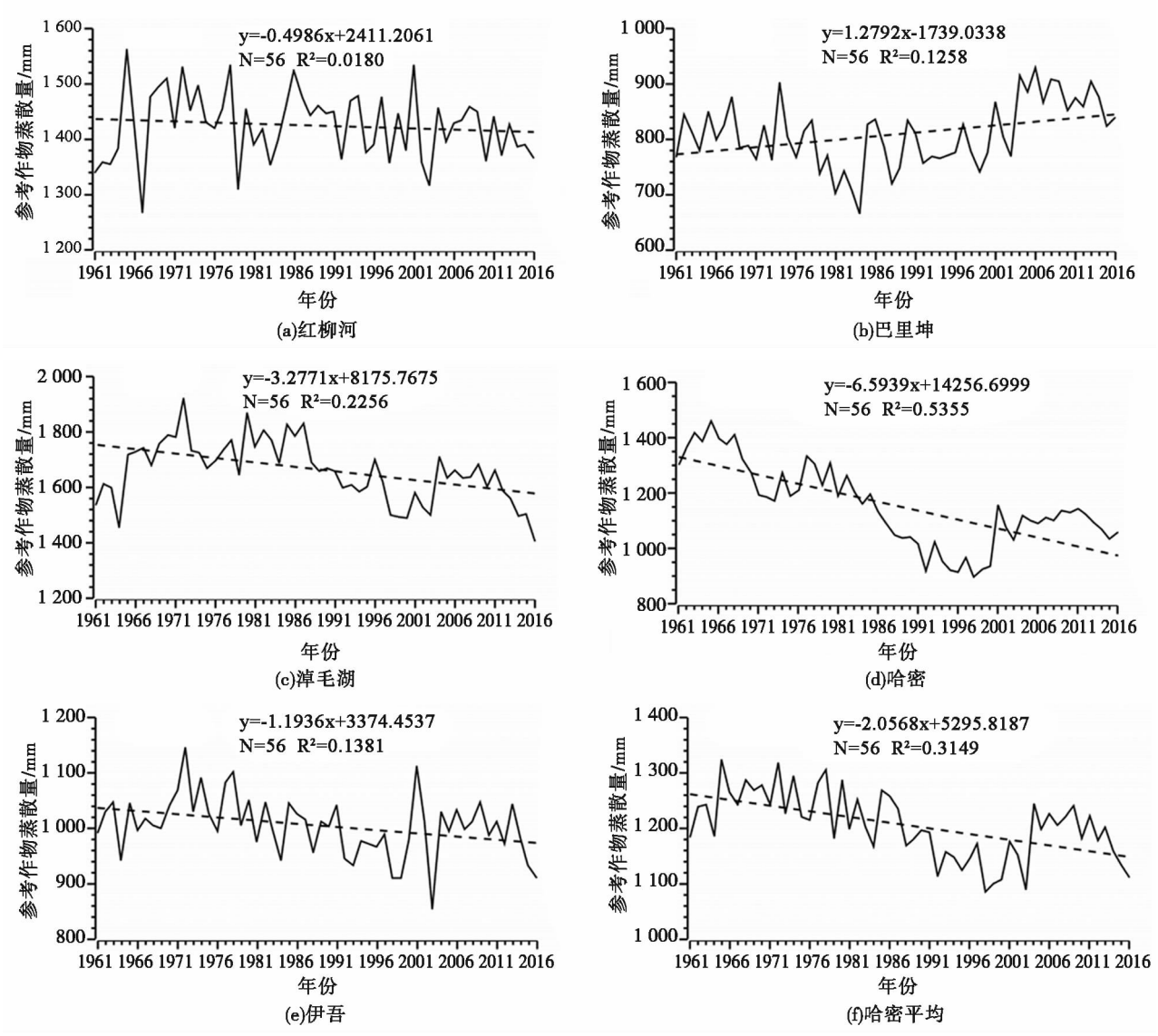


图 2 哈密地区参考作物蒸散量变化趋势

Fig. 2 Temporal change trends of $ET_0$ in Hami

1965 1 325.2 mm/a 1.22 $ET_0$
661.31 ~ 1 925.37 mm/a
804.72 1 659.19 1 001.04 1 144.70 1 419.82 mm/a
1961 – 2016 $ET_0$ – 20.57 mm/10a 2
[7] 4 –
65.94 mm/10a – 32.77 mm/10a – 11.94 mm/10a – 4.99 mm/10a
12.79mm/10a 1961 – 2010 $ET_0$
– – – – – –
– – – – – – – –
– – – 2011 1

表 1 哈密不同地区参考作物蒸散量年代际变化

Table 1 Variations of $ET_0$ in different decades in Hami

| | | | | | | |
|---|---|---|---|---|---|---|
| 1961 – 1970 | 809.14 | 1 663.49 | 1 008.99 | 1 365.33 | 1 412.38 | 1 251.86 |
| 1971 – 1980 | 794.30 | 1 757.90 | 1 056.61 | 1 233.86 | 1 447.07 | 1 257.95 |
| 1981 – 1990 | 829.58 | 1 749.90 | 998.56 | 1 130.25 | 1 432.96 | 1 212.90 |
| 1991 – 2000 | 752.84 | 1 587.62 | 959.22 | 941.17 | 1 415.02 | 1 135.21 |
| 2001 – 2010 | 861.70 | 1 609.75 | 999.04 | 1 091.27 | 1 407.78 | 1 193.91 |
| 2011 – 2016 | 798.85 | 1 537.97 | 972.33 | 1 080.72 | 1 392.99 | 1 168.61 |
| 1961 – 2016 | 804.72 | 1 659.19 | 1 001.04 | 1 144.70 | 1 419.82 | 1 205.89 |

## 2.2 哈密地区参考作物蒸散量的季节变化趋势

56 561.82 mm/a
375.48 mm/a 217.07 mm/a 51.52 mm/a $ET_0$ 31.14%

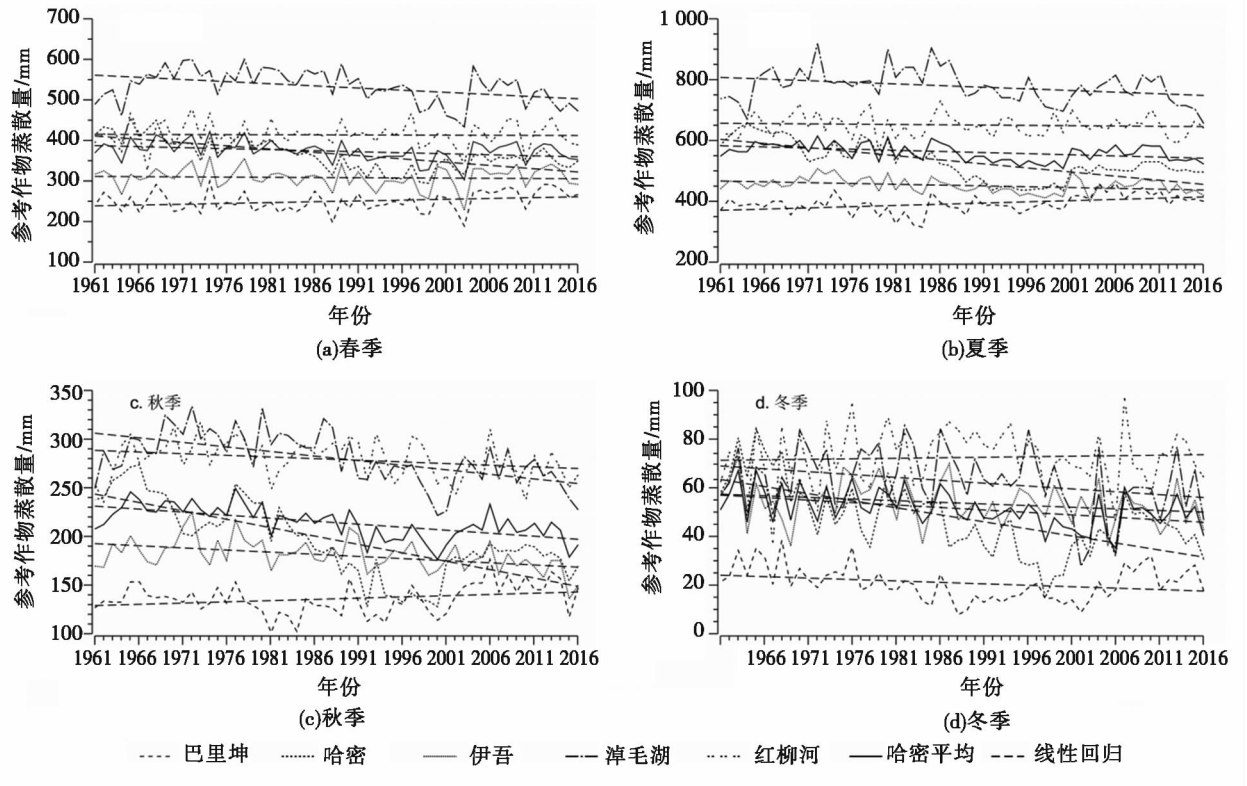


图 3 哈密地区年参考作物蒸散量季节变化曲线

Fig. 3 Temporal change trends of $ET_0$ in different seasons in Hami

46.59% 18.00% 4.27% $ET_0$ 533.67 mm/a 779.52 mm/a 283.32 mm/a $ET_0$ 72.57 mm/a 4 $ET_0$ 251.29 mm/a 393.88 mm/a 138.63 mm/a 20.92 mm/a $ET_0$ 3

0.37 mm/10a

−1.95 mm/10a 3

**2.3 哈密地区年参考作物蒸散量累积距平曲线分析**

1961 − 2016 4 4 $ET_0$ 1987 1122.71 mm 1961 −22.14 mm 1961 − 1987 2004 − 2009 $ET_0$ 1987 − 2003 2010 − 2016 $ET_0$ $ET_0$ 1967 1994 1968 − 1978 1985 − 1994 2003 − 2009 $ET_0$ 1961 − 1967 1979 − 1984 1995 − 2002 1010 − 1016 $ET_0$ 2000 $ET_0$ 1968 1961 − 1968 2001 − 2016 $ET_0$ 1969 − 2000 $ET_0$ $ET_0$ 1964 1990 1965 − 1990 $ET_0$ 1961 − 1964 1991 − 2016 $ET_0$ 1961 $ET_0$ 1982 1961 − 1982 $ET_0$ 1983 − 2016 $ET_0$ 2016 $ET_0$ 1985 1961 − 1985 $ET_0$ 1986 − 2016 $ET_0$

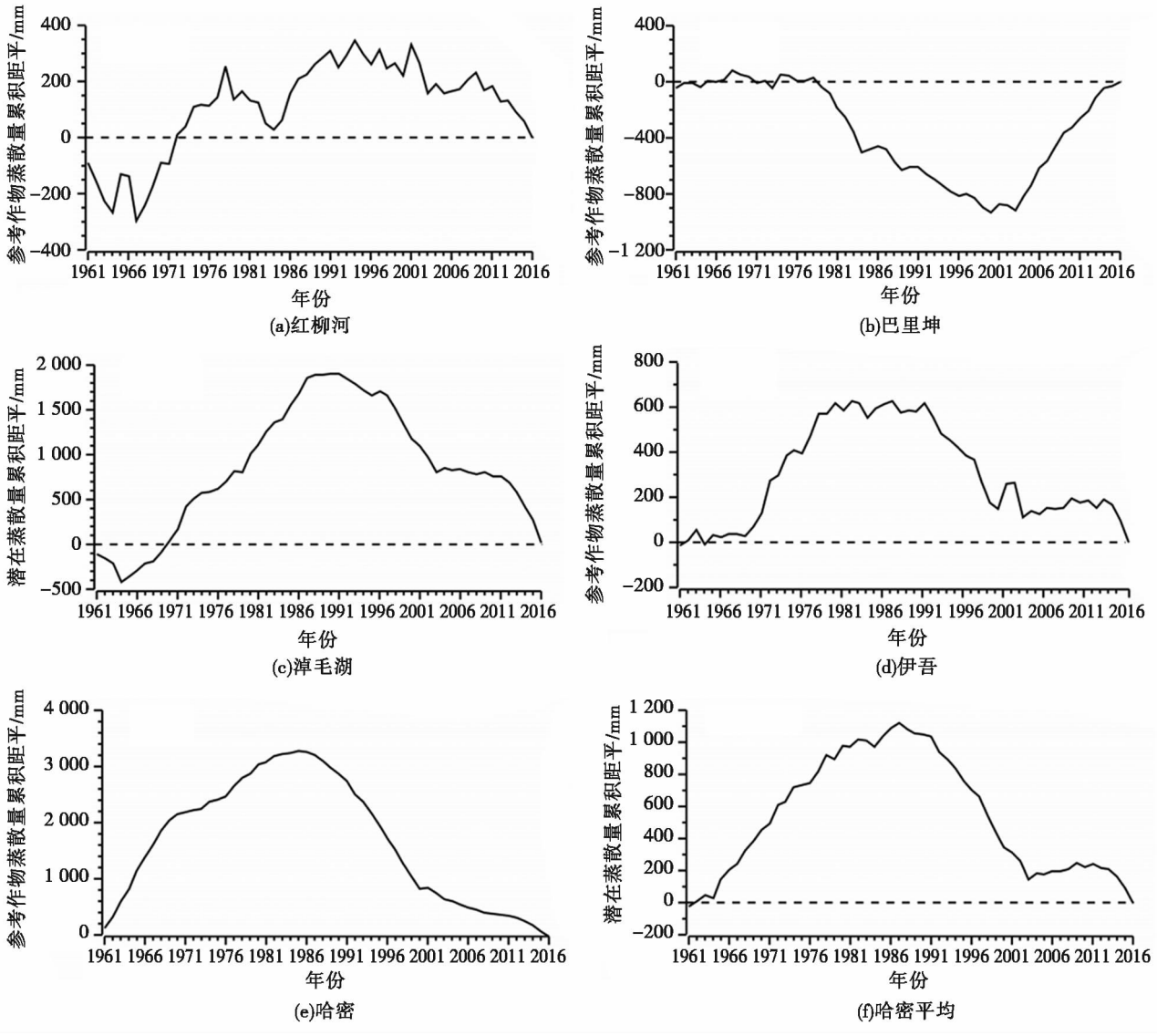


图 4 哈密地区年参考作物蒸散量累积距平曲线

Fig. 4 Cumulative anomalies of $ET_0$ in Hami

## 2.4 哈密地区年参考作物蒸散量突变分析

Mann-Kendall $ET_0$ 5 5 $ET_0$ $ET_0$ UF 1983 UF < 0 1983 UF UB 1983 ± 1.96 1983 1984 – 2016 1175.12 mm/a 74.93 mm/a 1961 – 2002 $ET_0$ UF > 0 1961 – 2002 2003 – 2016 $ET_0$ UF 0 2003 $ET_0$ UF UB 2009 2009 1961 – 1970 2006 – 2016 $ET_0$ UF 0 $ET_0$ 1971 – 2005 $ET_0$ UF < 0 $ET_0$ 1971 – 2005 UF UB 2003 2003 2004 – 2016 876.07 mm/a 91.83 mm/a 1961 – 1994 1995 UF UB 1996 ± 1.96 2003 2009 2 ± 1.96 0.05 1996 1961 – 1984 1984 – 2016

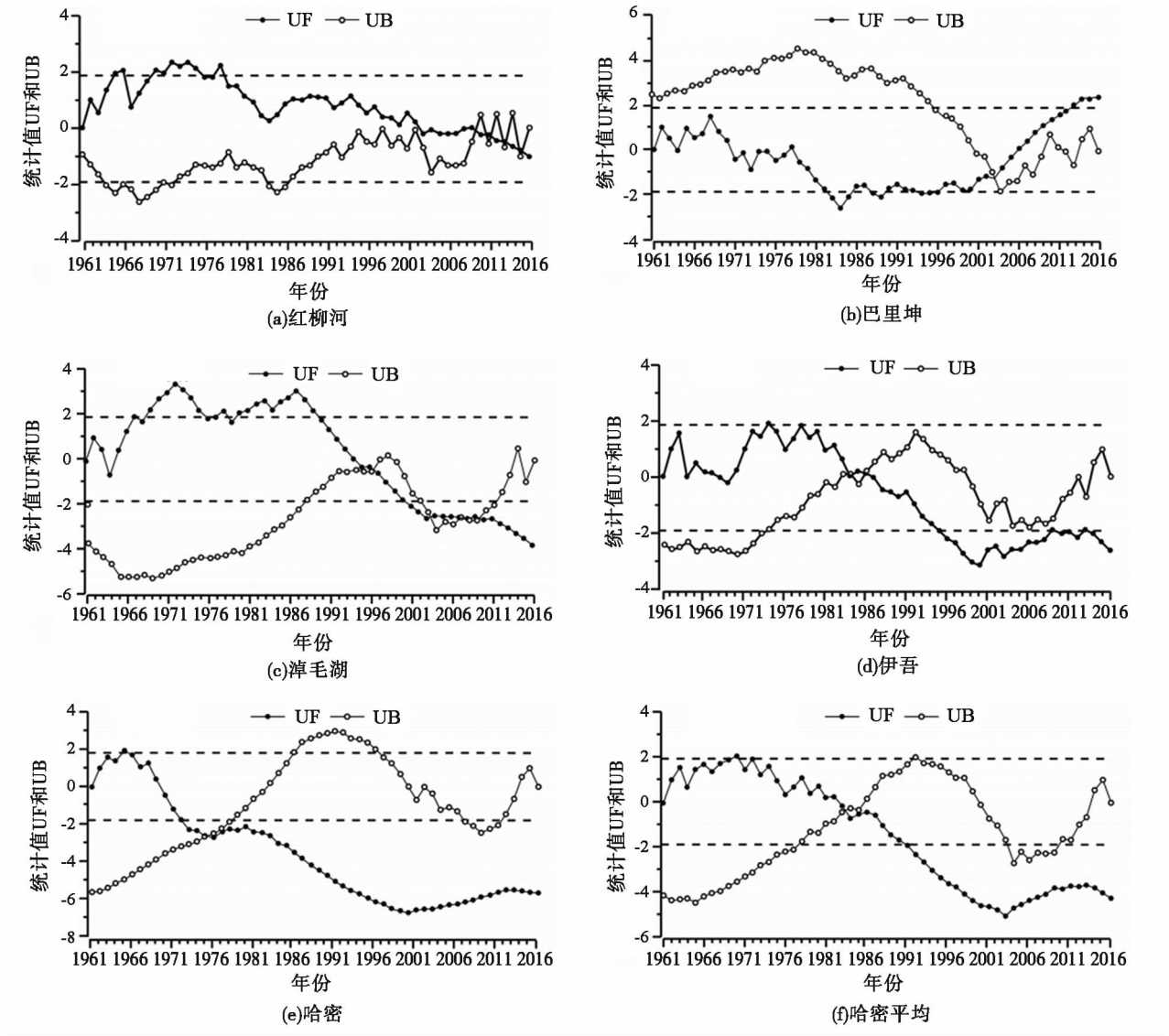


图 5 哈密地区年参考作物蒸散量 Mann-Kendall 检验曲线

Fig. 5 Mann-Kendall test curve of evapotranspiration in Hami

1986 1987 – 2016 981.68 mm/a
43.98 mm/a 1961 – 1969 1970
UF UB 1975 ±1.96 $a = 0.05$

### 2.5 参考作物蒸散量影响因子分析

$ET_0$ 4
$ET_0$
6
2 2 $ET_0$
、
、
、
、
18

56

表 2 哈密地区参考作物蒸散量与气象因素的显著性相关分析

Table 2 Significance correlation analysis between meteorological factor and evapotranspiration in Hami

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.571 * * | 0.621 * * | 0.505 * * | – 0.783 * * | 0.509 * * | 0.145 | – 0.106 |
| – 0.372 * * | – 0.247 | – 0.447 * * | – 0.462 * * | 0.823 * * | 0.342 * * | – 0.421 * * |
| 0.056 | 0.087 | 0.022 | – 0.677 * * | 0.671 * * | 0.619 * * | – 0.642 * * |
| – 0.175 | – 0.288 * | – 0.231 | – 0.701 * * | 0.960 * * | 0.447 * * | – 0.399 * * |
| – 0.13 | 0.086 | – 0.068 | – 0.467 * * | 0.574 * * | 0.225 | – 0.362 * * |

* * 0.01 * 0.05

## 3 结论

1 1961 – 2016 – 20.57 mm/10a
5 4 –
65.94 mm/10a – 32.77 mm/10a – 11.94 mm/10a – 4.99 mm/10a
12.79 mm/10a
3

2 Mann-Kendall 20 80
1983 2009
2003 1996 1986
3
56

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