

# Regional difference of aridity/humidity conditions change over China during the last thirty years

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**Abstract** The meteorological data of 616 stations in China were used to calculate the potential evapotranspiration and aridity/humidity index by applying the modified FAO-Penman-Monteith model. Regional difference of trends in precipitation, potential evapotranspiration and aridity/humidity index over China and their interdecadal variations were analyzed from 1971 to 2000. The results show that all the four climatic factors trends have obvious regional difference and interdecadal variations. Annual precipitation during the 30-year period shows an increasing trend over most regions of China, with decreasing trends in potential evapotranspiration and aridity/humidity index. Most regions in China become more humid, especially significant in northern Xinjiang, eastern Tibet, western Sichuan, and northern Yunnan. The average value over China would mask the regional difference of climate change because of the complex environmental condition in China. Therefore regional difference should be analyzed to further understand climate change and its impacts. Both water supply and demand need to be considered when attempting to study regional aridity/humidity conditions.

**Keywords:** aridity/humidity conditions, climate change, regional difference, potential evapotranspiration, Penman-Monteith model.

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Scientists have found that the global average surface temperature has increased by  $0.6\pm 0.2^{\circ}\text{C}$  since the late 19th century based on various evidence<sup>[1]</sup>. From the 1980s, temperature has experienced the most rapid warming to an extent of abrupt change statistically<sup>[2,3]</sup>. Global warming has attracted extensive attention from multiple departments and has been an important issue related to global politics. Many scientific communities have made great efforts on climate change research and global environmental response<sup>[4-9]</sup>.

Temperature changing trend in China was similar to that in the Northern Hemisphere. Most regions over China became warmer in recent decades except Sichuan Province and its neighbor areas where decreasing trends in temperature were detected<sup>[6,7]</sup>. Aridity/humidity conditions also changed on different spatial and temporal scales associated with the widespread warming over China. Study on regional difference of aridity/humidity conditions change would benefit the rational water resources allocation and utilization, and providing a scientific basis for researching on future climate change, exploring the driving factors of environmental change, preventing eco-vulnerability zones from further ecological deterioration and developing regional agriculture and economy.

Precipitation is a directly observable component of aridity/humidity conditions and has complex spatial and temporal variations over China<sup>[8,9]</sup>. However, regional difference of aridity/humidity conditions change could not be indicated only by precipitation. For example, precipitation over western Northwest China (northern Xinjiang) was observed to increase in recent 20 years, but whether aridity/humidity conditions were improved or not is far less conclusive and needs more evidence<sup>[1]</sup>. The imbalance of water supply (mainly precipitation) and demand (mainly potential evapotranspiration) determines the regional aridity/humidity conditions<sup>[10]</sup>. The climate would become humid if water supply exceeds demand, and be arid on the contrary<sup>[11]</sup>. Some studies found that both the observed pan evaporation (closely correlated with potential evapotranspiration) and the calculated potential evapotranspiration had decreased significantly over several regions in the world in recent decades<sup>[12-15]</sup>. Therefore, aridity/humidity conditions influenced by precipitation and potential evapotranspiration would also change over China, which has attracted extensive attention. Shi et al. concluded a climatic shift from warm-dry to warm-wet in Northwest China according to the evidence of significant runoff increase and lake water level rise due to the increase of precipitation and melt-water much more than that of evapotranspiration<sup>[16]</sup>. Thomas indicated that potential evapotranspiration decreased from 1954 to 1993 in China, with slightly increasing trends in northeast and southwest China, significant decreasing trends in northwest and southeast China, and nearly no change in part areas of northeast and south China and eastern Tibet<sup>[17]</sup>. Yang pointed out that precipitation had decreasing trends in northeast and north China during 1951—1990, while increasing trends in the east of northwest and southwest regions; evaporation had increasing trends in northeast China and decreasing trends in north China, the east of northwest and southwest regions. Therefore, climate was

1) Ma, Z. G., Huang, G., Gan, W. Q. et al., Multi-scale temporal characteristics of the dryness/wetness over Northern China in last century, Chinese Journal of Atmospheric Sciences, 2005, in press.

drying in northeast and north China, wetting slightly in the east of northwest China and wetting greatly in southwest China regions<sup>[18]</sup>.

There was less consensus about aridity/humidity conditions change partially due to the complexity of climate change and different analysis methods and periods. The selection of weather stations also affects conclusions. Only a small amount of stations could not reflect regional difference of climate change accurately in China where widely varying land use and climate regimes are featured, such as the study of Thomas who used only 65 stations<sup>[17]</sup>. In this study we selected more weather stations and a worldwide used potential evapotranspiration model which is also suitable for China. We analyzed the aridity/humidity conditions during the last three decades by incorporating potential evapotranspiration and precipitation. The objective of this study is to derive regional difference of changing trends and interdecadal variations of aridity/humidity conditions including precipitation, potential evapotranspiration and aridity/humidity index. The results of this study may provide evidence for further investigations to understand the aridity/humidity conditions change over China under global climate change, and enhance our understanding of climate change and its impacts.

## 1 Materials and methods

### 1.1 Materials

The meteorological data sets used in this study including latitude, longitude and altitude of weather stations and daily data of the maximum and minimum temperatures, wind speed, relative humidity, sunshine hours and precipitation were derived from the National Climatic Data Center of China Meteorological Administration (CMA). A popular meteorological baseline period is a 30-year 'normal' period in global climate change studies, and the period 1971–2000 could reflect the normal climate status reasonable<sup>[19]</sup>. Close examination of the data sets shows that 616 weather stations (Fig. 1) in China have observed data with good quality after discarding stations built after 1971, or removed before 2000, or moved during the study period, or with too much missing data. A few of missing data of the selected weather stations were replaced by an average value from other years. To illustrate the regional difference over China more easily, we described China using eight physical geographical regions: (1) Northeast China, (2) North China, (3) Central China, (4) South China, (5) Inner Mongolia, (6) Southwest China, (7) Northwest China, and (8) Tibetan Plateau<sup>[20]</sup> (Fig. 1).

### 1.2 Methods

It is important in studying aridity/humidity conditions

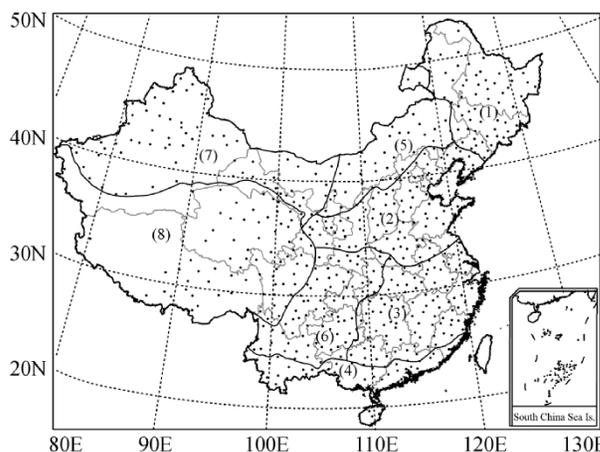


Fig. 1. Distribution of the 616 weather stations and the eight physical geographical regions of China.

change to choose proper indexes to reflect potential evapotranspiration and aridity/humidity conditions<sup>[21,22]</sup>. Potential evapotranspiration reflects the maximum water demand of environment to keep water balance. There have been many relative researches since Thornthwaite<sup>[23]</sup> and Penman<sup>[24]</sup> brought forward potential evapotranspiration definitions successively in 1948. However a uniform definition does not exist until now, not to mention estimate or measure method. Huang used a simple "evaporation rate" to express the meaning<sup>1)</sup>. In the Modern Geographical Dictionary the maximum evapotranspiration over a surface under certain meteorological conditions without water limitation is called the maximum potential evaporation, and also potential evaporation, evaporation rate or evaporation potential<sup>[25]</sup>. Many different definitions and methods are usually suitable for a particular region<sup>[26]</sup>. Since the routine and long-term continuous observations of potential evapotranspiration are not available in China, it was resolved by choosing an appropriate model according to the climate characteristics in China. The Penman-Monteith model modified in 1998 by Food and Agricultural Organization (FAO), popularly used and accurate for both arid and humid conditions, meets the above qualifications<sup>[27,28]</sup>. The FAO-Penman-Monteith model defined a hypothetical reference crop with an assumed crop height of 0.12m without moisture limitation, a fixed surface resistance of 70 s/m and an albedo of 0.23 to calculate reference crop evapotranspiration (also as potential evapotranspiration). The reference surface closely resembles an extensive surface of green grass of uniform height, actively growing, completely shading the ground and having adequate water. The formula of potential evapotranspiration ( $ET_0$ ) is

1) Huang, B. W., Research on evaporation rate (unpublished), 1963

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)},$$

where  $\Delta$  is the slope of saturation vapor pressure curve,  $R_n$  is the net radiation,  $G$  is the soil heat flux,  $\gamma$  is the psychrometric constant,  $T$  is the mean of maximum and minimum temperature,  $U_2$  is the wind speed at 2 m height,  $e_s$  is the mean saturation vapor pressure,  $e_a$  is the actual vapor pressure. All parameters use the International System of Units. This model takes many factors into account such as the maximum and minimum temperatures, wind speed, relative humidity and solar radiation. The parameters were calculated by methods described in FAO except the net radiation which required regional revision. Zuo et al.<sup>[29]</sup> obtained the empirical coefficients special for China based on measurements of average monthly total radiation and sunshine rate, and monthly total radiation under clear sky. So  $R_n$  can be expressed as

$$R_n = (1 - 0.23) \times \left( 0.248 + 0.752 \frac{n}{N} \right) R_{so} - \sigma \left[ \frac{T_{\max,k}^4 + T_{\min,k}^4}{2} \right] \\ \left( 0.56 - 0.08\sqrt{e_a} \right) \left( 0.1 + 0.9 \frac{n}{N} \right),$$

where  $n$  is actual sunshine hours,  $N$  is potential sunshine hours,  $R_{so}$  is clear-sky solar radiation,  $\sigma$  is Stefan-Boltzmann constant ( $4.903 \times 10^{-9} \text{ MJ K}^{-4} \cdot \text{m}^{-2} \cdot \text{d}^{-1}$ ), and  $T_{\max,k}$ ,  $T_{\min,k}$  are the maximum and minimum temperatures in Kelvin's thermometric scale respectively.

Regional aridity/humidity conditions, considering water demand and supply, were expressed as the ratio of  $ET_0$  and precipitation ( $P$ ), i.e. aridity/humidity index ( $I_a$ ):

From global view, regions are generally divided into four types: humid ( $I_a \leq 0.99$ ), sub-humid ( $1.00 < I_a \leq 1.49$ ), semi-arid ( $1.50 < I_a \leq 3.99$ ), and arid ( $I_a \geq 4.00$ ), which represent four types of natural vegetation and land scape: forest, forest-steppe (meadow), steppe/meadow-steppe and desert, respectively<sup>[30]</sup>.

Trends of average annual temperature, precipitation, potential evapotranspiration and aridity/humidity index of 616 stations over China were calculated by linear trend method through the 30-year time series (1971–2000). Slopes of linear regression by least-squares method were used as indicators for climate trends. Positive (negative) values stand for increasing (decreasing) trend. The trend of a time series was tested using a non-parametric Mann-Kendall method which has been popularly used to investigate whether the time series exhibit a significant increasing or decreasing trend<sup>[31]</sup>. The regional difference

of aridity/humidity conditions trend was analyzed using trend surfaces by the spline interpolation of station values. Interdecadal variations were illustrated by comparing anomalies in 1970s, 1980s and 1990s which were predefined as the departures from the 1971–2000 annual mean.

## 2 Results

### 2.1 Temperature trend in the last thirty years

An average annual mean increasing trend in surface air temperature of about  $0.03^\circ\text{C/a}$  has been observed over China, with regional difference ranging from  $-0.07^\circ\text{C/a}$  to  $0.13^\circ\text{C/a}$ . Warming trends are shown in most regions in China except Sichuan Province and the surrounding areas. The Mann-Kendall significant test was employed to evaluate the significance of the 30-year period trends in temperature at each station. The results reveal that 482 stations (about 78%) have statistically significant warming trends (at a confidence interval greater than 90%). The significant test reveals a statistically significant increasing trend in temperature. The detailed spatial and temporal variation of temperature across China is not described in this study because there have been similar conclusions about the general changing character to the results of this study.

### 2.2 Precipitation trend and interdecadal variations

The time series of annual total precipitation in China suggests an increasing trend at a rate of  $0.57 \text{ mm/a}$  on average. Variations of trends in the 616 stations are between  $-11.9$  and  $16.8 \text{ mm/a}$ . Since the average value would mask the considerable regional variability and could not describe climate change accurately, changing trend needs to be studied on regional level. Trends in precipitation of stations were interpolated to indicate the regional distribution (Fig. 2(a)). Over northern part of Tibetan Plateau and most of Northwest China, precipitation increases slightly with a trend of no more than  $1 \text{ mm/a}$ . The higher increasing trends of precipitation mainly center in Central China, the west of Southeast China, northeastern Tibetan Plateau, northern Xinjiang and most parts of Northeast China, reaching up to  $1 \text{ mm/a}$ . Over western Sichuan, eastern Tibet, northern Yunnan and part of Central China, precipitation shows increasing trends of even more than  $5 \text{ mm/a}$ . Precipitation with obvious decreasing trends less than  $-5 \text{ mm/a}$  scatters in South China and parts of North China. Over coastal zone in South China, North China and the north of Southwest China, decreasing trends in precipitation are less than  $-1 \text{ mm/a}$ . Over southwestern Tibetan Plateau, the Qaidam Basin and its neighbor areas, southern Qinghai Province, and small parts of Northeast China and Inner Mongolia, slightly decreasing trends in precipitation of more than  $-1 \text{ mm/a}$  occur. Mann-Kendall method was used to test the annual precipitation trends of

the 30-year period. Precipitation shows increasing trends in 52 stations and statistically significant decreasing trends in 15 stations, accounting for about 8% and 2% of the total 616 stations, respectively. The significant test reveals that over northern Xinjiang, eastern Tibet, western Sichuan and central part of Central China, annual precipitation shows statistically significant increasing trends, while over the rest majority regions, precipitation displays insignificant trends.

The spatial distribution of precipitation anomaly (Fig. 2 (b)–(d)) reveals the decadal variations of precipitation across China. In general, precipitation is less than the normal 30-year average value in the first decade of 1970s. Precipitation has negative anomalies over most of Northeast China, Xinjiang, Tibetan Plateau and Central China. In the west of China, anomaly value of precipitation mainly varies from zero to  $-10$  mm with small areas from  $-10$  mm to  $-50$  mm. In the east part it is mostly less than  $-10$  mm, and even  $-50$  mm in small areas. The minority positive anomaly of precipitation between zero and 50 mm mainly distributes in North China, eastern Southwest and South China and western Inner Mongolia. In 1981–1990, negative anomaly of precipitation exists over Inner Mongolia, parts of Northwest China, Yungui Plateau, hilly regions in Shandong and south to the Yangtze River. Absolute value is relatively high in southern regions (mostly less than  $-50$  mm) compared with that in northern regions (mainly more than  $-50$  mm). Precipitation in the rest areas has positive anomalies and mostly more than 10 mm. Compared with 1970s, three regions including Northeast China, Tibetan Plateau and Xinjiang show greater decadal variability increasing from negative to positive anomaly. While precipitation decreases over Inner Mongolia, hilly regions in Shandong and part of Southwest China, Xinjiang and Tibet. Weather stations in the Tarim Basin are scarce and the increase of precipitation there would be caused by one or two rainfall events at single station. More observed data are needed to validate the trends and the representativeness. Precipitation generally increases and exhibits a positive anomaly more than 10 mm in 1990s, only decreasing to negative anomalies over several regions including most of North China, northern Southwest China, southern Northeast China, part of Tibetan Plateau and coastal zone in South China.

### 2.3 Potential evapotranspiration trend and interdecadal variations

Average annual potential evapotranspiration ( $ET_0$ ) has a decreasing trend at a rate of  $-1.3$  mm/a over China in 1971–2000. The regional trends in  $ET_0$  range between  $-15.5$  and  $9.6$  mm/a. Most regions show decreasing trends in the study period (Fig. 3(a)). In most western regions  $ET_0$  trend is less than  $-1$  mm/a, and even less than  $-5$  mm/a in parts of Xinjiang and Gansu.

Trends at three isolated stations of Qiemo, Hami, Anxi are less than  $-10$  mm/a. Over Northeast China, North China and part of coastal zone, trends of  $ET_0$  are positive, with more than 5 mm/a only in Qijiaoqing, Weihai and Huinong stations. On precondition of unchanged precipitation, the results that  $ET_0$  in most regions shows decreasing trends would benefit the enhancement of humid conditions in these regions. The Mann-Kendall method was used to test the trend of the 30-year time series of  $ET_0$ . There are 262 stations with statistically significant decreasing trends, and 45 stations with statistically significant increasing trends, accounting for 43% and 7% of the total 616 stations, respectively. Over Northwest China, Tibetan Plateau, Southwest China and parts of the east of China including central part of Central China, southern Northeast China and part of Inner Mongolia,  $ET_0$  shows statistically significant decreasing trends.

In 1970s,  $ET_0$  is above average value with anomalies of 10–50 mm over most regions, and more than 50 mm in small regions (Fig. 3(b)). In 1980s, the positive anomalies in  $ET_0$  increase over Tibetan Plateau, part of Southwest and Central China, Xinjiang and southern Northeast China; and most of these regions have anomalies of more than 50 mm. The other regions have negative anomalies of more than  $-50$  mm (Fig. 3(c)). In 1990s,  $ET_0$  has positive anomalies of more than 10 mm over North China, coastal zone in South China and portions of Northeast China. In the rest regions,  $ET_0$  decreases below average value, with negative anomalies ranging from  $-10$  mm to  $-50$  mm in most regions. The absolute anomalies of  $ET_0$  in 1990s increase from east to west generally (Fig. 3(d)). Compared with 1980s, there is obvious difference in two main changing patterns of  $ET_0$ , with anomalies increasing from negative to positive in North China and coastal zone in South China, and decreasing from positive to negative in Tibetan Plateau and most of Southwest and Central China.

### 2.4 Aridity/humidity index trend and interdecadal variations

The aridity/humidity index ( $I_a$ ) decreases at a rate of  $-0.02$  per year on average across China, and ranges between  $-2.5$  and  $0.4$  per year on a regional basis. While in most regions of China  $I_a$  shows decreasing trends, and slightly increasing trends only occur over North China, the Qaidam Basin and coastal zone in South China. In general, the decreasing trends enhance from east to west (Fig. 4(a)). The trend test by Mann-Kendall method of  $I_a$  time series during the last three decades across China reveals that 96 stations have decreasing trends and 16 have increasing trends both of which are statistically significant, accounting for 16% and 3% of the total 616 stations, respectively. Regional difference of changing trends in  $I_a$  is obvious.

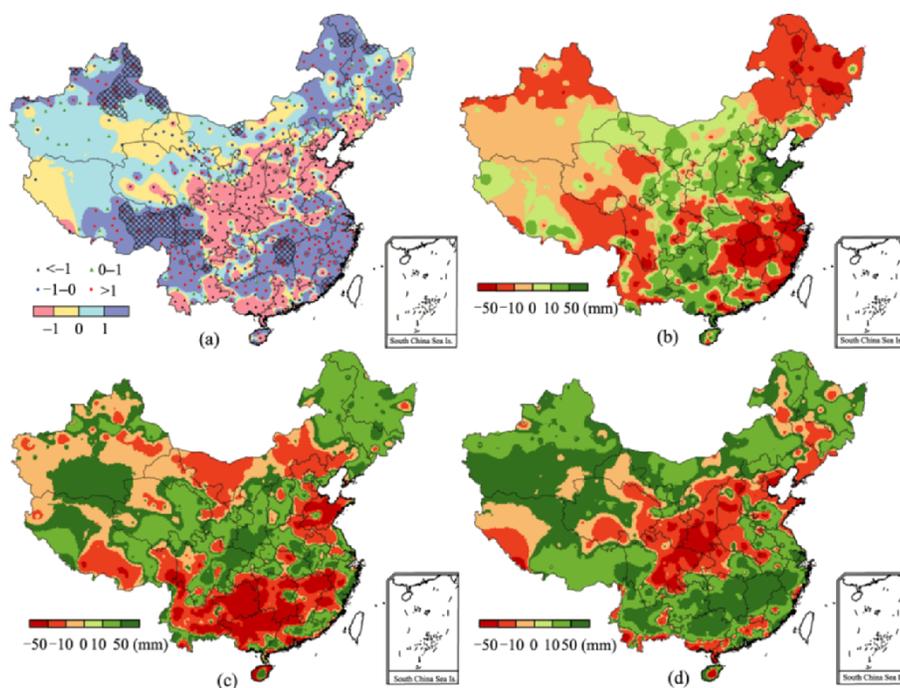


Fig. 2. Precipitation changing character over China in 1971–2000. (a) Regional difference of trend in precipitation (mm/a), circles and shaded areas represent stations and regions respectively with statistically significant trends; (b) anomaly in 1970s; (c) anomaly in 1980s; (d) anomaly in 1990s.

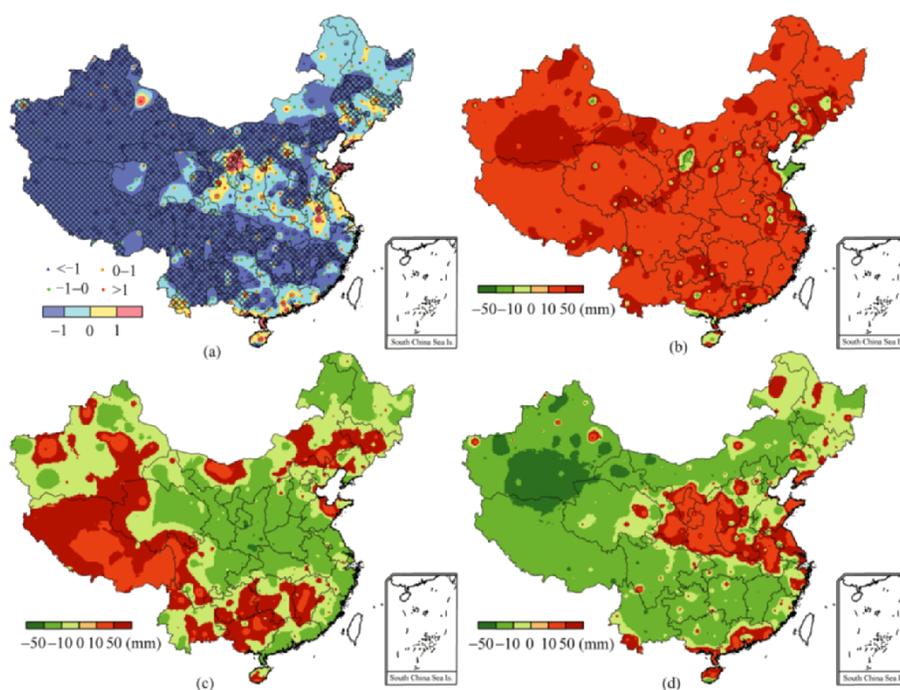


Fig. 3. Potential evapotranspiration changing character over China in 1971–2000. (a) Regional difference of trend in potential evapotranspiration (mm/a), circles and shaded areas represent stations and regions respectively with statistically significant trends; (b) anomaly in 1970s; (c) anomaly in 1980s; (d) anomaly in 1990s.

Statistically significant trends of  $I_a$ , mostly decreasing trends, mainly center in northern Xinjiang, eastern Tibet, western Sichuan, and northern Yunnan and central part of Central China. The results indicate that those regions change to more humid statistically significantly during the 30-year period.

Over Northwest China  $I_a$  shows obvious decreasing trends in recent three decades and more or less turns to more humid conditions. However, the increase of humidity in Northwest China would not change the original nature characteristics fundamentally in short period because of the essentially poor physical environment there. Northwest China is still the most arid region with vulnerable ecotope. Simultaneously, increasing trends in  $I_a$  mainly occur in North China. Agricultural water demand would not be satisfied and agricultural production would be restricted in this main grain producing region if such a less humid tendency still intensifies, together with the fact that the lower reaches of the Yellow River has often dried up since 1970s.

The distribution patterns of  $I_a$  trend are similar to those of precipitation trend (Fig. 2(a)). The study areas with increasing trend in precipitation have decreasing trend in  $I_a$  during the period analyzed; but the contrary is not always true. For example, over western Tibetan Plateau and some regions in Qinghai, Inner Mongolia, Gansu and Sichuan provinces,  $I_a$  has decreasing trends despite the decreasing trends in precipitation. Reasons

for that are unveiled by comparing with the  $ET_0$  trends (Fig. 3(a)), which show stronger decreasing trends of less than  $-1$  mm/a generally in the regions mentioned above. Therefore, aridity/humidity conditions change is not determined only by precipitation, but should integrate water supply and demand, i.e. precipitation and potential evapotranspiration.

In 1970s,  $I_a$  generally has positive anomalies except the east of Northwest and North China, south edge of Tibetan Plateau, and part of Guangxi and Guizhou where negative anomaly in  $I_a$  and more humid conditions above average are revealed. The east of Northwest China is covered by negative anomalies less than  $-0.1$ . Most of the other regions have negative anomalies above  $-0.1$  (Fig. 4(b)). Departure pattern of  $I_a$  in 1980s is opposite to the former decade, i.e. humid (arid) regions in 1970s change to arid (humid) in 1980s, but with dissimilar boundary (Fig. 4(c)). In 1990s, most regions become more humid than normal except North China and its neighbor regions, southern Northeast China and coastal zone in South China. Absolute values of negative anomalies in  $I_a$  increase from southeast to northwest gradually (Fig. 4(d)).

#### 2.5 Relationships of aridity index with potential evapotranspiration and precipitation

By comparing different changing trends in  $I_a$  with those in  $ET_0$  and precipitation (Table 1), it demonstrates that the

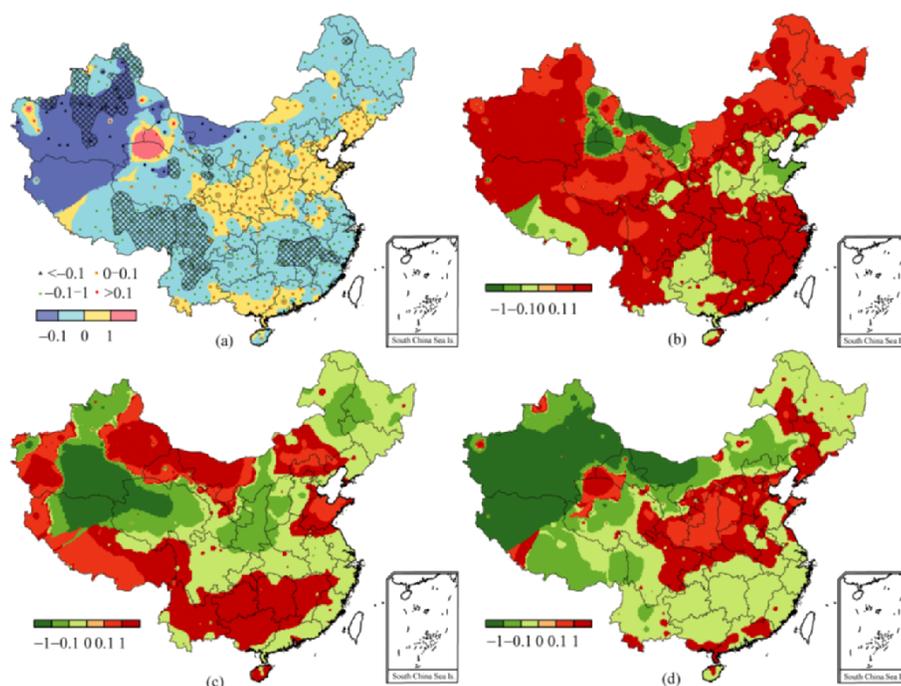


Fig. 4. Aridity/humidity index changing character in 1971–2000 over China. (a) Regional difference of trend in aridity/humidity index. Circles and shaded areas represent stations and regions respectively with statistically significant trends; (b) anomaly in 1970s; (c) anomaly in 1980s; (d) anomaly in 1990s.

Table 1 Comparison of different changing trends in  $I_a$  with those in  $ET_0$  and precipitation respectively

$ET_0$ /mm		$I_a$			Precipitation/mm		$I_a$		
				Percentage(%)					Percentage(%)
increase	170	increase	107	63	increase	348	increase	27	8
		decrease	63	37			decrease	321	92
decrease	446	increase	115	26	decrease	268	increase	196	73
		decrease	331	74			decrease	72	27

percentages of stations with increasing (decreasing) trends in  $I_a$  account for 63% and 74% of the corresponding trends in  $ET_0$ , respectively, and the percentages of stations with decreasing (increasing) trends in  $I_a$  are 92% and 73% of the reverse trends in precipitation, respectively. The results reveal a more close relationship between precipitation and aridity/humidity index. Given the fact that environment has very evident regional difference across China, both  $ET_0$  and precipitation should be considered when analyzing aridity/humidity conditions on a regional scale. Only considering a single factor would induce more mistakes and probably misdirect the agricultural development and ecological construction.

### 3 Summary

The potential evapotranspiration across China over the past thirty year was calculated using the FAO-Penman-Monteith model in this study and then aridity/humidity index was investigated. The aridity/humidity index could reflect the water supply and demand to illustrate regional aridity/humidity conditions by synthesizing the basic climatic factors such as precipitation, air temperature, wind speed, sunshine hours and relative humidity. Main results of this study are concluded as follows:

(1) Across China, the average annual precipitation during the period 1971–2000 displays increasing trend with a rate of 0.57 mm/a and ranges from –11.9 to 16.8 mm/a in different regions. While the average annual potential evapotranspiration shows decreasing trend at –1.3 mm/a and ranges between –15.5 and 9.6 mm/a. Decreasing trend of 0.02 per year is found in average annual aridity/humidity index with ranging from about –2.5 to 0.4 per year.

(2) The average value across China would mask the regional variability of climate change because of the complex environments over China. So it is necessary to study the regional difference of climate change to further understand it and its impacts more accurately. Precipitation trend in recent thirty years has obviously regional difference. Over Northeast China, Northwest China, Central China and large part of Tibetan Plateau, precipitation in the study period shows increasing trends, while over North China, northern Southeast China and coastal zone in South China, it exhibits decreasing trends. Trend test of Mann-Kendall method reveals that statistically significant increasing trends in precipitation distribute in northern Xinjiang, eastern Tibet, western Sichuan and central part

of Central China, while over most of the rest regions, precipitation does not indicate significant trends. The potential evapotranspiration shows decreasing trends in most regions, and statistically significant decreasing trends mainly over Northwest China, Tibetan Plateau, Southwest China, central part of Central China and parts of Northeast China, and it indicates marginal increasing trends in only a few stations scattering in Northeast China, North China and coastal zones. On a regional basis, slightly increasing trends in aridity/humidity index are confined to North China, the Qaidam Basin and coastal zone in South China, while the other areas are mainly covered by decreasing trends with various extents. Over northern Xinjiang, part of Central China, eastern Tibet, western Sichuan and northern Yunnan, aridity/humidity index displays statistically significant decreasing trends, which indicates these regions changing to more humid conditions in the last thirty years. Anomalies of precipitation, potential evapotranspiration and aridity/humidity index in three decades of 1970s, 1980s and 1990s reveal obvious inter-decadal variations and regional difference.

(3) Regions that show increasing trends in annual precipitation are generally with decreasing trends in aridity/humidity index (more humid conditions). However, regions that show decreasing trends in precipitation are not always with increasing trends in aridity/humidity index. Some regions display decreasing trends in both aridity/humidity index and precipitation, such as western Tibetan Plateau and parts of Qinghai, Inner Mongolia, Gansu and Sichuan, because in these regions stronger decreasing trends in potential evapotranspiration play a more important role. This study suggests that the regional aridity/humidity conditions change is mainly coupled with precipitation, but only precipitation is not enough to explain the regional difference. Therefore, it is necessary to integrate the two factors of precipitation and potential evapotranspiration, i.e. water supply and demand, to evaluate aridity/humidity conditions change.

(4) Aridity/humidity conditions change has great influences on the future agricultural production and ecotope in China. Theoretically, regions with decreasing aridity/humidity index would be more humid, and as a result, most regions of China have changed to more humid conditions during the last thirty years. Two regions, including North China where less humid tendency exists under global warming and Northwest China where the arid condition is

relieved but still the most arid region in China with vulnerable ecotope, need more attentions.

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