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AN EVALUATION OF METEOROLOGICAL VARIATIONS AND DROUGHT EFFECTS IN CHINA OVER THE PERIOD 1980-2010

B. Wagan[1,2], Z. Zhanyu[1*], F. Baoping[1], S. Memon[3] and S. Han[1]

[1]College of Water Conservancy and Hydropower Engineering, Hohai University, 1 Xikang Road, Nanjing 210098, China
[2]Department of Farm Structures, Faculty of Agricultural Engineering; [3]Department of Plant Breeding and Genetics, Faculty of Crop Production, Sindh Agriculture University, Tando Jam, 70060, Sindh, Pakistan
Corresponding Author E-mail: Zhanyu216@hotmail.com

ABSTRACT

The main objective of this study is to examine the role of meteorological variables as an important aspect of climate change and their role in determining environmental changes such as drought for nine Chinese weather stations over the period 1980-2010. We use Statistix 8.1 software and Standardized Precipitation Index (SPI) together with a large dataset of five major meteorological variables: temperature, humidity, wind velocity, solar radiation and precipitation to determine positive or negative trends in our dataset. Our main findings are as follows. First, we find that Anyang and Changzhi stations of China have remained under high wind velocity. Second, Xingtai station has high solar radiation, wind velocity and also there is evidence of drought. Third, we find highest coefficient of variation for humidity (23.3%) for Yushe station. Overall, there is an increasing trend in temperature, solar radiation, humidity and wind velocity and decreasing trend in precipitation from 1980 to 2010. We conclude that all these factors contributed to shortage of rainfall and resulted in drought.

Key words: Meteorological variations, drought, Statistix 8.1, SPI, China.

INTRODUCTION

Major climatic changes have been observed worldwide over the last three decades. Climate change is a threat to sustainable development and leads to deteriorating living conditions and increase poverty. Climatic variations such as temperature variation, rainfall variation, changes in wind, humidity, solar radiation, hail and foggy weather have most discernible effects on environment (Kenworthy, 1984). There is considerable increase in global mean temperature in the past 100 years (Sümer and Kiliç, 1995).

At ocean basin, regional and continental scales numerous long term variations in other aspects of climate have been observed. Level of precipitation has decreased in Mediterranean, southern Africa and parts of eastern Asia. Internationally, the area affected by drought has increased since 1970s. In this regard China is an important country due to its large landmass and heterogeneous climate regions. Ren *et al*. (2000) found decreasing trend over the Yellow River basin and an increasing summer precipitation over the middle and the lower Yangtze River. Bordi and Sutera (2001) used Standardized Precipitation Index (SPI) as an indicator of drought condition and their analysis revealed a downward trend for the SPI over Mediterranean basin and central Europe, entailing an overall decline of precipitation in the above mentioned regions.

Zhai *et al*. (2005) analyzed trends in both total and extreme precipitation from 1951 to 2000. They found that annual total precipitation has significantly increased in western China, the southeastern coast, and the Yangtze River valley but has significantly decreased over north China, southern northeast China and over the Sichuan Basin.

The forecast trend of climatic change in the 21st century showed that climate in China would continue to significantly warm up and also precipitation will increase (Yihui, 2006). The Intergovernmental Panel on Climate Change (IPCC) is the principal international body for the assessment of climate change defines climate change as "a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity" (IPCC Fourth Assessment Report, 2007). The relationship between climate change and productivity in agriculture is an important one. Several studies found that potential yield of wheat is decreased due to climatic warming, radiation decline and improper soil and crop management (Tao *et al.*, 2008; You *et al*., 2009; Piao *et al*., 2010). Chen *et al*. (2011) showed that water management strategies and climate change affected regional levels of crop production in North China Plain. Chen *et al*. (2013) and Ju *et al*. (2013) found that potential changes in precipitation, temperature and solar radiation had important impacts on future climate change and on agricultural production systems for specific regions.

Guoyong and Qiuhong (2014) showed potential effects of climate variability in assessing climate change and impacts on irrigation. Climate change in future 21st century China and their uncertainties were evaluated by Tian Di (2015). They found that the national average precipitation anomaly percentage was smallest in winter and largest in spring and its uncertainty was smallest in autumn and largest in winter demonstrate discernible seasonal variations. Research on temperature, precipitation, wind velocity and solar radiation showed that these meteorological variables can be used as a tool to determine climate change. However, not much research is carried out for Anyang, Changzhi, Shijiazhuang, Taiyuan, Xinxiang, Yangcheng, Yushe, Xingtai and Zhengzhou stations as most of these stations have semi-arid climate and are experiencing major climate changes over the last few decades which may have significant implications for agriculture sector. This study is an attempt to bridge this gap in literature by evaluating the impact of major meteorological variables on climate change and drought conditions for above nine stations in China.

MATERIALS AND METHODS

Data details and methodology: Data is taken on daily basis averaged over each year for five meteorological variables: solar radiation, relative humidity, temperature, precipitation and wind speed for nine weather stations of China over the period 1980-2010. We use Statistix 8.1 software and Standardized Precipitation Index (SPI) for our analysis.

Standardized Precipitation Index (SPI): Standardized Precipitation Index (SPI) McKee *et al.* (1993) was calculated for monitoring and defining and drought. SPI is best to demonstrate and determine drought or an anomalously dry or wet event at a different time scale for any location in the world that has a precipitation record.

Thom (1966) found the gamma distribution to fit climatological precipitation time series well. The gamma distribution is defined by its frequency or probability density function:

$$g(x)=\frac{1}{\sim.\Gamma(\sim)}\,x^{\sim-1}e^{-x/}\quad,\quad x>0 \tag{1}$$

Where $\sim$ = shape parameter, = scale parameter, x = precipitation amount, $\Gamma(x)$ = gamma function and calculated as:

$$\Gamma(\sim)=\int_0^\infty y^{\sim-1}e^{-y}\,dy \tag{2}$$

Parameters $\sim$ and are determined by the method of maximum probability for a multiyear data:

$$\sim_{pro}=\frac{1}{4A}\left(1+\sqrt{1+\frac{4A}{3}}\right) \tag{3}$$

$$A=\ln(x_{sr})-\frac{\sum_{i=1}^{n}\ln(x_i)}{n} \tag{4}$$

$$_{pro}=\frac{x_{sr}}{\sim_{pro}} \tag{5}$$

Where x_{sr} = mean value of precipitation, n = precipitation measurement number, x_i = quantity of precipitation data. The obtained parameters further used to calculate cumulative probability of precipitation for certain time scale. The cumulative probability can be calculated as:

$$G(x)=\int_0^x g(x)dx=\frac{1}{_{pro}^{\sim_{pro}}\Gamma(\sim_{pro})}\int_0^x x^{\sim_{pro}-1}e^{-x/_{pro}}\,dx \tag{6}$$

Since the gamma function has not been defined for $x=0$ and precipitation amount may become to zero, under this condition cumulative probability becomes:

$$H(x)=q+(1-q)G(x) \tag{7}$$

Where q = probability of precipitation equals to zero, and presented as:

$$q=m/n \tag{8}$$

Where m = number which shows how much precipitation was zero in data, n = precipitation number in data.

Standardized Precipitation Index (SPI) is calculated by using equation given by Abramowitz and Stegun (1965) as:

$$SPI=\begin{cases}-\left(t-\dfrac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right), & 0<H(X)\le 0.5\\[2ex] +\left(t-\dfrac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right), & 0.5<H(X)\le 1.0\end{cases} \tag{9}$$

Where t is determined as:

$$t=\begin{cases}\sqrt{\ln\dfrac{1}{(H(x))^2}}, & 0<H(x)\le 0.5\\[2ex] \sqrt{\ln\dfrac{1}{(1-H(x))^2}}, & 0.5<H(x)\le 1.0\end{cases} \tag{10}$$

And c_0, c_1, c_2, d_1, d_2, d_3 are the coefficients:

$c_0 = 2.515517$, $c_1 = 0.802853$, $c_2 = 0.010328$, $d_1 = 1.42788$, $d_2 = 0.189269$, $d_3 = 0.001308$.

SPI Showing the number of standard deviations above or below that an event is from the mean. **Autocorrelation test:** To removing serial dependence from the series is one of the main problem in testing and interpreting time series data. Von Storch and Navarra (1995) suggested test, by using nonparametric test to detect trends can significantly affect the results.

$$r_1 = \frac{\frac{1}{n-1}\sum_{i=1}^{n-1}\left(x_i - \text{«}(x_i)\right)\cdot\left(x_{i+1} - \text{«}(x_i)\right)}{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - \text{«}(x_i)\right)^2} \qquad (11)$$

$$\text{«}(x_i) = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad (12)$$

Where $\text{«}(x_i)$ is mean of sample data and n is sample size.

The autocorrelation coefficient value of r_1 recommended at 95% significance level and r_1 can be computed by:

$$r_1(95\%) = \frac{-1 \pm 1.96.\sqrt{n-2}}{n-1} \qquad (13)$$

Where n is the sample size.

Description of Statistical parameters: The statistical parameters of meteorological variables of nine weather stations over the period 1980-2010 are summarized in Table 1. Standard deviation (SD) and coefficient of variation (CV %) are determined for five meteorological variables. The results depict that Changzhi station has highest coefficient of variation (12.6 %) and Xinxiang station has lowest coefficient of variation (9.6 %). Shijiazhuang station has the highest standard deviation (7.01) of precipitation. However, maximum coefficient of variation is found for Changzhi station (97.5 %). The highest solar radiation is seen in Anyang with 125.74 standard deviation. In this regard Xingtai is found to have the highest Coefficient of variation (168.6 %).

In our results, Yushe station reveals the highest coefficient of variation (23.3 %) for humidity and lowest coefficient of variation for Xinxiang (15.2 %). Changzhi station shows highest standard deviation of wind velocity. Xingtai station is also under high solar radiation over the period of our study which created drought trends. Changzhi with high level of precipitation and wind velocity leads to climate change. However, Yushe station reveals to have the highest coefficient of variation for humidity.

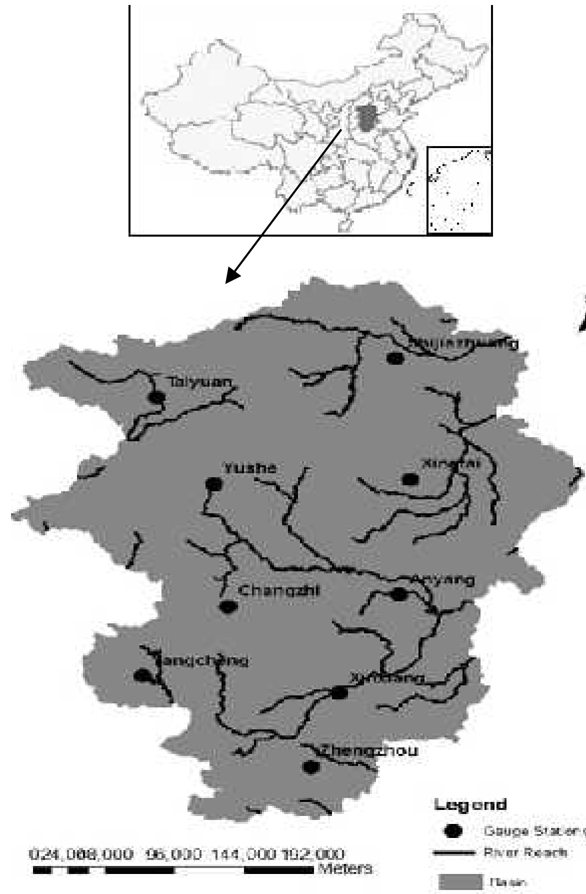

Figure 1: Map of study Area.

RESULTS AND DISCUSSION

In our study, we analyzed the series of annual mean of air temperature, precipitation, relative humidity, wind velocity and solar radiation.

Trends in Annual mean of Temperature: From 1980 to 2010 trends in annual mean of the meteorological variables were recorded at all the stations as shown in Tables 2 - 6. Table 2 shows positive trend in mean temperature. Zhengzhou has maximum temperature during 2002 (30.4 c°) and 2010 (29.7 c°). 2002 and 2010 were the warmest years in the series. Different trends were observed in minimum temperature as compared to maximum temperature. Annual minimum temperature increased from 1980 up to 1983, this trend declined afterwards. Maximum trend in minimum temperature (115.1 c°) was detected in Xinxiang station during 2010. Hence, increasing trends in both T_{max} and T_{min} series increased evapotranspiration and dry conditions. Increasing global warming has led to more frequent and severe droughts. Our finding is in line with the findings of Piao *et al*. (2010) and Yang *et al*. (2013).

Trends in Annual mean of Precipitation: Precipitation followed negative trend (Table. 3). It is evident that all stations faced shortage of rain fall leading to drought conditions during period under study. All stations demonstrated negative trends at varying intensity and Frequency. Xingtai station was the most affected station from 1980 to 1994. While upward and downward trends were detected in the annual maximum precipitation. Zhengzhou was most affected by drought (-12.3 mm) in 2004 where annual rainfall amount dropped to the minimum. Anyang station appeared to have more precipitation (12 mm) during 2000. Two stations revealed to have positive trend in annual minimum precipitation over the period 1980-2010. One is Shijiazhuang (9.8 mm) in 1996 and second station is Zhengzhou (1.3 mm) in 2004. Except these two stations remaining all stations revealed negative trend in the annual minimum precipitation. Maximum negative trends appeared in Changzhi (-31.7.mm) in 2010, Taiyuan (-32.8 mm) in 1982 and Shijiazhuang station faced drought conditions. 1982, 2000 and 2010 were worst years with respect to lack of precipitation which resulted in drought in these stations. All the factors impact climate which in turn affects agriculture and its productivity due to differences in soil type, production technology and ecological system.

Trends in Annual mean of solar radiation: Table 4 exhibits trends in solar radiation and sunshine hours. Yangcheng showed maximum solar radiation (107 mj/m^2/day) during 1980. Anyang and Changzhi were having maximum solar radiations and sun hours (723 mj/m^2/day) in 1985 and (9631.3 mj/m^2/day) in 1996 respectively. The mean maximum annual solar radiation shows increasing trend in Changzhi during 1996 (7409.1 mj/m^2/day). On the other hand mean of annual minimum solar data shows smooth positive trend throughout the study period. It maintains two peaks, one with a minimum solar radiation in Changzhi (24.2 mj/m^2/day) during 1981 and second with minimum solar data in 1996 (19.6 mj/m^2/day) at Zhengzhou weather station. Warmer climate could lead to increasing droughts.

Trends in Annual mean of Humidity: Table 5 shows positive trends in humidity on annual mean basis. These trends increased and decreased over the period but from 1980 to 1994 Xinxiang and Zhengzhou stations revealed drastic trends in mean humidity. Anyang revealed maximum humidity (0.7 %) in 2003. Yearly mean of maximum humidity rate indicates an increasing trend. Minimum mean for humidity shows positive trend in Zhengzhou in 1984 (0.8 %).

Trends in Annual mean of Wind Velocity: Mean annual wind velocity trend is represented in Table. 6. This trend increased from 1980 to 1981 and decreased afterwards (1981 to 1991) except Zhengzhou. Maximum wind velocity appeared in Anyang (2.9 m/sec) in 2002. Changes in atmospheric conditions result in changes in wind velocity. Annual maximum mean of wind velocity rises slightly between 1980 and 1983. During this period Changzhi station revealed maximum wind velocity (4.3 m/sec). Annual minimum mean of wind velocity shows increasing and decreasing trends from 1980 to 1992 at different stations with varying frequency.

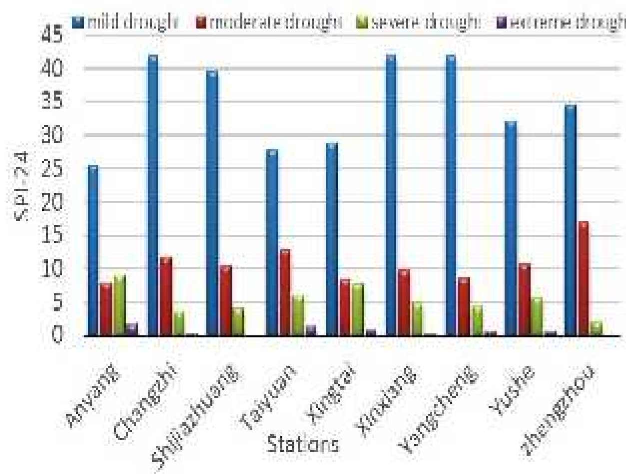

Figure 2. Time series of SPI-24 at nine stations during the period 1980-2010

Analysis of SPI-24 time scale with different meteorological variables: The characteristics of drought with time series of SPI-24 at nine stations during the period 1980-2010 are shown in figure 2. It should be noted that the all stations was faced mild drought to severe drought at all nine stations during the study period, while extreme drought appeared at low percentage at eight stations except Zhengzhou station. Figure 2 depicted that mild drought was appeared with high percentage at all stations during the 1980-2010. The serial correlation can improve the verification of the independence of data time series. Autocorrelation plots for SPI-24 time scale with various meteorological variables at nine stations are presented in figure 3.

meteorological variables over the period 1980-2010

Standard Deviation (SD)					Coefficient of Variation (CV %)				
Temp (^{0}C)	Precp (mm)	Solar (mj/m^2/day)	Hum (%)	Wind (m/sec)	Temp (^{0}C)	Precp (mm)	Solar (mj/m^2/day)	Hum (%)	Wind (m/sec)
2.58	6.33	125.74	10.61	0.54	11.43	85.32	79.05	16.28	26.49
2.41	5.98	96.48	13.12	0.56	12.65	97.56	60.21	22.43	26.99
2.51	7.01	110.35	11.85	0.35	11.62	90.62	84.53	19.88	20.75
2.25	6.67	73.00	13.01	0.48	12.23	96.80	82.45	22.53	25.87
2.60	6.73	266.75	11.68	0.40	12.14	78.80	168.6	19.69	24.58
2.22	5.95	66.43	10.14	0.46	9.62	75.29	88.54	15.26	23.52
2.41	6.80	35.55	12.53	0.44	11.24	77.77	58.64	20.69	25.86
2.26	6.35	76.39	13.37	0.35	12.27	81.07	93.62	23.30	22.81
2.44	6.19	56.23	10.60	0.47	10.02	75.91	69.91	16.46	20.36

ature (c°) over the period 1980-2010

82	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
.99	27.11	26.36	25.95	27.56	28.59	27.00	27.08	26.91	27.16	27.83	28.38	28.34	26.94	27.28	28.37	28.53	27.25	27.19	27.12	28.73	26.94	27.34	26.69	27.81	26.88	27.98	28.36	26.73
.30	23.44	23.08	22.71	23.79	25.08	24.11	23.16	23.23	24.08	24.44	24.11	24.91	24.19	24.57	25.13	25.62	24.68	24.20	23.64	25.72	24.13	24.73	23.85	24.14	23.93	24.40	24.58	26.73
.04	26.73	26.17	26.04	26.94	28.80	26.61	26.91	25.13	26.71	27.66	27.53	27.31	26.86	27.58	28.30	29.31	27.43	27.13	27.68	29.10	27.31	27.23	27.13	27.54	27.53	27.68	28.61	26.94
.80	23.14	22.71	22.87	22.93	24.78	22.62	23.03	23.73	24.50	24.48	24.10	24.75	23.64	24.05	25.28	25.94	25.18	23.87	23.64	26.13	23.92	25.33	24.59	25.66	24.00	24.88	25.50	26.04
.37	27.15	26.78	26.37	27.10	28.96	27.17	27.09	26.05	27.31	27.94	28.46	27.56	27.43	27.53	28.13	28.98	27.36	26.93	27.58	29.51	26.73	27.97	27.48	28.01	27.23	28.13	28.77	27.29
.75	26.95	26.54	26.13	26.94	27.99	26.79	27.03	26.52	26.78	27.81	27.81	28.16	27.13	27.16	28.51	28.16	27.00	27.01	27.03	29.05	27.23	27.63	26.78	28.26	27.88	28.21	28.53	27.96
.38	24.44	24.18	24.07	25.05	26.03	24.35	24.64	24.69	25.34	25.68	25.69	26.28	25.46	25.18	26.24	26.45	26.34	25.59	25.49	27.76	25.65	26.32	25.74	25.62	25.96	25.77	26.62	26.28
.65	22.35	22.16	22.04	23.04	24.34	22.22	22.54	22.33	23.53	23.98	23.42	23.92	23.15	24.02	24.63	25.15	24.15	23.94	23.23	25.79	23.68	24.48	24.14	24.43	23.24	24.18	24.74	24.96
.21	27.09	27.05	26.49	28.17	28.92	28.29	22.54	27.19	27.52	28.40	29.16	28.96	27.80	27.96	28.98	29.07	28.21	27.68	28.01	30.43	27.71	28.85	27.45	28.54	28.62	29.13	29.41	29.70

ation (mm) over the period 1980-2010

32	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
12	-7.23	-10.32	-6.44	-8.97	-8.80	-9.95	-9.89	-9.12	-8.13	-8.75	-6.84	-7.83	-6.68	-8.28	-9.19	-9.54	-6.51	-7.91	-10.61	-6.05	-6.86	-5.60	-3.63	-4.70	-5.19	-4.29	-5.70	-7.25
11	-8.12	-4.24	-6.36	-9.92	-7.28	-5.95	-8.26	-6.78	-7.03	-5.14	-3.78	-3.15	-3.38	-4.65	-9.20	-9.87	-6.22	-4.60	-7.10	-4.93	-3.95	-5.84	-6.68	-4.19	-4.67	-7.29	-10.61	-8.27
58	-7.92	-9.50	-11.07	-9.70	-6.96	-12.32	-8.09	-10.29	-6.11	-10.41	-10.50	-7.96	-6.48	-3.80	-6.94	-10.34	-4.82	-7.57	-10.31	-6.32	-7.46	-7.17	-8.78	-6.24	-6.08	-6.96	-5.11	-9.16
63	-8.63	-7.40	-9.13	-8.98	-8.20	-11.44	-10.18	-7.43	-6.58	-4.04	-7.33	-6.14	-4.38	-3.38	-10.41	-7.63	-7.43	-5.62	-8.50	-5.90	-5.39	-7.06	-5.49	-6.91	-5.81	-6.33	-5.59	-8.75
43	-12.34	-10.67	-12.12	-12.91	-9.72	-11.46	-12.18	-12.63	-9.85	-7.55	-7.06	-11.10	-5.40	-9.07	-7.59	-10.72	-6.93	-7.52	-9.65	-6.56	-6.34	-5.75	-8.89	-8.75	-8.11	-4.88	-4.28	-4.76
27	-8.55	-5.98	-9.95	-7.94	-8.29	-9.79	-10.25	-7.58	-10.50	-4.26	-6.25	-10.15	-8.58	-6.04	-11.02	-11.46	-6.85	-10.66	-10.81	-7.21	-6.85	-5.73	-6.63	-6.77	-7.04	-2.77	-6.78	-4.89
55	-9.20	-7.62	-9.96	-8.84	-6.67	-8.55	-12.78	-10.27	-11.57	-8.04	-8.73	-8.69	-5.42	-8.02	-9.06	-7.17	-6.52	-6.75	-9.68	-6.24	-9.20	-6.74	-6.57	-6.30	-8.59	-7.17	-10.26	-9.83
12	-9.60	-8.97	-10.00	-12.14	-8.80	-14.88	-12.40	-8.93	-8.24	-8.61	-7.27	-7.17	-4.90	-8.79	-10.04	-7.38	-5.48	-5.82	-9.16	-4.06	-7.32	-6.46	-5.47	-7.62	-3.04	-6.07	-6.25	-6.09
22	-4.94	-5.71	-10.23	-10.06	-7.57	-9.31	-12.36	-7.54	-6.78	-5.45	-9.21	-6.70	-9.15	-11.50	-8.41	-10.63	-8.08	-11.20	-9.74	-8.46	-6.86	-5.99	-7.58	-4.34	-9.81	-6.33	-8.00	-6.46

diation (mj/m²/day) over the period 1980-2010

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	102.78	279.70	723.04	197.74	15.46	15.31	14.87	15.28	15.04	15.17	14.39	14.43	15.42	14.00	15.10	13.56	14.43	105.33	14.06	14.15	12.67	13.99	14.02	13.07	12.71	13.35	14.01	13.51
	102.78	14.04	14.95	16.47	16.20	15.00	106.30	15.73	16.00	16.00	15.50	16.26	16.35	631.23	16.07	15.07	16.21	15.78	15.99	16.18	15.10	16.29	16.55	15.94	15.52	15.69	15.60	15.02
1	545.65	15.11	15.35	15.17	16.40	194.40	13.31	102.40	14.91	191.69	15.10	14.20	13.57	14.37	15.51	13.26	14.50	13.88	14.24	15.15	12.27	15.23	14.61	14.70	14.35	14.83	14.74	15.08
	14.74	14.98	14.52	15.82	15.63	14.93	14.84	15.56	15.79	15.28	15.74	15.76	15.96	14.35	15.87	194.90	104.03	197.68	103.37	15.30	14.16	15.31	16.18	14.81	102.54	103.52	15.55	15.26
3	104.02	15.51	102.42	105.22	107.05	191.81	104.16	192.28	15.49	106.14	454.65	15.76	15.11	14.81	16.79	15.61	103.47	14.65	278.99	15.05	192.58	14.32	14.97	289.97	102.03	14.52	189.89	371.52
	106.52	14.43	14.65	15.97	15.09	14.54	13.96	14.52	14.76	14.95	14.25	15.41	15.61	14.03	16.13	15.00	103.46	14.78	105.43	14.69	13.07	14.28	14.59	13.72	101.56	102.53	13.91	14.21
0	15.41	14.51	15.02	16.46	16.24	15.37	15.04	15.63	15.96	16.07	15.71	15.74	16.13	14.70	16.28	15.60	16.27	16.19	104.57	16.69	15.60	16.87	16.91	16.03	15.01	15.59	15.21	14.99
	15.15	15.01	15.20	104.60	16.12	14.92	15.59	15.30	106.18	15.31	15.17	103.81	15.57	14.66	16.19	106.61	15.60	15.28	15.48	15.59	14.45	15.63	103.78	106.09	14.96	14.99	105.41	13.62
0	15.08	14.24	14.83	16.14	103.48	109.10	14.06	14.82	14.61	15.03	14.38	15.05	15.32	13.34	15.08	13.93	14.46	13.84	14.53	13.83	11.60	13.23	13.13	13.49	13.22	13.52	13.66	12.89

y (%) over the period 1980-2010

982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
.64	0.65	0.66	0.67	0.61	0.66	0.60	0.66	0.71	0.67	0.63	0.66	0.65	0.61	0.65	0.64	0.65	0.63	0.66	0.65	0.67	0.75	0.69	0.66	0.68	0.67	0.66	0.69	0.65
.60	0.58	0.62	0.66	0.56	0.63	0.59	0.68	0.68	0.62	0.59	0.62	0.62	0.57	0.60	0.59	0.62	0.58	0.64	0.60	0.60	0.69	0.60	0.59	0.63	0.61	0.58	0.59	0.59
.61	0.61	0.62	0.67	0.61	0.64	0.60	0.65	0.71	0.66	0.59	0.61	0.61	0.58	0.59	0.59	0.62	0.59	0.61	0.60	0.59	0.66	0.54	0.52	0.55	0.59	0.56	0.57	0.55
.59	0.61	0.60	0.62	0.56	0.62	0.59	0.65	0.65	0.62	0.60	0.61	0.60	0.55	0.58	0.56	0.58	0.53	0.57	0.57	0.58	0.66	0.56	0.53	0.58	0.55	0.53	0.54	0.52
.60	0.61	0.62	0.65	0.59	0.65	0.58	0.64	0.68	0.63	0.58	0.62	0.61	0.58	0.59	0.58	0.61	0.61	0.59	0.58	0.58	0.67	0.57	0.54	0.60	0.57	0.54	0.55	0.54
.68	0.67	0.69	0.71	0.67	0.71	0.66	0.71	0.74	0.70	0.67	0.70	0.68	0.67	0.68	0.66	0.68	0.66	0.69	0.67	0.64	0.72	0.65	0.63	0.64	0.63	0.60	0.62	0.62
.62	0.62	0.63	0.63	0.57	0.64	0.61	0.67	0.68	0.63	0.62	0.65	0.63	0.56	0.62	0.59	0.65	0.59	0.64	0.60	0.62	0.69	0.59	0.58	0.62	0.57	0.56	0.55	0.53
.56	0.57	0.58	0.61	0.52	0.58	0.57	0.62	0.65	0.61	0.57	0.59	0.60	0.54	0.58	0.55	0.57	0.53	0.57	0.58	0.59	0.67	0.59	0.56	0.59	0.59	0.57	0.58	0.59
.67	0.67	0.67	0.71	0.64	0.68	0.64	0.70	0.73	0.71	0.67	0.69	0.67	0.62	0.66	0.65	0.68	0.64	0.67	0.64	0.62	0.69	0.62	0.59	0.62	0.60	0.58	0.61	0.56

elocity (m/sec) over the period 1980-2010

982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
.94	1.88	1.67	1.55	1.49	1.75	1.52	1.48	1.63	1.70	2.28	2.41	2.36	2.38	1.94	2.01	2.36	2.83	2.65	2.75	2.97	2.71	2.76	2.30	2.28	2.09	2.00	1.99	1.98
.30	2.45	2.20	1.92	2.03	2.18	2.09	1.90	1.93	1.93	1.93	2.02	2.53	1.89	1.81	2.05	2.03	1.79	1.79	2.31	2.48	2.30	2.08	1.95	1.98	1.86	1.95	2.02	2.13
.98	1.95	1.88	1.89	1.94	1.85	1.77	1.71	1.69	1.72	1.70	1.62	1.52	1.78	1.71	1.52	1.66	1.75	1.63	1.77	1.57	0.98	1.51	1.50	1.45	1.43	1.45	1.49	1.50
.94	1.75	1.77	1.65	1.66	1.68	1.71	1.32	1.66	1.86	1.79	1.58	2.17	2.40	2.28	2.13	1.90	1.96	1.86	2.19	1.69	1.32	2.11	2.07	1.99	1.85	1.88	1.70	1.81
.67	1.57	1.42	1.46	1.52	1.59	1.32	1.54	1.62	1.75	1.71	1.72	1.62	2.40	1.59	1.70	1.61	1.77	1.82	1.85	1.73	1.55	1.79	1.78	1.73	1.64	1.66	1.72	1.72
.94	1.95	1.75	1.84	1.64	1.72	1.56	1.43	1.52	1.61	1.91	1.97	2.23	2.09	2.32	2.48	2.32	2.45	2.43	2.37	2.32	2.34	2.36	2.18	2.07	1.97	2.05	2.06	2.10
.91	1.80	1.83	2.01	1.96	1.89	1.80	1.56	1.66	1.64	1.61	1.66	1.82	1.93	1.70	1.67	1.41	1.63	1.37	1.59	1.66	1.59	1.65	1.52	1.51	1.68	1.70	1.74	1.79
.17	1.24	1.21	1.30	1.36	1.41	1.31	1.27	1.29	1.33	1.55	1.63	1.98	1.94	1.86	1.57	1.41	1.43	1.31	1.46	1.47	1.46	1.97	2.08	2.13	2.07	2.11	2.09	2.18
.65	2.50	2.38	2.43	2.29	2.36	2.20	2.13	1.99	1.99	2.15	2.18	2.17	2.25	2.28	2.22	2.28	2.30	2.26	2.33	2.30	2.35	2.22	2.17	2.10	2.03	2.11	2.10	2.17

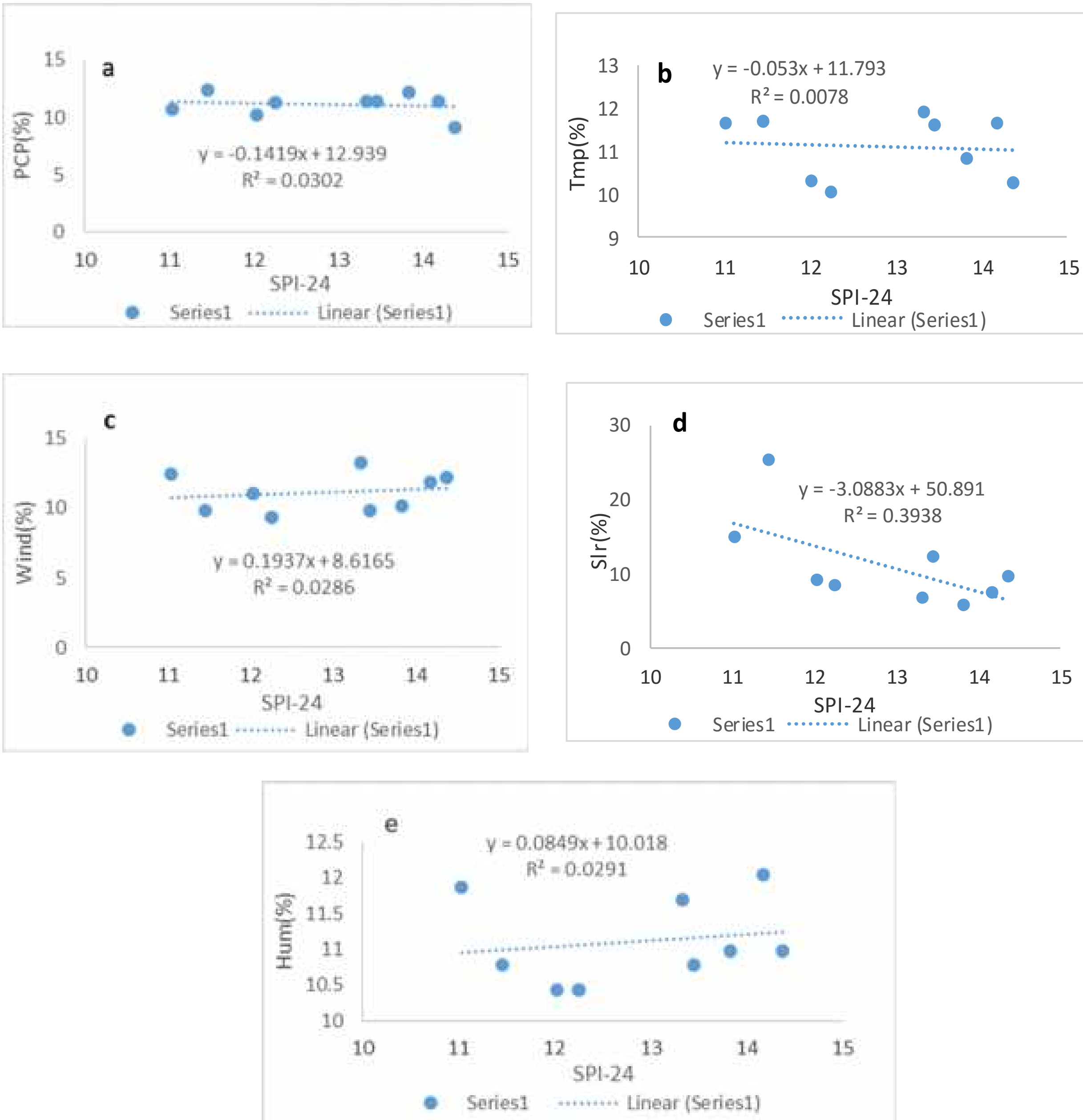

Figure 3. Correlation between SPI-24 and meteorological variables at nine stations

Interestingly, we observed significant relationships between SPI-24 time scale and all meteorological variables. The relationship of SPI-24 with precipitation and wind showed positive correlation (R^2 = 0.0302, $P < 0.05$, R^2 = 0.0286). However, both the variables displayed same direction of relationship and the values influenced that as the SPI-24 increased the precipitation and wind velocity revealed almost at the same direction. The other three variables interpreted positive correlation but were variably different from each other. The solar relationship with SPI was variably distributed, amazingly as the SPI-24 increased the solar radiation increased among the nine drought stations, similarly, the temperature and humidity displayed the variables with SPI to positive selection (R^2 = 0.0078, $P <$ 0.05, R^2 = 0.0291).

Conclusions: The interpretation of annual mean following maximum and minimum data of nine weather stations of China using five major meteorological parameters: precipitation, air temperature, solar radiation, relative humidity and wind speed demonstrated the existence of tremendous variations and different trends in parameters of interest. There was an increasing trend in temperature, solar radiation, humidity and wind velocity in both annual mean series from 1980-2010. However, precipitation analysis demonstrated negative effect trend over the period under study. All these factors contributed to climate change and shortage of rainfall leading to frequent droughts in these stations.

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