Sensors and Materials, Vol. 35, No. 2 (2023) 657–668
MYU Tokyo

S & M 3201

Variations in Droughts and Wet Spells and Their Influence in the Beijing–Tianjin–Hebei Region

Shuang Wu,[1,2,3] Meizi Yang,[4] Tiantian Yu,[1,3] and Bogang Yang[3,5*]

[1]Beijing Institute of Surveying and Mapping, No. 60 Nanlishi Road, Xicheng District Beijing 100038, China
[2]Beijing Normal University, Beijing 100875, China
[3]Beijing Key Laboratory of Urban Spatial Information Engineering, Beijing 100038, China
[4]School of Architecture and Urban Planning, Beijing University of Civil Engineering and Architecture, Beijing 100044, China
[5]Research on the Application of Urban Spatial Big Data Analysis Yang Bogang Staff Innovation Studio, Beijing 100038, China

(Received October 31, 2022; accepted February 6, 2023)

Keywords: wet, drought, distributions, Beijing–Tianjin–Hebei region, climate change

The wetness index (W) was calculated using gridded monthly precipitation and potential evapotranspiration (PET) in the Beijing–Tianjin–Hebei region of China. Meteorological data from 1991 to 2020 were provided by the Climate Research Unit. The change in W and the factors influencing it were analyzed at regional and urban levels. The results show that (1) W of the Beijing–Tianjin–Hebei region fluctuated greatly year by year. W decreased ($p < 0.05$) during the years from 1991 to 2000, rose slightly ($p < 0.05$) from 2001 to 2010, and experienced almost no change in the last decade. (2) In the last two decades, W in some areas of the Beijing–Tianjin–Hebei region increased, probably owing to the increase in precipitation in this area. (3) In the context of climate warming, W values in the Beijing–Tianjin–Hebei region and major cities are affected by precipitation, while temperature has little impact on the values.

1. Introduction

Drought is defined as a 'prolonged absence or marked deficiency of precipitation', a 'deficiency that results in water shortages for some activities or for some groups', or a 'period of abnormally dry weather sufficiently prolonged for the lack of precipitation to cause a serious hydrological imbalance'.(1,2) The impact of recent extreme climate events, such as heat waves, droughts, floods, cyclones and wildfires, indicates that certain ecosystems and many human systems have significant vulnerability and exposure to current climate variability.(3) Many studies show that, in recent years, climate warming has led to frequent disasters, which have had an impact on the economy, society, and environment.(4–6) Drought is one of the worst natural disasters related to climate and costs huge losses to the society and economy.(7)

In recent years, many studies have used meteorological station monitoring, remote sensing, and reanalysis data to evaluate dry and wet conditions in different regions. With the continuous

*Corresponding author: e-mail: bogangy@126.com
https://doi.org/10.18494/SAM4224

ISSN 0914-4935

updating of sensors and the continuous improvement of monitoring quality, the use of monitoring data and remote sensing data is becoming increasingly common. Dai *et al.* in 2004 found that the area of severe global drought (PDSI < −3.0) has been increasing since the 1970s owing to the decrease in precipitation and the increase in temperature.(8) Zhang in 2010 calculated the annual drought area in China using data from meteorological records and showed that the drought area has increased since 1951.(9) From 1954 to 1983, the trend in droughts in North China, Northeast China, Central China, and East China was significant, and the degree of drought was higher than that in other regions.(10) Since the late 1990s, the severity and frequency of drought have become more serious,(11,12) and the area of drought has increased by about 3.72% every decade.(12) Two serious droughts(13) occurred in the North China Plain in 1962–1963 and 2010–2011. Xu *et al.* in 2015 found that the reduction in precipitation was the main reason for drought in the region.(14)

Many studies have been carried out on drought and wet indicators and methods for their evaluation.(1) Owing to different objectives, geographical locations, and time periods of these studies, significant differences exist in the applicability of drought and wet indicators to regional levels and over various time scales.(15) According to existing research, drought and wetness indicators can be divided into two categories. One category is based on the principle of drought, comprehensively considering physical processes (e.g., soil moisture evaporation, surface runoff, surface water supply, and surface heat flux) to improve the accuracy of the determination of drought strength and duration. The other category is based on meteorological methods that consider precipitation, temperature, potential evapotranspiration (PET), and other meteorological factors to reflect the intensity and duration of drought. Common indicators are the standardized precipitation index,(16) composite index,(17) and wetness index (W).(18) Wu and Yan have elaborated the advantages and disadvantages of these methods. Most studies focus on the watershed or national scale, but few on city clusters.(19) Therefore, we used W to analyze the change in drought and the mechanism of impact of drought in the Beijing–Tianjin–Hebei (JingJinJi) region from 1991 to 2020. We examined the influence of various meteorological conditions on regional changes in wetness and drought.

2. Materials and Methods

2.1 Study area

The JingJinJi region is in the North of China and includes Hebei Province, Beijing, and Tianjin (Fig. 1). The region has temperate semi-humid and semi-arid monsoon climate and is dominated by mountains and plains. There are 12 municipalities and prefectural cities under the jurisdiction of the region. By the end of 2021, four cities had a permanent resident population of more than 10 million, namely, Beijing, Tianjin, Shijiazhuang, and Baoding. The total population of the four cities had reached 58.2579 million, accounting for more than 50% of the total population of JingJinJi. In recent years, the total economic output of the JingJinJi region has increased nearly threefold, from 2298.494 billion yuan in 2006 to 6835.014 billion yuan in 2019.

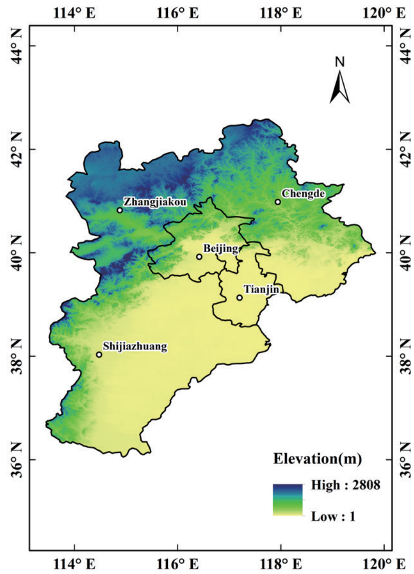

Fig. 1. (Color online) Map of digital evaluation in JingJinJi.

2.2 Meteorological data

In 2020, Harris *et al.* updated the gridded climate dataset with high-resolution data (referred to as CRU TS 4.06) from monthly observations at meteorological stations across world's land areas, which was then released by the Climatic Research Unit at the University of East Anglia[20]. This dataset provides mean monthly data on ten surface climate variables from January 1901 to May 2022, the spatial resolution of which is 0.5 × 0.5 degrees (about 50 km). These variables are mean temperature (TMP), maximum temperature (TMX), minimum temperature (TMN), diurnal temperature range (DTR), frost day frequency (FRS), precipitation (PRE), potential evapotranspiration (PET), vapor pressure (VAP), wet day frequency (WET), and cloud cover (CLD). The sources of the data were the World Meteorological Organization (WMO) and the US National Oceanographic and Atmospheric Administration [NOAA, via its National Climatic Data Center (NCDC)]. It is worth noting that the sources of data include 160 climate base stations providing observational data released by the National Climate Center of China. The meteorological observation instruments at these stations use a variety of sensors, which is not only of great significance to the development of sensors but also provides a basis for the application of remote sensing observation in the meteorological field. PET data, analyzed in this paper, were obtained from CRU TS 4.06 and derived from half-degree gridded absolute values of TMP, TMN, TMS, VAP, and CLD. These gridded values were calculated using the Penman–Monteith method, which is provided by the Food and Agricultural Organization (FAO); the values were used to estimate PET at the same resolution.

In this study, we divided the time series (from 1991 to 2020) into three periods and analyzed the temporal and spatial distributions of PET during these three periods. Each period was 10 years in length: 1991–2000 (P1), 2001–2010 (P2), and 2011–2020 (P3).

2.3 Identification and calculation of W

W was defined by Ci and Wu in 1997 on the basis of the definition of the United Nations.[18] They identified W as a measure of the potential incidence of desertification in China. In the past ten years, many people have used and improved using this concept. In 2004, Liu used this index to study drought and wetness changes in China and Central Asia and separated the area into five climate regions.[21] Mao *et al.* in 2008 used the FAO-56 Penman–Monteith equation instead of the Thornthwaite equation to calculate PET, which produced a favorable evaluation for the Qinghai-Tibet Plateau.[22] After that, W, which was improved by Mao, was used at the national scale by Shen *et al.*[23] and Zhao *et al.*[24] Compared with the traditional W in China, W calculated using the Penman–Monteith equation better portrays current dry and wet conditions, especially in very humid and very dry Northeast China.[23] The equation for the calculation is

$$W = \frac{PRE}{PET}. \quad (1)$$

Here, W is the wetness, PRE is the precipitation in mm/month, and PET is the potential evapotranspiration in mm/month.

2.4 Contributions of meteorological factors

With the multiple regression model, relative contributions of the independent meteorological variables for W are defined by:

$$W = a_{PET}PET + a_{PRE}PRE + a_{TMP}TMP, \quad (2)$$

$$\eta_i = \frac{|a_i|}{|a_{PET}| + |a_{PRE}| + |a_{TMP}|}, \quad (3)$$

where W is the dependent variable; *PET, PRE,* and *TMP* are independent variables; *aPET*, *aPRE*, and *aTMP* are regression coefficients; η_i is the relative contribution; and i = *PET, PRE,* and *TMP.*

3. Results and Discussion

3.1 Annual W

By calculating the anomaly value of W in the JingJinJi region from 1991 to 2020, we found that W gradually decreased (the region became drier), and from 2001 to 2010, the region was dry for most of the time. Compared with previous years, the degrees of wetness in 2003 and 2016 were higher than those in normal years (Fig. 2).

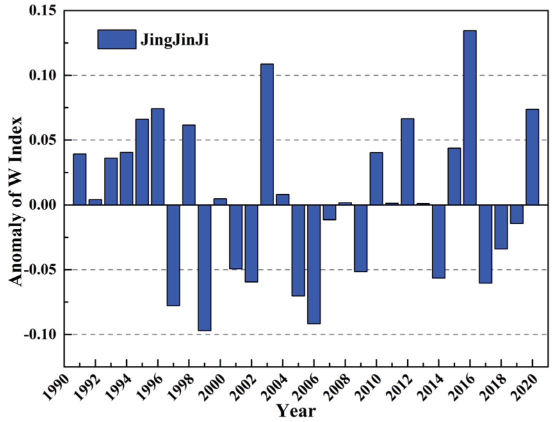

Fig. 2. (Color online) Anomaly value of W in JingJinJi region from 1991 to 2000.

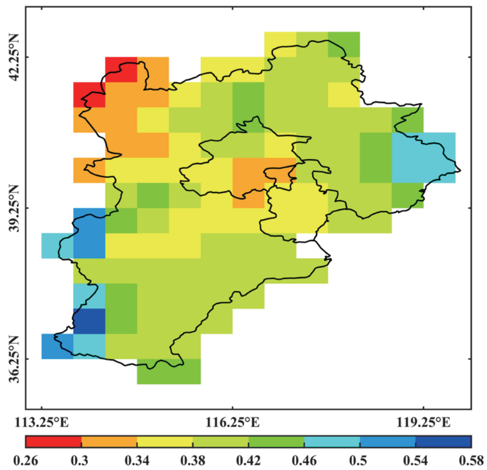

Fig. 3. (Color online) Multi-year averaged W from 1991 to 2020.

The multi-year averaged W in JingJinJi (Fig. 3) shows that W of most areas in JingJinJi was between 0.34 and 0.42, a value belonging to semi-arid areas, which is consistent with the results of the studies by Shen *et al.*(23) and Wu and Yan.(19) W in the northwest and central regions of JingJinJi was lower than that in the other regions ($W < 0.34$), while W in the southwest and eastern regions was higher ($W > 0.46$).

3.2 Drought and wet variations in different periods

3.2.1 Trend of decadal drought and wetness in JingJinJi

Through an analysis of the tendency for dry and wet changes in the JingJinJi region in different time periods, we found that all areas in the JingJinJi region showed a drying trend to varying degrees from 1991 to 2000, with the most significant drought in the west of Shijiazhuang ($p < 0.05$). From 2001 to 2010 and from 2011 to 2020, varying degrees of dry and wet changes occurred in the region. The difference is that, from 2001 to 2010, the degree of wetness in most areas from the northeast to the southwest of JingJinJi increased, while that in other areas decreased, especially in the northwest of JingJinJi near Zhangjiakou. From 2011 to 2020, the degrees of dryness and wetness in the north of the region increased by 0.04–0.06, especially in the area near Chengde. The dryness and wetness in other regions decreased to varying degrees, especially in the central JingJinJi region (Fig. 4).

3.2.2 Trends of decadal drought and wetness in different cities

On the basis of the geographical distribution of major cities in JingJinJi and the number of urban permanent residents and their economic level, we selected five cities, Beijing, Tianjin, Shijiazhuang, Zhangjiakou, and Chengde, and analyzed the trends of changes in dryness and wetness at the urban level (Fig. 5): (1) From 1991 to 2020, W fluctuated between 0.22 and 0.58.

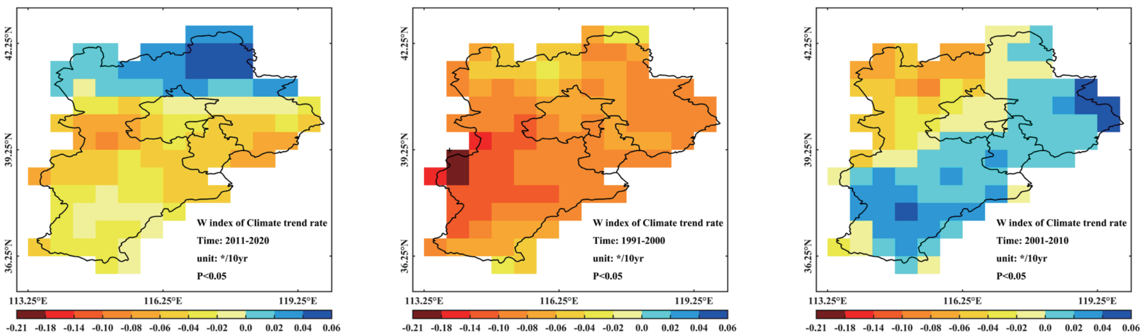

Fig. 4. (Color online) Decadal trend of W in different periods.

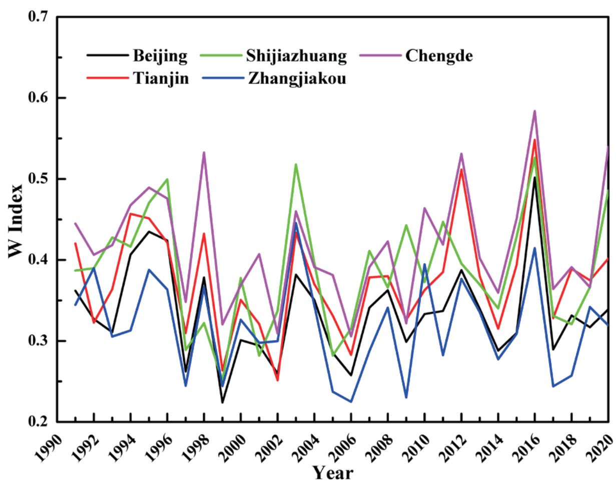

Fig. 5. (Color online) Annual W of each city.

Over the past 30 years, W fluctuated frequently and showed no obvious trends in changes in dryness and wetness. The mean values of W in Beijing, Tianjin, Shijiazhuang, Zhangjiakou, and Chengde were 0.3345 ± 0.0581, 0.3752 ± 0.0660, 0.3854 ± 0.0708, 0.3181 ± 0.0577, and 0.4177 ± 0.0703, respectively. (2) During 1998, 2003, and 2017, the dryness and wetness of the five cities showed significant increases (humidification). (3) Although the overall trends in the changes in the dryness and wetness of the five cities were basically the same over the past 30 years, there were some occasional differences or opposite trends in the dryness and wetness in the five cities in some years.

By analyzing the anomalies in W for the five cities (Fig. 6), we found that (1) W of JingJinJi in 2003 and 2016 was significantly higher than that of normal years; the anomaly values were more than 0.1. However, the W values of Shijiazhuang and Zhangjiakou in 2003 were high and

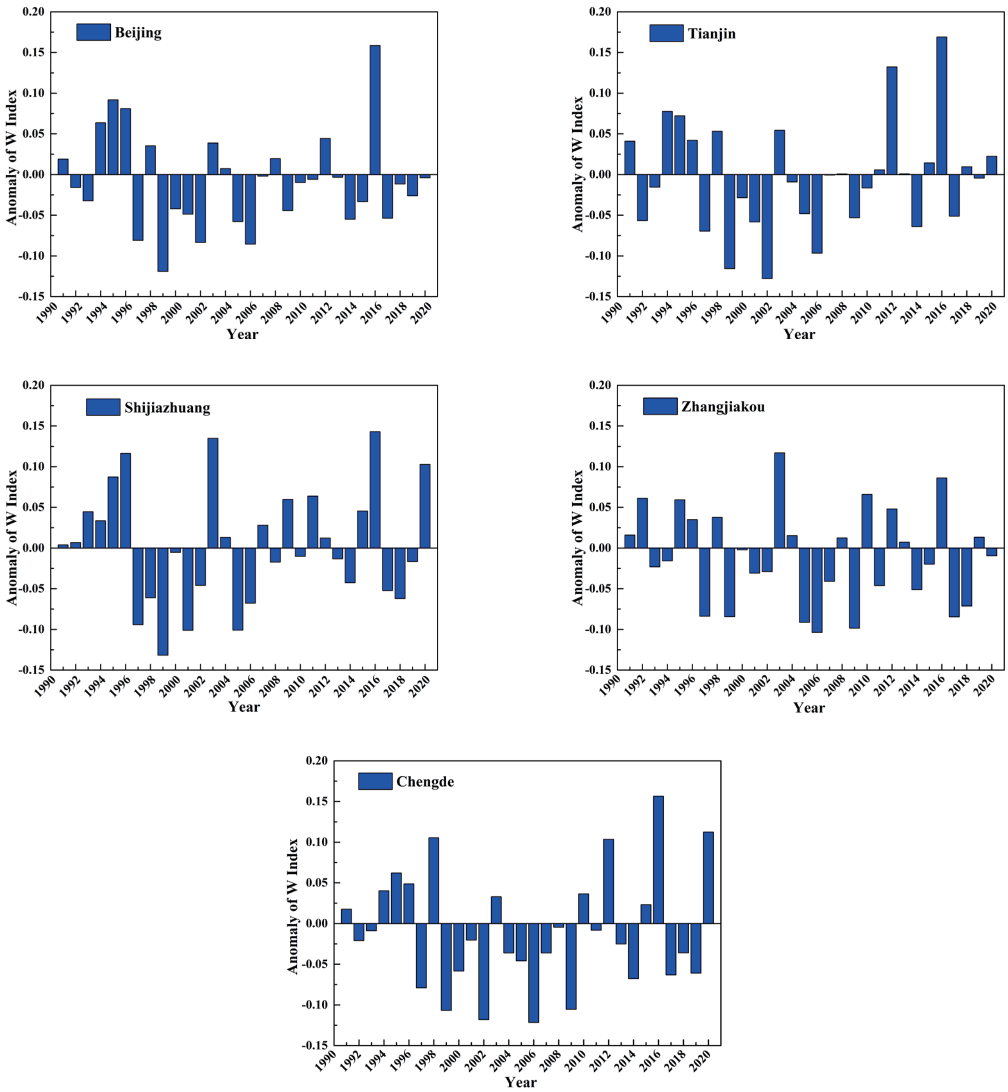

Fig. 6. (Color online) Anomalies in W of five cities (1991–2000).

consistent with the anomaly in the W of JingJinJi. Although W was high in other regions, its range was very small. In 2016, the deviation in W values of the other four cities was consistent with that of JingJinJi, except for Zhangjiakou, where the deviation in W was 0.086. (2) The analysis results indicated that the deviations in W in Zhangjiakou in 2011 and 2019 were in the opposite direction to that of the other cities.

3.3 Influence of meteorological factors on drought and wetness

3.3.1 Influence of various factors on W in JingJinJi

We calculated the annual averages of different meteorological factors and their trending changes over the same time period (Fig. 7). We also analyzed the impact of various meteorological elements on W and determined the factors that affect the drought and wetness changes in the region and cities during the recent 30 years (Table 1). It is worth noting that,

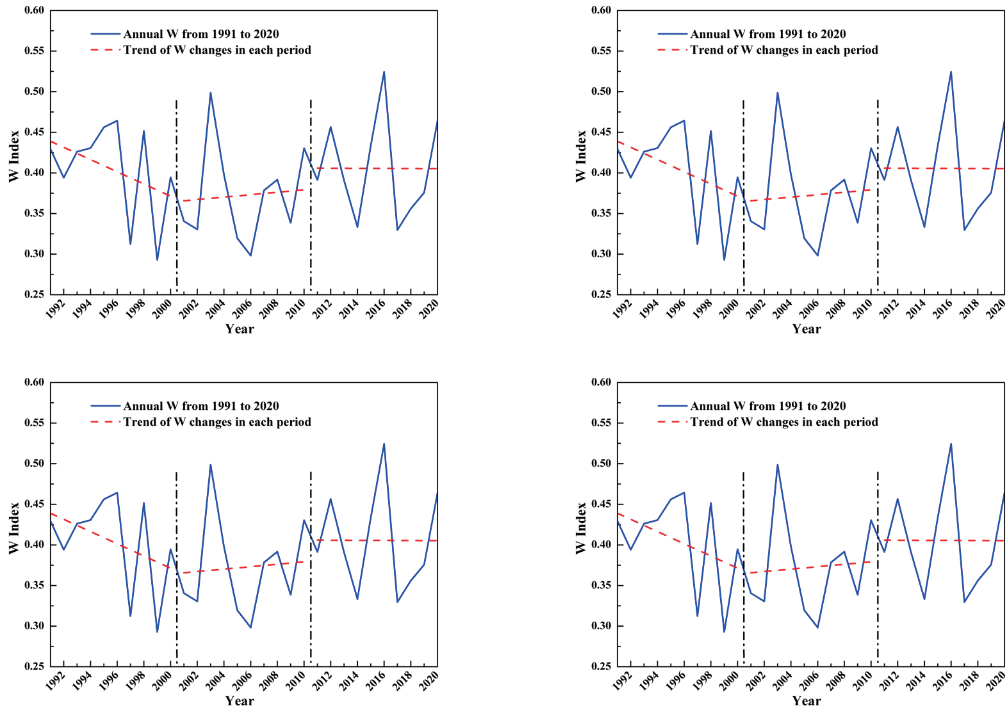

Fig. 7. (Color online) Annual averages of W, PRE, PET, and TMP in JingJinJi.

Table 1
Contribution of meteorological factors to W (%).

	1991–2000	2001–2010	2011–2020
PET	23.04	11.40	3.61
PRE	61.54	78.53	89.31
TMP	15.41	10.07	7.08

because W was between 0 and 1, while the values of PRE, PET, and TMP were greater than 1, or even greater than 1000, the large difference in magnitude makes the results of analyzing the impact of meteorological factors statistically insignificant. Therefore, PRE, PET, TMP and W were standardized using a normalization method before calculating the total contribution of meteorological factors, so that the dimensions were unified.

On the basis of these results, we found that the change in PRE was the main reason for the change in W, and the influence of PRE on changes in dryness and wetness in the region is gradually increasing. Although TMP showed a significant upward trend, its degree of influence was the lowest.

3.3.2 Influence of various factors on W in five cities

The annual values of W, PRE, PET, and TMP of each city show that (1) the degrees of dryness and wetness of each city were similar, and the degree of wetness over the last ten years going from highest to lowest values was observed in Chengde, Tianjin, Shijiazhuang, Beijing, and Zhangjiakou. (2) Although the temperature of each city showed a significant upward trend over the recent 30 years, the changes in dryness, wetness, and precipitation were highly consistent (Fig. 8). (3) The magnitude of and changes in PRE over time in each city were the same as those in W. The difference was that the TMP and PET of Zhangjiakou and Chengde

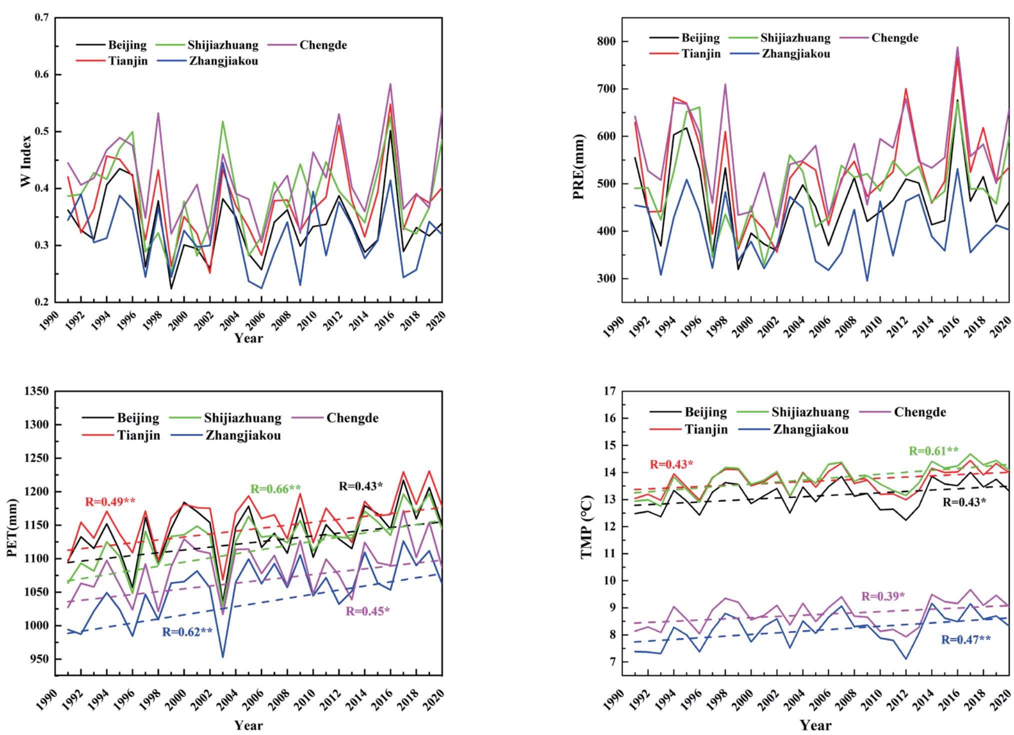

Fig. 8. (Color online) Annual W, PRE, PET and TMP in five cities.

Table 2
Contribution of meteorological factors to W of five cities (%).

	Beijing	Tianjin	Shijiazhuang	Zhangjiakou	Chengde
PET	3.89	5.62	7.35	10.36	4.40
PRE	92.30	90.93	81.19	75.32	93.95
TMP	3.80	3.45	11.45	14.32	1.65

were lower than those of other regions because these two cities are located in the northwest and northeast regions of the Beijing– Tianjin– Hebei region, which are at a higher altitude. Zhangjiakou is short of water resources, while Chengde has a relatively developed water system. Although Chengde has a low temperature, it is more humid than other cities, while Zhangjiakou has the lowest humidity.

From the contribution of each meteorological factor to W (Table 2), we found that (1) precipitation is the main factor affecting W in all cities, which is consistent with the results in the JingJinJi region. (2) Ninety percent of changes in dryness and wetness in Beijing, Tianjin, and Chengde were due to precipitation, while the dryness and wetness changes in Shijiazhuang and Zhangjiakou were slightly less affected by precipitation (about 75–81%), and the next greatest contributor in these two cities was TMP.

4. Conclusions

We analyzed the changes in conditions of drought and wetness in the Beijing–Tianjin–Hebei region over the recent 30 years and determined the meteorological factors affecting these changes. We found the following:

(1) W in the northwest and central areas of the Beijing–Tianjin–Hebei region was lower than that in other areas ($W < 0.34$), while W in the southwest and eastern areas was higher ($W > 0.46$). W in this entire region fluctuated greatly year by year. From 1991 to 2000, W decreased significantly, and from 2001 to 2010, W increased slightly ($p < 0.05$). In the last ten years, there was almost no change in the value.

(2) The spatial analysis of the ten-year trend of W in the Beijing–Tianjin–Hebei region showed a decreasing trend in W from 1991 to 2000. In the most recent 20 years, W of some regions gradually increased, which was primarily caused by the increase in precipitation in the region. At the same time, the influence of precipitation on W in the region gradually increased.

(3) In the context of climate warming, the temperature increase in the Beijing–Tianjin–Hebei region and its major cities in the most recent 30 years was not the main meteorological factor affecting the changes in dryness and humidity. Precipitation plays a decisive role in influencing the degree of change in W in the areas studied.

In future work, changes in dryness and wetness in the Beijing–Tianjin–Hebei region in 2060 will be simulated on the basis of the meteorological data of nearly 30 years, and the results, combined with remote sensing data, will impact the urban development planning for this region.

Acknowledgments

This research was supported by the Beijing Postdoctoral Research Foundation (2022-EE-096), by the Beijing Key Laboratory of Urban Spatial Information Engineering (20220107), and by the State Key Laboratory of Geo-Information Engineering and the Key Laboratory of Surveying and Mapping Science and Geospatial Information Technology of MNR, CASM (2022-04-05).

References

1 R. R. Jr. Heim: Bull. Am. Meteorol. Soc. **83** (2002) 1149. https://doi.org/10.1175/1520-0477-83.8.1149
2 Core Writing Team, R. K. Pachauri, and A. Reisinger: Climate Change 2007: Synthesis Report (IPCC, Geneva, Switzerland, 2007). http://www.ipcc.ch/report/ar4/
3 Core Writing Team, R. K. Pachauri, and L.A. Meyer: Climate Change 2007: Synthesis Report (IPCC, Geneva, Switzerland, 2014). http://www.ipcc.ch/report/ar5/
4 Y. Ding, M. Mu, J. Zhang, J. Tong, and S. Zhang: Climate and Environmental Change in China: 1951–2012 (Springer, Berlin, Heidelberg, 2016) pp. 69–92. https://doi.org/10.1007/978-3-662-48482-1_4
5 Z. Shi: Open Access Library J. **5** (2018) 1. https://doi.org/10.4236/oalib.1104934
6 V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou: Climate Change 2021: The Physical Science Basis (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2021). https://doi.org/10.1017/9781009157896, https://www.ipcc.ch/report/ar6/wg1/
7 C. A. Woodhouse and J. T. Overpeck: Bull. Am. Meteorol. Soc. **79** (1998) 2693. https://doi.org/10.1175/1520-0477
8 A. G. Dai, K. E. Trenberth, and T. Qian: J. Hydrometeorol. **5** (2004) 1117. https://doi.org/10.1175/JHM-386.1
9 D. E. Zhang: Chin. J. Nat. **32** (2010). 213. https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CJFD&dbname=CJFD2010&filename=ZRZZ201004007&uniplatform=NZKPT&v=P94p8xMaSn4FlDnH18LnkMfzOUYr0B4yy2L7EQ5amKGKZxUZG4BOSUzNFw1b48as
10 S. Wu, L. B. Wang, Q. X. Cai, and X. D. Yan: Phys. Chem. Earth. Parts A/B/C/ **116** (2020) 1. https://doi.org/10.1016/j.pce.2020.102838
11 X. Zou, P. Zhai, and Q. Zhang: Geophys. Res. Lett. **32** (2005) 1. https://doi.org/10.1029/2004GL021853
12 M. Yu, Q. Li, M. J. Hayes, M. D. Svoboda, and R. R. Heim: Int. J. Climatol. **34** (2014) 545. https://doi.org/10.1002/joc.3701
13 L. C. Song: Yearbook of Meteorological Disasters in China (China Meterological Press, 2004).
14 K. Xu, D. Yan, H. Yang, Z. Li, Y. Qin, and Y. Shen: J. Hydrol. **526** (2015) 253. https://doi.org/10.1016/j.jhydrol.2014.09.047
15 W. Yuan and G. Zhou: Acta Phytoecologica Sin. **28** (2004) 523. https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CJFD&dbname=CJFD2004&filename=ZWSB200404010&uniplatform=NZKPT&v=rsNWdAJzwTANYMU0iFnyqyjB0cS9Y6MzVW_bNgDIEun1fyrGBpW1GdGfE4izi2Ir
16 T. B. Mckee, N. J. Doesken, and J. Kleist: Proc. 8th Conf. Applied Climatology (Am Meteor Soc, Boston, 1993) 179–184.
17 Q. Zhang, X. Zou, and F. Xiao: Classification of Meteorological Drought, GB/T 20481-2006 (China Standardization Association, 2006).
18 L. Ci and B. Wu: J. Desert Res. (1997) 107. https://kns.cnki.net/kcms/detail/detailaspx?dbcode=CJFD&dbname=CJFD9697&filename=ZGSS702.000&uniplatform=NZKPT&v=ISCtj3IW5VJeA_uWuihYzOrudvxWN-fPEQtuES6Tqx_GvvdEPZEQrnOroahrz9i3
19 S. Wu and X. D. Yan: Theor. Appl. Climatol. **135** (2019) 623. https://doi.org/10.1007/s00704-018-2405-9
20 I. Harris, T. J. Osborn, P. Jones, and L. David: Sci. Data **7** (2020) 109. https://doi.org/10.1038/s41597-020-0453-3
21 A. Liu: Remote Sensing Monitoring of Desertification in China and Central Asia (PhD Dissertation. Institute of Remote Sensing Applications, Chinese Academy of Sciences, 2004).
22 F. Mao, S. Tang, H. Sun, and J. Zhang: Chin. J. Atmos. Sci. **3** (2008) 499. https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CJFD&dbname=CJFD2008&filename=DQXK200803006&uniplatform=NZKPT&v=Iz23IHydOnnnKJWFEFufO4p4UdnPNdZ42QhP9XJsT_BoeW_tKjjKoYWcUBbxVgrj

23 S. Shen, F. Zhang, and Q. Sheng: Trans. Chin. Soc. Agric. Eng. **25** (2009) 11. https://kns.cnki.net/KXReader/Detail?invoice=n5YCi2X0XjYLOOaWUPn2Lg7kFdq%2F3WG%2FY2fXfxi8uPdtJYtq5vttuEygi32Kfux%2Bnf%2FHEG09lhBMN1MA0K0%2Btq0F3wmw0p9T47hd%2BzVpe3fkKI2RULqyUNdEhrVjKBOcQeCokfnDxS%2Bpe%2BwzJh45tbwY7FghugUc5isVzpdBTIE%3D&DBCODE=CJFD&FileName=NYGU200901006&TABLEName=cjfd2009&nonce=F3390E09039D4217A218F7182060AF12&uid=&TIMESTAMP=1670227450439
24 J. F. Zhao, J. P. Guo, J. W. Xu, F. Mao, X. G. Yang, and Y. H. Zhang: Trans. Chin. Soc. Agric. Eng. **26** (2010) 18. https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CJFD&dbname=CJFD2010&filename=NYGU201008005&uniplatform=NZKPT&v=BYpwk_-lElhLxYHipHfUrG5AnRW612X7fndeqtln0npjiYcrU_Eb0jU97Yu_WfD8

About the Authors

Shuang Wu received her B.S. and M.S. degrees from Harbin Normal University, China, in 2011 and 2014, respectively. She received her Ph.D. degree from the Beijing Normal University, China, in 2021. Since 2021, she has been working at the Beijing Institute of Survey and Mapping. Her research interests are in urban spatial analysis, climate change, and sensors. (Shuang_1988@hotmail.com)

Meizi Yang received her B.E. degree from Beijing University of Civil Engineering and Architecture, China, in 2019, and her M.S. degree from the University of Texas at Austin, USA, in 2020. Since 2021, she has been a Ph.D. candidate at Beijing University of Civil Engineering and Architecture. Her research interests are in urban design, urban planning, environment, and sensors. (meiziy777@163.com)

Tiantian Yu received her B.S. degree in computer science and technology from Beijing University of Aeronautics and Astronautics. She has been engaged in the production of new construction data monitored by street view image technology, 3D modeling, warehousing of underground pipelines, and urban fine 3D modeling.

Bogang Yang received his Ph.D. degree from Beijing Forestry University, China, in 2006 and was engaged in postdoctoral work at Peking University from 2007 to 2009. Since 1983, he has been working at the Beijing Institute of Survey and Mapping, and since 2004, he has been a professor level senior engineer. He is the Director of the Beijing Key Laboratory of Urban Spatial Information Engineering. His research interests are in surveying and mapping technologies, smart city construction, and urban spatial analysis. (bogangy@126.com)