天津百年均一化气温日值序列的构建

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长年代连续的日值观测资料是研究百年来极端气候事件及其变化特征的重要基础支撑。本文基于天津市气象档案馆馆藏的三类数据源：1）天津英租界工部局工程处记录的1890年9月1日—1931年12月31日；2）华北水利委员会测候所记录的1932年1月1日—1950年12月31日；3）天津地面气象观测数据月报文件提取的1951年1月1日—2019年12月31日地面日最高和最低气温观测记录，通过数据延长插补和质量控制，建立了天津1887—2019年（最低气温1890年以来)完整且连续的逐日最高和最低气温基础序列。利用惩罚最大t检验（PMT），通过美国伯克利地球研发中心的月平均地表温度数据（Berkeley Earth）、英国东英格利亚大学气候研究中心的全球月平均地表温度数据（CRUTS4.03）以及美国国家气候资料中心的全球历史气候数据（GHCNV3）建立的参考序列，对建立的逐日基础序列进行均一性检验，并采用分位数匹配法(QM)对检验得到的统计显著断点进行了订正，由此建立了天津地区百年尺度均一化逐日气温序列。基于构建的逐日最高和最低气温序列统计得到，天津近130年以来年平均气温增暖趋势为0.154±0.013℃/10a（95%不确定性水平估计），极端温度事件的趋势变化相对均一化订正前更具一致性，年平均冷夜日数（TN10p）、暖夜日数（TN90p）、冷昼日数（TX10p）、暖昼日数（TX90p）的变化趋势分别为-1.454 d/10a、1.196 d/10a、-0.140 d/10a、0.975 d/10a，均通过95%显著性检验。

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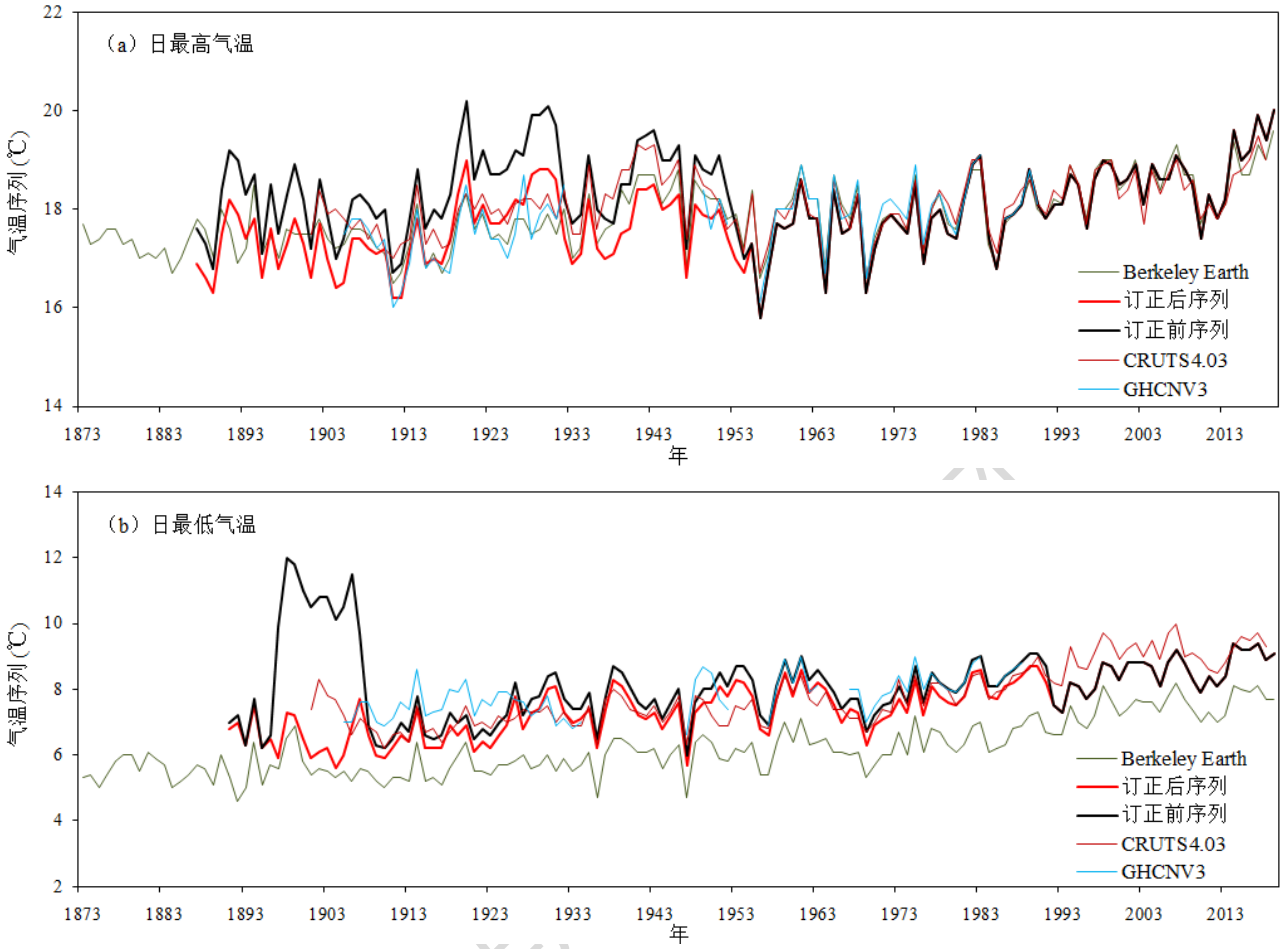

图 天津地区 1887（最低气温始于 1891 年）—2019 年均一性订正前后的年平均最高（a）和最低（b）气温序列及其对应 Berkeley Earth（1873—2019 年）、 CRUTS4.03（1901—2018 年）和 GHCNV3（1905—1990 年）天津站点气温序列

参考文献

Bai, K. X., Li, K., Wu, C. B., Chang, N. B., and Guo, J. P.: A homogenized daily in situ PM2.5 concentration dataset from the national air quality monitoring network in China, Earth Syst. Sci. Data, 12(4): 3067-3080, https://doi.org/10.5194/essd-12-3067-2020, 2020.

Cao, L. J., Yan, Z. W., Zhao, P., Zhu, Y. N., Yu, Y., Tang, G. L., and Jones P.: Climatic warming in China during 1901-2015 based on an extended dataset of instrumental temperature records, Environ. Res. Lett., 12(6): 064005, https://doi.org/10.1088/1748-9326/aa68e8, 2017.

Della-Marta, P. M., and Wanner, H.: A method of homogenizing the extremes and mean of daily temperature measurements, J. Climate, 19(17): 4179-4197, https://doi.org/10.1175/JCLI3855.1, 2006.

Dienst, M., Lindén, J., Engström, E., and Esper, J.: Removing the relocation bias from the 155-year Haparanda temperature record in Northern Europe, Int. J. Climatol., 37(11): 4015-4026, https:// doi.org/10.1002/joc.4981, 2017.

Hansen, J., Ruedy, R., and Sato Makiko K. Lo.: Global surface temperature change, Rev. Geophys., 48, RG4004, https://doi.org/10.1029/2010RG000345, 2010.

Haimberger, L., Tavolato, C., Sperka, S.: Homogenization of the global radiosonde temperature dataset through combined comparison with reanalysis background series and neighboring stations, J. Climate, 25(23): 8108-8131, https:// doi.org/10.1175/JCLI-D-11-00668.1, 2012.

Hewaarachchi, A. P., Li, Y. G., Lund, R., and Rennie, J.: Homogenization of Daily Temperature Data, J. Climate, 30, 985-999, https:// doi.org/10.1175/JCLI-D-16-0139.1, 2017.

Huang, J. Y., Liu, X. N., Li, Q. X.: The experimental study of reconstruction for summer precipitation and temperature in China, Journal of Applied Meteorological Science, 15(2): 200-206, 2004(in Chinese).

IPCC: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Stocker TF, Qin D, Plattner G K, TignorM, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM. (eds.): 1535 pp. Cambridge University Press: Cambridge, UK 25 and New York, NY, 2013.

Jones, P. D., Lister, D., Osborn, T. J., Harpham, C., Salmon, M., and Morice C.: Hemispheric and large-scale land-surface air temperature variations: an extensive revision and an update to 2010, J. Geophys. Res., 117, D05127, https:// doi.org/10.1029/2011JD017139, 2012.

Lawrimore, J. H., Menne, M. J., Gleason, B., Williams, C. N., Wuertz, D. B., Vose, R. S., and Rennie, J.: An overview of the Global Historical Climatology Network monthly mean temperature data set, Version 3, J. Geophys. Res., 116, D19, https://doi.org/10.1029/2011JD016187, 2011.

Leeper, R. D., Rennie, J., Palecki, M. A.: Observation perspectives from U.S. Climate Reference Network (USCRN) and Cooperative Observer Program (COOP) Network: temperature and precipitation comparison, J. Atmos. Oceanic Technol., 32(4): 703-721, https://doi.org/10.1175/JTECH-D-14-00172.1, 2015.

Lenssen, N. J. L., Schmidt, G. A., Hansen, J., Menne, M. J., Persin, A., Ruedy, R., and Zyss, D.: Improvements in the GISTEMP uncertainty model, J. Geophys. Res., 124(12): 6307-6326, https://doi.org/10.1029/2018JD029522, 2019.

Li, Q. X., Sun, W. B., Huang, B. Y., Dong, W. J., Wang, X. L., Zhai, P. M., and Jones, P.: Consistency of global warming trends strengthened since 1880s, Science Bulletin, https://doi.org/10.1016/j.scib.2020.06.009, 2020a.

Li, Q. X., Sun, W. B., Huang, B. Y., Dong, W. J., Wang, X. L., Zhai, P. M., and Jones, P.: An updated evaluation on the global Mean Surface Temperature trends since the start of 20th century, Climate Dynamics, 56:635-650, https://doi.org/10.1007/s00382-020-05502-0, 2021..

Li, Q. X., Dong, W. J., and Jones, P.: Continental Scale Surface Air Temperature Variations:

Experience Derived from the Chinese Region, Earth-Science Reviews, 200, 102998, https://doi.org/10.1016/j.earscirev.2019.102998, 2020b.

Li, Q. X., Zhang, L., Xu, W. H., Zhou, T. J., Wang, J. F., Zhai, P. M., and Jones, P.: Comparisons of time series of annual mean surface air temperature for China since the 1900s： Observation, Model simulation and extended reanalysis, Bull. Amer. Meteor. Soc., 98(4):699-711, https://doi.org/ 10.1175/BAMS-D-16-0092.1, 2017.

Li, Q. X., Dong, W. J.， Li, W., Gao, X. R., Jones P., Parker D., and Kennedy J.: Assessment of the uncertainties in temperature change in China during the last century，Chin. Sci. Bull. 55(19): 1974-1982, https://doi.org/10.1007/s11434-010-3209-1, 2010.

Li., Q. X., Zhang., H. Z., Liu., X. N., and Huang., J. Y.: Urban heat island effect on annual mean temperature during the last 50 years in China, Theor. Appl. Climatol., 79, 165-174, https://doi.org/10.1007/s00704-004-0065-4, 2004.

Li, Y., Tinz, B., Storch, H., Wang, Q. Y., Zhou, Q. L., and Zhu, Y. N.: Construction of a surface air temperature series for Qingdao in China for the period 1899 to 2014, Earth Syst. Sci. Data, 10(1): 643-652, https:// doi.org/10.5194/essd-10-643-2018, 2018.

Lv, Y. M., Guo, J. P., Yim, S. H., Yun, Y. X., Yin, J. F., Liu, L., Zhang, Y., Yang, Y. J., Yan, Y., and Chen, D. D.: Towards understanding multi-model precipitation predictions from CMIP5 based on China hourly merged precipitation analysis data, Atmos. Res., 231(1): 104671, https://doi.org/10.1016/j.atmosres.2019.104671, 2020.Menne, M. J., Durre, I., Vose, R. S., Gleason, B., and Houston, T. G.: An overview of the global historical climatology network-daily database, J. Atmos. Ocean. Technol., 29(7): 897-910, https://doi.org/10.1175/JTECH-D-11-00103.1, 2012.

Menne, M. J., Williams, C. N., Gleason B. E., Rennie J. J., and Lawrimore, J. H.: The global historical climatology network monthly temperature dataset, Version4, J. Climate, 31(24): 9835-9854, https://doi.org/10.1175/JCLI-D-18-0094.1, 2018.

Png, I. P. L., Chen, Y., Chu, J. H., Feng Y. K., Lin, E. K. H., and Tseng W. L.: Temperature, precipitation and sunshine across China, 1912-51: A new daily instrumental dataset, Geosci. Data J., 1-13, https://doi.org/10.1002/gdj3.91, 2020.

Quayle, R. G., Easterling, D. R., Karl T. R., Hughes, P. Y.: Effects of recent thermometer changes in the cooperative station network, Bull. Amer. Meteor. Soc., 72(11):1718-1723, https://doi.org/10.1175/1520-0477(1991)0722.0.CO;2, 1991.

Rahimzadeh, F., and Zavareh, M. N.: Effects of adjustment for non-climatic discontinuities on determination of temperature trends and variability over Iran, Int. J. Climatol., 34(6): 2079-2096, https://doi.org/10.1002/joc.3823, 2014.

Rohde, R., A., Muller, R. A., Jacobsen, R., Muller, E., Perlmutter, S., Rosenfeld, A., Wurtele J.,

Groom, D., and Wickham, C.: A new estimate of the average earth surface land temperature spanning 1753 to 2011, Geoinfor. Geostat: An overview, 1: 1, https://doi.org/10.4172/2327-4581.1000101, 2013.

Rohde, R., A., and Hausfather, Z.: The Berkeley Earth Land/Ocean Temperature Record, Earth Syst. Sci. Data, 12, 3469-3479, https://doi.org/10.5194/essd-12-3469-2020, 2020.

Si, P., Zheng, Z. F., Ren, Y., Liang, D. P., Li, M. C., and Shu, W. J.: Effects of urbanization on daily temperature extremes in North China, J. Geogr. Sci., 24(2): 349-362, https://doi.org/10.1007/s11442-014-1092-4, 2014.

Si, P., Hao, L. S., Luo, C. J., Cao, X. C., and Liang, D. P.: The interpolation and homogenization of long-term temperature time series at Baoding observation station in Hebei Province, Climate Change Research, 13(1): 41-51, 2017 (in Chinese).

Si, P., Luo, C. J., and Liang, D. P.: Homogenization of Tianjin monthly near-surface wind speed using RHtestsV4 for 1951-2014, Theor. Appl. Climatol., 132 (3-4): 1303-1320, https://doi.org/10.1007/s00704-017-2140-7, 2018.

Si, P., Luo, C. J., and Wang, M.: Homogenization of Surface Pressure Data in Tianjin, China, J. Meteor. Res., 33(6): 1131-1142, https://doi.org/10.1007/s13351-019-9043-8, 2019.

Si, P., Wang, J., Li, H. J., and Nian, F. X.: Homogenization and application of meteorological observation data at provincial level. Beijing: China Meteorological Press, 76-91, 2020(in Chinese).

Si, P., and Li, Q. X.: Tianjin homogenized daily surface air temperature over century-long scale. PANGAEA, https://doi.pangaea.de/10.1594/PANGAEA.924561, 2020.

Sun, X. B., Ren, G. Y., Xu, W. H., Li, Q. X., and Ren, Y. Y.: Global land-surface air temperature change based on the new CMA GLSAT data set, Science Bulletin, 62(4): 236-238, http://doi.org/10.1016/j.scib.2017.01.017, 2017.Trewin, B.: A daily homogenized temperature data set for Australia, Int. J. Climatol., 33(6): 1510-1529, http://doi.org/10.1002/joc.3530, 2013.

Harris, I. C., Jones, P. D. CRU TS4.03: Climatic Research Unit (CRU) Time-Series (TS) version 4.03 of high-resolution gridded data of month-by-month variation in climate (Jan. 1901- Dec. 2018). Centre for Environmental Data Analysis, 22, http://doi.org/10.5285/10d3e3640f004c578403419aac167d82, 2020.

Vincent, L. A., Wang, X. L., Milewska, E. J., Wan, H. Yang, F., and Swail, V. R.: A second generation of homogenized Canadian monthly surface air temperature for climate trend analysis, J. Geophys. Res., 117, D18110, http://doi.org/10.1029/2012JD017859, 2012.

Vincent, L. A., Zhang, X., Bonsal, B. R., and Hogg, W. D.: Homogenization of daily temperature over Canada, J. Climate, 15:1322-1334, http:// doi.org/10.1175/1520-0442(2002)0152.0.CO;2, 2002.

Wang, S. W., Ye, J. L., Gong, D. Y., Zhu, J. H., and Yao, T. D.: Construction of mean annual temperature series for the LSAT one hundred years in China, Quarterly Journal of Applied Meteorology, 9(4): 392-401, 1998(in Chinese).

Wang, S. W., Gong, D. Y., Ye, J. L., and Chen, Z. H.: Seasonal precipitation series of Eastern China since 1880 and the variability, Acta Geographica Sinica, 35(3): 281-293, 2000 (in Chinese).

Wang, X. L., Wen, Q. H., and Wu Y. H.: Penalized maximal t test for detecting undocumented mean change in climate data series, J. Appl. Meteor. Climatol., 46, 916-931, http:// doi.org/10.1175/JAM2504.1, 2007.

Wang, X. L., Chen, H. F., Wu, Y. H., Feng, Y., and Pu, Q.: New techniques for the detection and adjustment of shifts in daily precipitation data series, J. Appl. Meteor. Climatol., 49, 2416-2436, http:// doi.org/10.1175/2010jamc2376.1, 2010.

Wu, Z. X.: China Modern Meteorological Station. Beijing: China Meteorological Press, 180-182, 2007 (in Chinese).

Xu, C. D., Wang, J. F., and Li, Q. X.: A new method for temperature spatial interpolation based on sparse historical stations, J. Climate, 31(5): 1757-1770, http:// doi.org/10.1175/JCLI-D-17-0150.1, 2018.

Xu, W. H., Li, Q. X., Jones, P., Wang, X. L., Trewin, B., Yang, S., Zhu, C., Zhai, P. M., Wang, J. F., Vincent, L. A., Dai, A. G., Gao, Y., and Ding, Y. H.: A new integrated and homogenized global monthly land surface air temperature dataset for the period since 1900, Clim. Dynam., 50(15): 2513-2536, http:// doi.org/10.1007/s00382-017-3755-1, 2018.

Xu, W. Q., Li, Q. X., Wang, X. L., Yang, S., Cao, L. J., and Feng, Y.: Homogenization of Chinese daily surface air temperatures and analysis of trends in the extreme temperature indices, J. Geophys. Res. Atmos., 118, http:// doi.org/10.1002/jgrd.50791, 2013.

Yan, Z. W., Chi, Y., and Jones, P.: Influence of inhomogeneity on the estimation of mean and extreme temperature trends in Beijing and Shanghai, Adv. Atmos. Sci., 18(3): 309-322, http:// doi.org/10.1007/BF02919312, 2001.

Yu, J., Li, Q. X., Zhang, T. W., Xu, W. H., Zhang, L., and Cui, Y.: The merging test using measurements, paleoclimate reconstruction and climate model data based on Bayesian model, Acta Meteorologica Sinica, 76(2): 304-314, 2018(in Chinese).

Zhang, X., Alexander, L., Hegerl, G.C., Jones, P.D., Klein Tank, A., Peterson, T.C., Trewin, B. and Zwiers, F.W.: Indices for monitoring changes in extremes based on daily temperature and precipitation data. WIREs Climate Change, 2, 851-870, http:// doi.org/10.1002/wcc/147, 2011.

Zheng, J. Y., Liu, Y., Ge Q. S., Hao, Z. X.: Spring phenodate records derived from historical documents and reconstruction on temperature change in Central China during 1850-2008, Acta

Geographica Sinica, 70(5): 696-704, 2015(in Chinese).

Zhai., P. M., Chao., Q. C., and Zou., X. K.: Progress in China's climate change study in the 20th century, J. Geograph. Sci., 14(1): 3-11, https://doi.org/10.1007/BF02841101, 2004.