COMPARISONS OF TIME SERIES OF ANNUAL MEAN SURFACE AIR TEMPERATURE FOR CHINA SINCE THE 1900S
Observations, Model Simulations, and Extended Reanalysis

QINGXIANG LI, LEI ZHANG, WENHUI XIU, TIANJUN ZHOU, JINFENG WANG, PANMAO ZHAI, AND PHIL JONES

This paper assesses the similarities and differences of several annual average surface air temperature time series for China based on historical meteorological observations since the 1900s.

Over the past century, global-scale climate warming has been accelerating, and climate change is drawing increasing attention from the media and the public. Surface air temperature (SAT) is the major subject of concern within the context of climate change. Starting in the second half of the last century (after 1950), the warming of the climate has been obvious at the global scale (Brohan et al. 2006; Hansen et al. 2010; Lawrimore et al. 2011; Jones et al. 2012; Morice et al. 2012; Vose et al. 2012; Hartmann et al. 2013). In the Intergovernmental Panel on Climate Change’s (IPCC) Fifth Assessment Report (AR5) headline statements from the Summary for Policymakers, it was noted that many changes in the climate system since 1950 are unprecedented when compared to earlier decades. From 1880 to 2012, the global average sea and land surface temperature shows an increasing linear trend of 0.85°C. From 2003 to 2012, the average temperature increased by 0.78°C (0.72°–0.85°) compared with that from 1850 to 1900 (Hartmann et al. 2013). Further, IPCC AR5 notes that the warming rate has slowed down recently (1998–2012). This short 15-yr period has been discussed by a number of authors (Easterbrook 2008; Easterling and Wehner 2009; Kaufmann et al. 2011; Fyfe et al. 2013; Guemas et al. 2013; Met Office 2013a,b,c; Karl et al. 2015; Lewandowsky et al. 2016).

Brohan et al. (2006) indicated that temperature series have three types of uncertainty: station errors, sampling errors, and bias errors. For China, the observational (station) errors in the SAT series are relatively small and well understood. Errors caused by the homogeneity adjustment of temperature series have been evaluated and discussed (Jones et al. 2008; Li et al. 2010a). Sampling errors in China are an issue when the number of observational sites is reduced.
and Wang J times series (see Table 1 for details). In this study, we supplement these four existing time series with two time series derived from the CRUTEM3 (Brohan et al. 2006) and CRUTEM4 datasets, which represent global historical land surface air temperatures and near-surface air temperature anomalies over land, respectively (Jones et al. 2012). Analysis of these six time series leads to divergent conclusions about SAT variations because of their differences in station densities and data-processing techniques.

Global climate models have shown reasonable performance on the global scale, but large uncertainties in regional-scale performance still exist. The performance of the models used in the third phase of the Coupled Model Intercomparison Project (CMIP3; Meehl et al. 2007) and CMIP5 (Taylor et al. 2012) for simulating Chinese SAT changes has been evaluated in many studies [for details on these simulations see the supplemental material for this paper (SM), which is available online at http://dx.doi.org/10.1175/BAMS-D-16-0092.2] (Zhou and Yu 2006; Xu and Xu 2012; Guo et al. 2013; Zhang et al. 2013; Jin and Zhou 2014). However, the observed time series used in these comparisons are different. The climate modeling community needs to pay more attention to the uncertainty of the observed time series. In addition, the first reanalysis product at centennial scales [Twentieth Century Reanalysis (20CR)], developed by the National Oceanic and Atmospheric Administration (NOAA), provides new opportunities for data–model comparisons. The near-surface air temperatures in 20CR provide useful results [especially in terms of the continuity of series; Cheng et al. (2013)] that can be verified by the simulation of global SAT variation (Compo et al. 2011, 2013). In this study, the SAT time series derived from 20CR data are also compared to the observational data.

The objective of this study is to assess the similarities and differences of these annual mean SAT time series for China based on historical meteorological observations since 1900. The existing observed time series are compared to the results of CMIP5 model simulations and the 20CR reanalysis. The overall temperature trend of China SAT is investigated, and the characteristics of each type of data are discussed.

**DATA AND METHODS.** High-quality climate datasets are the basis for the detection and attribution of climate changes (Karl and Williams 1987; Gullet et al. 1990; Peterson et al. 1998). For years, temperature analyses across China, especially on local or subregional scales, saw discrepancies due to the inhomogeneity of the baseline data (Li et al. 2004a). To solve this problem, considerable efforts have been devoted to the homogenization of the SAT station...
data for China (Li et al. 2004, 2009; Song et al. 2004; Li and Yan 2009; Xu et al. 2013; SM). The first homogenized SAT datasets for the whole country, starting at the beginning of twentieth century, were published in 2010 (Li et al. 2010a). Currently, there are four sets of SAT time series that have been widely used in climate change studies in China (see Table 1 for details); these four sets of data are used in our analysis. The WangS series (Wang et al. 1998) and Tang series (Tang and Ren 2005) are described in Cao et al. (2013); the Li series (Li et al. 2010a) and WangJ series (Wang et al. 2014) are both developed from Li et al. (2010a).

In addition to the aforementioned China average time series, the CRUTEM3/4 datasets (Brohan et al. 2006; Jones et al. 2012) were also used to estimate the Northern Hemisphere/China surface temperature changes. Another homogenized global land surface air temperature (LSAT) dataset [Global Historical Climatology Network–Monthly (GHCN–M); Lawrimore et al. (2011)], developed by NOAA’s National Centers for Environment Information (NCEI), was also used for comparison with the China observational dataset. The climate anomaly method (CAM; Jones and Hulme 1996) was applied to gridded deviations from the climatological average (anomalies) to construct a regional average time series over all of China.

The twentieth-century historical climate simulations of CMIP5 models (Taylor et al. 2012) were used in our analysis. The results of 41 CMIP5 models were compared to the historical observational data. Because the historical climate simulation of the CMIP5 models ends in 2005, our model–data comparison focuses on the period from 1900 to 2005. The Taylor diagram (Taylor 2001) was used in model evaluations. First, data from the 41 models were regridded to $1^\circ \times 1^\circ$ resolution grids, and the China average SAT series for each model was calculated by averaging all the anomalies series for each grid by latitude cosine weighting. This was nearly the same methodology applied by Jones and Hulme (1996) with the exception of a different resolution between the model ($1^\circ \times 1^\circ$) and observation ($5^\circ \times 5^\circ$) datasets. The China SAT series

<table>
<thead>
<tr>
<th>Series</th>
<th>Data coverage</th>
<th>Quality control</th>
<th>Mean temperature</th>
<th>Calculation method of regional series</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>WangS</td>
<td>Observations from the China Meteorological Administration (CMA) and proxy data</td>
<td>—</td>
<td>Arithmetic average of fixed observations (the times were different)</td>
<td>Subregional series derived by arithmetic means of single series and national series through area-weighted averaging across 10 regional series</td>
<td>Wang et al. (1998)</td>
</tr>
<tr>
<td>Tang</td>
<td>Observations from CMA</td>
<td>—</td>
<td>Arithmetic average of $T_{\text{max}}$ (Tx) and $T_{\text{min}}$ (Tn)</td>
<td>Griding then calculating the regional series by the climate anomaly method (CAM)</td>
<td>Tang and Ren (2005)</td>
</tr>
<tr>
<td>Li</td>
<td>Same as above</td>
<td>Homogenized station series</td>
<td>Same as above</td>
<td>CAM</td>
<td>Li et al. (2010a)</td>
</tr>
<tr>
<td>WangJ</td>
<td>Same as above</td>
<td>Same as above</td>
<td>Same as above</td>
<td>Biased Sentinel Hospitals Areal Disease Estimation and Means of Stratified Nonhomogeneous Surface (BSHADE-MSN), which takes into account prior knowledge of geographical spatial autocorrelation and nonhomogeneity of target domains, remedies the biased sample, and maximizes an objective function for the best linear unbiased estimation of the regional mean quantity</td>
<td>Wang et al. (2014)</td>
</tr>
</tbody>
</table>

| CRUTEM3 | Climatic Research Unit (CRU) temperature data collected and processed | Same as above | Same as above | CAM | Brohan et al. (2006) |
| CRUTEM4 | CRU temperature data collected and processed | Same as above | Same as above | CAM | Jones et al. (2012) |
Comparison of observed time series. A comparison of the six time series of average SAT in China (see Table 1 for details; all series plotted relative to 1961–90 average) for the period of 1909–2006 (when all data are available) is shown in Fig. 1. Note that all series, with the exception of the WangS series, have a large amount of missing data from the western parts of China. For example, in the Li series (which has the densest observational station data coverage among the series with the exception of WangS) the length of gridpoint time series to the west of 110°E is 46–85 years. The station series for western China began between 1922 and 1961. The WangS series augmented western China station data with proxy climate data. First, they derived regional annual SAT series (starting in 1880) for northeast China, north China, east China, south China, Taiwan, central China, southwest China, northwest China, Xinjiang, and Tibet based on observations. In addition, they included ice-core data from the Dasuopu Dunde and Guliya ice caps along the Tibetan Plateau, historical documentary information, and tree-ring data. Data for the WangS series were then obtained from Chinese SAT time series by area weighting the averages of all regions (Wang et al. 1998). The WangJ series differs from the others because a grid was not developed; instead, the Chinese average was calculated as one domain.

All six SAT series for China reveal similar decadal variations since the 1900s. The period from 1909 to 2006 can be divided into the following epochs: from 1909 to the mid-1940s (the first stage of the SAT rise), the mid-1940s to the late 1960s (the stage of SAT decline), and the late 1960s to 2006 (the second stage of accelerating SAT rise). The differences among the series are mainly evident during the period before the 1950s. The Tang anomaly series is slightly lower in the first 10 years, while the WangS anomaly series is higher than the other series from 1909 to 1929. From the 1930s to the 1950s, the WangS and Tang anomaly series are slightly higher than those of Li and WangJ. After the 1950s, the six series are in much closer alignment with each other.

The reason for the spread among the existing time series lies in the methods and the basic data used; homogenization of the basic climate data is...
the key factor here. All of the homogenized series (Li, WangJ, and CRUTEM3/4) show less variance among one another. CRUTEM3 always lies in the middle of the various series, Li and CRUTEM4 are consistently slightly below the other series between 1916 and 1951, and WangJ is slightly below all the other series around 1936 and 1968. The basic data used for establishing the Li and WangJ series are identical, but the two series differ slightly from each other as a result of the utilization of different statistical methods (even after the 1950s). Tang uses non-homogenized station data but is closer to the other four series than WangS, which uses noninstrumental proxy data for the annual averages before the 1950s.

Four series are compared in Fig. 2 (CRUTEM3, CRUTEM4, WangJ, and Li). For additional comparison with larger-scale SAT variations, we also include the series for the Northern Hemisphere (NH_CRU), calculated using CRUTEM (here, we include both NH SAT series calculated from CRUTEM3 and CRUTEM4, which are extremely similar). The NH_CRU series also has high consistency with the Chinese series, which is similar to the findings of Bradley et al. (1987). This is likely related to the fact that China is a large midlatitude country and is a significant part of the NH landmass [see discussions in Jones et al. (1997, 2012)]. The China average series reveal a more pronounced warming period starting in the 1940s, with 1946 as the warmest year before 1980; however, for NH_CRU, the warmest year before 1980 is 1938. Thus, the first twentieth-century warming phase for NH_CRU ends earlier than in China’s series, and the subsequent NH temperature decline also ends earlier, which is consistent with Bradley et al. (1987).

**Comparative analysis of the China SAT time series simulated by climate models and reanalysis.** The annual mean SAT series simulated by 41 models for 1900–2005 (using 1961–90 as the base period) is shown in Fig. 3. As evident from the ensemble mean of the models (blue curve), the simulated SAT anomalies from the early 1920s to the 1960s are generally higher than those of the observed series (red curve), with an average differences close to 0.3°C before the 1940s. After the 1950s, the simulated rate of climate warming is still lower than the observations (Fig. 4b). A comparison between the long-term temperature change estimated by multiplemember ensemble historical runs from 41 models and seven observational series [the eastern China series by Cao et al. (2013) is also included here] is shown in Fig. 4a. The rate of change of mean SAT for China simulated by the 41 models for 1900–2005 is approximately 0.00°–0.20°C decade⁻¹, with an average of 0.06°C decade⁻¹, and the average rate simulated for 1951–2005 is 0.15°C decade⁻¹ [less than the 0.19°C decade⁻¹ for observation (Li)]. The seven observational series exhibit different trends centered at approximately 0.09°C decade⁻¹ (red line in Fig. 4a). The trends for the model series are slightly smaller than those for observational series at the centennial scale, but the agreement is better for the last 55 years (1951–2005; see Fig. 4b).

Two additional approaches are adopted to additionally evaluate the simulation of the SAT anomalies over China. First, Pearson correlation coefficients (CCs) between the observational and simulated series for the full 106 years (1900–2005) are calculated. The highest CC is 0.75, found for the Flexible Global Ocean–Atmosphere–Land System Model, second spectral version (FGOALS-s2), which was developed by the Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences (CAS). In decreasing order of CC (larger than 0.6), the remaining seven
The top-ranking series are the Max Planck Institute Earth System Model, medium resolution (MPI-ESM-MR), with a value of 0.69; the Beijing Climate Center, Climate System Model, version 1.1 (BCC-CSM1.1), with a value of 0.67; the Beijing Normal University–Earth System Model (BNU-ESM), with a value of 0.67; the L’Institut Pierre-Simon Laplace Coupled Model, version 5A, low resolution (IPSL-CM5A-LR), with a value of 0.65; the BCC-CSM1.1, with a value of 0.62; the Community Earth System Model, version 1 (Whole Atmosphere Community Climate Model) [CESM1 (WACCM)], with a value of 0.62; and the CESM1 [Community Atmosphere Model with Chemistry (CAM-chem)] [CESM1 (FASTCHEM)], with a value of 0.61. It is interesting to note that four out of the eight top-ranking simulated series for China are derived from models developed by Chinese institutes. Another important observation is that using the homogenized series from Li provides higher correlations (the CCs shown here are higher than those given by Zhang et al. (2013), where the unadjusted (raw) observation data were used).

Figure 5 (Taylor diagram) is akin to Jiang and Tian (2013), which shows the performance of the models in their historic simulations of SAT anomalies from 1900 to 2005. The closer the distance between model series and REF (observations here are referring to the Li series), the better the performance of the corresponding model. The top-ranking models by distance are BCC-CSM1.1; the Geophysical Fluid Dynamics Laboratory Earth System Model with MOM, version 4 component (GFDL-ESM2M); the Centro Euro-Mediterraneo per I Cambiamenti Climatici Climate Model (CMCC-CM); the Second Generation Canadian Earth System Model (CanESM2); the CESM1 (Community Atmosphere Model, version 5) [CESM1 (CAM5)]; Norwegian Earth System Model, version 1 (intermediate resolution) (NorESM1-M); Model for Interdisciplinary Research on Climate, Earth System...
Model (MIROC-ESM); and MPI-ESM-MR. The average of the eight top-ranking models (whose normalized standard deviation is below 2.0) reproduces the SAT observational variations for the last 106 years with a correlation coefficient of 0.81 (Fig. 6a). Compared with the observations (Li), the model series average underestimates the observations before the 1970s except for the short period in the 1950s. As observed in Fig. 6b, the average of the eight top-ranking models reproduces the SAT observational variations for the last 105 years with a correlation coefficient of 0.79, which is slightly lower than in Fig. 6a. However, as a whole, the average model series agrees well with observations during the entire period.

Figures 3 and 6 also display the regional SAT time series of China calculated from 20CR (black bold lines). During the entire twentieth century, the long-term SAT warming trend for China is very well reflected in 20CR. For 20CR, the early temperature rise continues from the 1900s to the 1960s, followed by a sudden decline at the beginning of the 1960s and then a rise again after the mid-1960s. The average rate of rise of China’s SAT for 1900–2005 calculated by 20CR data is 0.10°C decade \(^{-1}\), which is close to the level of the observed time series (0.09°C decade \(^{-1}\)). In 20CR, temperatures begin to decrease in the mid-1990s. It is important to note that the analytical model of the 20CR dataset is driven by monthly average sea surface temperatures, and only surface pressure data are assimilated. Therefore, the SAT estimates obtained are completely independent from the myriad of land surface temperature observations. Without assimilating surface air temperature and/or time-varying anthropogenic aerosol data (though volcanic aerosols were included), the 20CR succeeded in reproducing the recent winter SAT cooling features in China but failed in reproducing the significant summer warming trends in southern China from 1998 to 2012 (Li et al. 2015; Fig. ES3 in SM). This has led to the underestimated of China’s average SAT in the past 15 years.

**DISCUSSION. SAT anomalies in the 1940s.**

Observations. There is little doubt about the high SAT anomaly during the 1940s over China because all six observational series collected for this study consistently show similar features (Fig. 1). However, the magnitudes of the SAT anomalies differ among these datasets (Li et al. 2010a). In the WangS series, the 1910s to the 1950s are warmer than the other series, while the Tang series only shows the high-temperature anomalies in the 1940s. The two series achieve comparable amplitudes (0.68°C and 0.88°C, respectively) with some years in the most recent warm period (2000s), while the remaining series have relatively lower amplitude (0.31°C for Li, 0.38°C for WangJ, and 0.36°C for CH_CRU in 1946). Note that the only difference between Li (and WangJ) and the Tang series is that the former series used a homogenized dataset, while
the latter did not, which indicates that data homogenization is likely to be the most significant cause of differences in the anomalies during the 1940s.

The uncertainties for SAT change series (Li) have been assessed in Li et al. (2010). Based on their evaluation, the average 95% annual uncertainty range is about 0.327°C during the 1940s (1941–50), so the decadal uncertainty would be $0.327/\sqrt{10} \approx 0.1°C$, which is smaller than 0.15°C in the 1930s, and about 0.20°–0.22°C in the 1900s, 1910s, and 1920s (Fig. ES2 in SM). Most of the uncertainty comes from the limited data coverage (Li et al. 2010, see their Fig. 5), and it agrees well with the station number changes during the 1900s to 1940s for eastern and western China (E China and W China), respectively (Fig. ES1 in SM). Western China has similar interannual and decadal changes with E China from the 1930s to the 2010s. This assures that the Li series can present the SAT change for all of China to a certain extent even if the series was built based on only the stations from E China in the earlier years (1900s to 1920s).

Because the observational data in the 1940s were disrupted because of World War II from 1937 to 1945, certain difficulties are associated with the detection of SAT variation in this time period. The Li series basically reflects the average for all 30 of the stations’ SAT anomaly changes since 1930s in western China (Fig. 7). Wang et al. (1998) introduced proxy data (tree rings, ice cores, and historical documents) to enhance estimates for the western half of China. But how to reliably estimate the missing instrumental observation with proxy data remains an open question. Annual averages for NH midlatitude continental areas are principally dominated by temperatures in winter, but proxy sources are mostly indicative of the summer half of the year. And the WangS series is composed of annual averages and does not include separate series for the seasons (Wang and Gong 2000). Even though the use of proxy data has the problems above, increasing the data coverage in the west is still a valuable endeavor and is worthy of further study with better proxy data and a more perfect treatment method.

**Fig. 6. Series of China SAT variations simulated by the eight top-ranking models in the CMIP5 and 20CR datasets (with 1961–90 as the base period).** Ranking by (top) correlation coefficients only and (bottom) correlation coefficients and normalized standard deviation.
Zhou and Yu (2006) noted that CMIP3 models do not yield a good simulation of abnormal climate warming in China in the 1940s, which may be related to the absence of solar forcing variations that should change over time between different simulation experiments for the twentieth century. For historical climate simulations using the CMIP5 models, most models still failed to reproduce the warmth of the 1940s. As is evident from the comparison between the average of the simulations using all models and the observed time series in Fig. 3, the warmth in the 1940s is less evident in the simulations. Using the observational average SAT time series (Li series) that has been established from the homogenized data used in Zhou and Yu (2006), the amplitude of the temperature rise before the 1940s is much lower and the extent of the abnormal temperature rise in the 1940s is also less significant. This result is also consistent with the 20CR data (Fig. 3). The 20CR reanalysis is somewhat like AMIP-type experiments, but the comparison of this aspect has been addressed in Compo et al. (2013). They showed that assimilations of the MSLP data were an improvement over the AMIP-type models (which featured only SST/sea ice assimilation). It seems that the abnormal climate warming revealed by the SAT time series in the 1940s may not be as high as the WangS and Tang series indicate.

Temperature change trend estimates from 1900 to 2015. In this section, we consider the series that includes the most recent year (2015), so only some of the series [CRUTEM4, GHCN-M (Lawrimore et al. 2011), and Li + Xu (Li et al. 2010); the data since 2007 are derived from Xu et al. 2013] can be used. The temperature anomaly series at the annual time scale are shown in Fig. 8. The linear change trends and 95% uncertainty ranges (Ebisuzaki 1997) are calculated in Table 2. Over the period from 1900 to 2015, the annual linear trend coefficients are 0.121°, 0.130°, and 0.114° ± 0.009°C decade\(^{-1}\) for Li + Xu, CRUTEM4, and GHCN-M version 3 (v3), respectively. All are slightly larger than the raw (“unadjusted” in the “Comparative analysis of the China SAT time series simulated by climate models and reanalysis” section) data (0.107° ± 0.009°C decade\(^{-1}\)). The difference between the raw and adjusted data happens mainly before the 1950s.

Finally, we consider the most recent period (1998–2015) in more detail. During this period, Li et al. (2015) state that a hiatus in warming occurs in most parts of China except for the southwest [as
Table 2. Comparisons of the raw and homogenized SAT trends during different periods (°C decade$^{-1}$).

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>RAW</td>
<td>0.107° ± 0.010°*</td>
<td>0.247° ± 0.021°*</td>
<td>0.381° ± 0.045°*</td>
<td>0.059° ± 0.13°</td>
</tr>
<tr>
<td>ADJ</td>
<td>0.121° ± 0.009°*</td>
<td>0.244° ± 0.021°*</td>
<td>0.379° ± 0.044°*</td>
<td>0.079° ± 0.13°</td>
</tr>
<tr>
<td>CRUTEM4</td>
<td>0.130° ± 0.009°*</td>
<td>0.243° ± 0.021°*</td>
<td>0.348° ± 0.051°*</td>
<td>−0.150° ± 0.14°</td>
</tr>
<tr>
<td>GHCN</td>
<td>0.114° ± 0.009°*</td>
<td>0.215° ± 0.021°*</td>
<td>0.297° ± 0.049°*</td>
<td>−0.093° ± 0.14°</td>
</tr>
</tbody>
</table>

* The trend has passed the significance test of 95%.

Fig. 8. Anomaly time series of China’s average annual SAT from 1900–2015 (1961–90 as the base period)

Also noted by Duan and Xiao (2015). Although 2015 is the second-warmest year on record (2007 is the warmest year), the temperature change trend for 1998–2015 remains 0.079° ± 0.13°C decade$^{-1}$, which is still much smaller than estimates for 1951–2015 (0.244° ± 0.021°C decade$^{-1}$) and for 1979–2015 (0.379° ± 0.044°C decade$^{-1}$) (Fig. 7). This agrees well with Li et al. (2015), though the recent trend is slightly larger than the 1998–2012 period trends. China averages calculated by both CRUTEM4 and GHCN-M v3 show negative trends during the 1998–2015 period, both of which are related to the slight underestimation of the temperature in recent years. It is worth noting that over this period none of the series have trends that are statistically significant at the 5% level.

Conclusions and Prospects. With the motivation of recommending the best estimates of Chinese average SAT series to the international climate research community, we have assessed the similarities and differences among the existing time series of annual average SAT for China. These time series are based upon historical meteorological observations since the 1900s, and the observed time series are further compared to the historical climate simulation of CMIP5 models and the twentieth-century reanalysis. Our major findings are summarized below.

1) Although there are still certain differences among the existing Chinese average time series during the 1940s warmth period that are due to the scant number of observations, SAT time series using homogenized temperature data have improved the agreement in long-term changes among all the datasets since the 1900s. The similarity between the Chinese observational average and the NH series, noted by Bradley et al. (1987), is confirmed, but the NH series peaks slightly earlier (1938) than does the China series (1946).

2) SAT time series using homogenized temperature data have also improved the agreement in long-term changes between the observational and model simulation datasets since the 1900s. Several Chinese models used in CMIP5 show better performance in the simulation of annual SAT variations over China in the past century in terms of correlation coefficients (all above 0.6). These models consistently show reasonable reproductions of decadal-scale variations of SAT in the past century, but tend to overestimate recent trends during the past 15 years. The 20CR simulations also reflect the interdecadal variations of China’s SAT at the century scale but greatly underestimate the temperature during the past two decades.

3) A new evaluation of the long-term trend based on the homogenized observed data was achieved: SAT in China reveals a warming trend (0.121° ± 0.009°C decade$^{-1}$) slightly greater than what the raw data indicates (0.107° ± 0.009°C decade$^{-1}$) from 1900 to 2015. The best estimations of linear change trends with 95% uncertainty ranges are 0.121° ± 0.009°, 0.244° ± 0.021°, 0.379° ± 0.045°, and 0.079° ± 0.13°C.
ACKNOWLEDGMENTS. Sincere and special thanks go to Prof. Shaowu Wang from Peking University, who had reviewed the draft of the manuscript and provided many valuable comments and suggestions. We express our deepest condolences on his passing due to illness on 11 January 2015.

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