The Effect of Observing Environment on Temperature in North China Plain Area

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ABSTRACT

Using a temperature dataset of 199 stations during 2005—2007 and corresponding 20 km environmental survey data in 2007, the observing environmental impacts on surface temperature have been investigated. All stations are selected from the same climatic region with flat topographic. The data is revised in latitude, longitude and altitude. Those stations in the residential areas and farmland stations are compared by the average total annual value of the anomaly, the yearly value, the monthly value and the hourly value. The results indicate that the environmental impacts of 20 km across the observing sites could reach 0.662°C at an annual scale, or 0.93°C at a monthly scale, or 0.84°C at an hourly scale. The larger the presence of the urban areas in the station’s vicinity, the larger the impact will be on temperature observation. It is also show that the urban development beyond the 5km area would have a limited impact on temperature observation if natural environment prevails in the 5km area.

In addition, the effects of shade projected area on the temperature also were studied. Results show that the sites sitting in a natural environment would see a noticeably increased temperature with the raised height of shade area. Those sites in an urban environment would have a weakened impact of rising temperature over a raised height of shade area, though the impact would go opposite on nighttime and minimum temperature observation.

Key words: observing environment; temperature measurement;

Text

1. Introduction

The observing environment where meteorological elements are collected has to be carefully selected to ensure the required representativeness, accuracy and comparability. A meteorological observing site, though limited in space, is supposed to strictly follow the given standards when laying out its observing instruments. However, site selection alone does not guarantee the outcome of accurate and representative data. The increased presence of structures and construction activities in the observing site’s vicinity would cast a much larger impact on the validity of the data collected, compared with instrumental errors. In an accelerated urbanization process, the meteorological observing sites that are mostly sitting in the rural areas are increasingly approached by newly appeared urban areas, or simply become part of the central urban area. The growing density of structures in the observing site’s vicinity would compromise the representativeness of observing environment. The data collected in such an environment would lead to the biased or even incorrect conclusions when dealing with climate change issues. Study shows that the observing sites sitting in an urban environment have universally registered a higher temperature rise, compared with the sites in the rural areas (Karl et al.1988, Peterson et al. 2003, Tang Guoli et al.)
2008). Furthermore, the urbanization process also changed the type of land use, which would in turn have an impact on the observed results (Gallo et al., 1996). The closer the changed to the observing sites, the larger the impact will be on temperature observation. Gallo et al. also found that the microscale impact would be larger than the mesoscale impact in the context.

In 2007, Chinese meteorological authorities launched a survey to investigate the meteorological observing environment. Investigators collected a range of data for the purpose, including shade projected angles, structures density in the vicinity, and the land use type within a 20km radius. In this paper, 374 observing sites that sit on a relatively simple terrain on the Huang-Huai-Hai Plains and under a similar climatic system are classified in environmental term, based on the survey results. Meanwhile, the temperature data collected in these sites are compared, and the impacts of observing environment on temperature observation are analyzed.

2. Target region and sites

A region at the junction of the Huang, Huai, Hai, and Wei rivers sharing the same warm and humid climate system is selected to be the target of the study. The region, stretching 786 km from south to north and 1,232 km from east to west, covers an area of 402,400 km², running through 9 provinces. As far as the type of land use in the region is concerned, 74% of the land are farmlands, and 17.6% the urban areas, with the remaining land use type in a very small proportion. To be typical and representative, we compared and analyzed the observing sites sitting in an environment with the presence of farmlands or urban areas reaching 60% in proportion within a 20km radius.

There are 374 national meteorological observing stations in the region, including 8 climate reference stations, 54 basic weather observing stations, and 312 generic weather observing stations. 31 observing sites that had relocated between 2005 and 2007, and 11 observing sites that exceed 500m in elevation are removed to avoid the possible impact of complex terrains and relocation. Of the remaining 332 stations, 199 stations are selected for being in an environment with the presence of farmlands or urban areas reaching 60% in proportion within a 20km radius, with 75 urban stations and 124 rural stations in number.

In the study, the urban stations sitting in a surrounding environment with the presence of urban areas reaching 70% or 80% in proportion, and the rural stations having the presence of rural areas reaching 70% or 80% in proportion are selected to analyze the environmental impacts on temperature observation by the size of the typical land use area.

3. Data processing

3.1 Data

In the study, the temperature data collected during the period of 2005-2007 are used. In addition, 3-year averages corresponding to each station’s annual, monthly, daily and hourly means are applied.

The averages derived from the 199 stations are defined as the regional averages. The difference between the station’s observed values and regional averages are the regional anomalies of the station.
3.2 Latitude, longitude and altitude corrections

The study region covers 15 latitudes and longitudes with the elevation of observing sites ranging from 1.3 m to 473.4 m. To reflect the temperature difference caused by the changed observing environment, latitudes, longitudes, and altitudes are corrected to remove the possible impacts of geographic factors.

J.Y. Fang studied the impacts of latitudes on temperature observation from a macro angle (Fang Jingyun, 1992), correcting the latitude coefficients based on the temperature difference between the observing sites at the same altitude but not on the same latitudes. In a similar manner, he corrected the altitude coefficients based on the temperature difference between the observing sites on the same latitude but not at the same altitudes, and corrected the longitude coefficients based on the relationship between the longitude and temperature at a given latitude and altitude. The corrected results fully agreed with the geographical distribution of observed temperatures. Here, the longitude, latitude and altitude are corrected using the approaches introduced by J.Y. Fang as follows:

\[
T' = T_0 + k_1(N - \bar{N}) + k_2(E - \bar{E}) + k_3(H - \bar{H})
\]

(1)

Where, \(T'\) is the corrected site temperature, \(T_0\) the temperature observed at the site. \(\bar{N}, \bar{E}, \bar{H}\) represents the latitudes, longitudes and altitudes at the reference points, respectively. \(N, E, H\) stands for the station's latitude, longitude and altitude, respectively. \(k_1, k_2, k_3\) shows the temperature variability over latitude, longitude and altitude.

The same approach is applied to correct the 199 stations' air temperature data over altitude, latitude and longitude.

3.3 Classify observing environment

In the study, the results derived from a survey launched by Chinese meteorological authorities in 2007 to investigate the observing environment are used. In the survey, the investigators examined the land use in the areas 0-0.5km, 0.5-1km, 1-5km, 5-10km, and 10-20km across the observing site, with the site as the center, radiating into the directions of east, west, south and north. 20 areas were investigated in the four directions. In this study, the same classification method is used. The stations sitting in a surrounding environment with the presence of urban areas reaching 60% in proportion (12 or more urban areas) are defined as the urban station. In the same manner, the stations surrounded by 12 or more farmland areas are defined as the rural station. There are 75 urban stations and 124 rural stations in number. Put together, they account for 53.21% of the observing stations in the study region.

4. Analysis

4.1 Annual temperature

The selected 199 stations' regional annual temperature anomalies before correction are given in Figure 1 (a). One can see from Figure 1 that the anomalies are noticeably distributed in line with latitudes. The regional anomalies without geographic impacts are shown in Figure 1b. Apparently,
the correction allows annual temperature difference to reflect the difference in a meso-scale observing environment in a more accurate manner.

Fig. 1. Regional anomaly of temperature in 199 stations during 2005-2007
(unit: °C; red triangle: residential stations; black cross: farmland stations) (a) before revised, (b) after revised

There are 3 high-value areas in Figure 1b., Beijing, Tianjin, and Zibo of Shandong from north to south. They are the cities enjoying a fast urban development, especially in Beijing. As a major grain producer, Henan Province has more rural stations that are featured with low regional temperature anomalies. However, one still can see that most of the stations sitting in the town or on the edge of the town have reported a site temperature that is relatively higher than the surrounding areas. Even the stations surrounded by the farmlands are becoming a kind of heat island with the station as the center. The urban development has cast a noticeable impact on the temperature curves as shown in the figure.

75 urban stations have an averaged regional anomaly at 0.412°C, and 124 rural stations at -0.249°C, with a difference up to 0.662°C between the two. The urban climate stations in Tianjin claim the highest regional anomaly at 1.94°C.

4.2 Monthly temperature

One can examine the impact of observing environment on the seasonal variation of observed air temperature based on the difference of monthly mean temperatures. Figure 2 shows the monthly mean, maximum, and minimum temperatures collected at two types of stations, along with the anomaly series averaged on the 199 stations. The urban stations universally have a positive anomaly, with the rural stations aligning on the negative side, suggesting that the urban stations have a temperature curve that is overall higher than the rural stations.

Figure 2 also shows that 1) the urban stations' anomalies are larger than the one recorded at the rural stations, indicating that urban areas have a larger impact on the temperatures collected by the stations, compared with the rural areas; 2) anomalies are descending from winter to spring, and further to autumn and summer, suggesting that the observing environment has the largest impact in the winter; 3) monthly maximum, mean, and minimum would have an increased temperature in a sequential order, indicating that the observing environment has the largest impact on the minimum temperature, and less so on the maximum temperature. The urban stations registered a monthly maximum, mean, and minimum temperatures at 0.22°C, 0.41°C, and 0.58°C, respectively, with the rural stations at -0.13°C, -0.25°C, and -0.35 °C, respectively.
4.3 Hourly temperature

We examined the daily impact of observing environment on temperature observation through hourly data. Figure 3 depicts the anomalies between the temperatures observed at 02h, 08h, 14h, and 20h (Beijing Time), and associated averages corresponding to the 199 stations. The impact of observing environment can be felt differently, depending on the given hour where the observation is made. For example, at 08h, one would see a noticeable seasonal variation of anomalies with the largest variation in the winter and the smallest in the summer. There are no noticeable variations of anomalies over season at 14h, with 02h and 20h basically on the same changing curve, though the urban stations would have a larger anomaly at 20h than at 02h, possibly due to the fact that the diurnal sunshine would result in a raised structure temperature, and the fact that the structure's temperature would be higher than the ambient temperature at the sunset, acting as a heat source, and affecting the urban stations at 20h.
The averaged environmental impact can be felt in a descending order of 02h, 20h, 08h, and 14h, with the urban stations at 0.52°C, 0.48°C, 0.43°C, and 0.21°C, respectively, and the rural stations at -0.32°C, -0.29°C, -0.26°C, and -0.13°C. Apparently, the urban stations would have a larger daily impact, compared with their rural counterparts.

### 4.4 The range of Land use area

The impact of urbanization can be calculated based on the temperature difference ($T_{r-f}$) between the urban and rural stations, through the following equation:

$$T_{r-f} = T_r - T_f$$  \hspace{1cm} (2)

where, $T_r$, $T_f$ represents the temperature observed at the urban and rural stations, respectively.

In the study, the urban stations sitting in a surrounding environment with the presence of urban areas reaching 70% or 80% in proportion, and the rural stations having the presence of rural areas reaching 70% or 80% are picked out to analyze the environmental impact on temperature observation in the context of the size of the area. 26 urban stations reached the proportion of 70%, and 10 stations 80%, with 65 rural stations at 70%, and 10 at 80%.

Analysis is made to understand the temperature difference between the two types of stations in an observing environment either with the presence of urban areas or with the presence of farmland, at a monthly, daily, and hourly scale. Figure 4 depicts the results stemmed from the analysis, showing that $T_{r-f}$ would be increased over an increased proportion. For example, both types of stations would have a $T_{r-f}$ that does not exceed 1°C at 60%, though would go beyond 1.5°C at 80%.

![Fig. 4. Comparison of temperature difference between two types of stations in line with typical environment area account for 60%, 70%, 80%](image)

### 4.5 Distance from the changed land use type

4 sample groups are selected from the 199 stations. Group 1, 24 stations in total, is surrounded mostly by the farmlands within 20km radius, desirable for a climate station. Group 2, 7 stations in
number, is surrounded mainly by the farmlands in the 5-km vicinity, though would be dominated by urban areas when stretching further out till 20 km. Group 3, 59 stations in total, has a strong presence of urban areas in the 5-km vicinity, though would be shifted to the farmlands when stretching out till 20 km. Last group, 13 stations in number, would be surrounded mainly by the urban areas.

Group 1 is compared with Group 3, and Group 2 with Group 4, to show the impact of changed land use type on temperature observation 5 km across the site. Figure 5 indicates that when the 5-20 km area is dominated by the farmlands, the impact of 5 km changed land use type would reach up to 0.97 °C, depending on the time scale. When stretching further out from 5 km with a dominant presence of urban areas, the impact on temperature observation in the 5 km area would rise to a steep 1.9 °C.

![Fig. 5. Temperature difference between two groups of stations in line with typical environment changed inside 5km](image1)

In the same manner, Group 1 is compared with Group 2, and Group 3 with Group 4, to understand the impact of changed land use type on temperature observation beyond the 5 km area. Figure 6 shows that when the 5 km area are dominated by the farmlands, the impact of changed land use type in the areas beyond 5 km would be smaller than 0.21 °C, which is negligible taking into account the 0.2 °C error range allowed for an operational observation. However, when the 5 km area furthers out and is dominated by the urban areas, the impact of changed land use type in the areas beyond 5 km would reach 1.08 °C.

![Fig. 6. Temperature difference between two groups of stations in line with typical environment changed beyond 5km](image2)
Apparently, the presence of natural environment in the 5km area can effectively diminish the impact of construction activities.

4.6 Shade projected angle

The shade projected angle around the site were used to calculate the site’s shade area at three levels (level-1 <500, level-2 500-1000, and level-3 >1000). Figure 7 illustrates the impact of shade area on temperature observation. At the rural stations, the larger the shade area is, the higher the temperature will be, or up to 0.32°C. However, the urban stations do not see the similar pattern, though the temperature observed at 02h and the lowest temperature would go up over an increased shade area. The remaining did not see the same rise, or simply ran the opposite. The phenomenon suggests that the impact of shade on temperature observation is associated with the changed land use type in the vicinity, especially in the 5 km area.

![Temperature difference between two shaded area levels of stations in line with typical environment](image)

5. Summary

Authors examined the impact of observing environment 20 km across the observing sites on temperature observation, based on the results of an observing site environmental survey and the temperature data collected by selected stations, and reached the following preliminary conclusions:

1) The observing environment of 20 km across the observing sites has a noticeable impact on temperature observation. The impact could reach 0.662°C at an annual scale, or 0.93°C at a monthly scale, or 0.84°C at an hourly scale. The impact can be mostly felt in the winter, or the least felt in the summer, with the largest impact seen at 02h and the smallest at 14h. The minimum temperature claims the largest impact, compared with the mean and maximum temperatures.

2) The larger the presence of urban areas in the station’s vicinity, the larger the impact will be on temperature observation. When urban areas reach 80% in proportion, the impact could rise to 1.5°C or above.

3) The urban development in the 5km area would compromise temperature observation by 0.97°C-1.9°C. When natural environment prevails in the 5km area, the urban development beyond the 5km area would have a limited impact on temperature observation.
4) The observing sites sitting in a natural environment would see a noticeably increased temperature over a raised height of shade area. The observing sites in an urban environment would have a weakened impact of rising temperature over a raised height of shade area, though the impact would go opposite on nighttime and minimum temperature observation.

The study results show that an observing site's regular microenvironment is not sufficient to guarantee the data's representativeness and accuracy. The mesoscale environment in the site's vicinity could produce an impact on air temperature observation that is strong enough to submerge the signals of climate change. In this context, one has to pay due attention to the use of the data collected in an affected environment. It is also suggested that temperature observation at a climate reference station shall be made at least 5km away from the urban areas.

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Reference