Differences between Automatic and Manual Meteorological Observation

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Abstract

Based on the data from both automatic and manual meteorological observation in 700 stations of China from 2001 to 2005, analyses have been made on the differences of automatic and manual observation in temperature, pressure, relative humidity, ground surface temperature, wind direction and velocity, and precipitation, together with the difference, percentage error and matching rate of wind directions between the two kinds of observation. The differences of all the elements have been studied to get the distribution feature in China and the possible influence of automatic temperature observation on the continuity of temperature data has been tested. The results show that there exists certain difference between automatic and manual meteorological observation, but in most areas the differences of all elements are accepted due to the error range of automatic stations. Many factors may cause the differences, including the flaw of instruments and different observational methods. The differences of all elements are distributed variously in the whole country. Even the difference of the same element may vary on different climatic conditions. The time series of auto and manual observation still need to be further tested to identify significant difference and make homogeneous correction if there is any, to make the data of auto and manual observation valid in use. Automatic observation station has some influence on the annual temperature time series. The general difference is not significant, but homogeneity test should be involved if the data of auto and manual observation in temperature are both referred to in practice.

Key word: automatic observation, manual observation, difference, homogeneity test

Introduction

Automatic meteorological stations are taking the place of manual observation ones in China. Since 2000, automatic meteorological stations have had the financial support from different projects including automatic system of meteorological observation and new weather radar system in national meteorological field and some regional meteorological programs. Till 2006, there have been altogether 1904 automatic stations functioning in the country and all the stations will have automatic meteorological observations in a few years. Great changes have taken place in the observational rules and methods of auto stations comparing with manual observations. Inhomogeneity of observational time series may be caused by many reasons and the change of observational instrument is an important one. Therefore, WMO and CCL have set clear requirement for the automatic stations: “in the automatization of meteorological observation, a certain period of parallel observation is needed. All the data should receive quality control under the same meteorological data saving and managing condition to ensure the homogeneity of historical data.” Based on this requirement, in the first two or three years when automatic meteorological stations are functioning in our country, manual observation is also kept. Except newly-built stations, all the auto stations have parallel manual observation for two or three years.

Since the functioning of auto stations, such issues as the data quality of auto observation, the differences between auto and manual observation data and continuous use of data have attracted attentions from scientists using auto observation data in their research. A lot of researches have been conducted abroad on the differences between auto and manual observations. The research results indicate that there are differences in the data of two observations. In USA, since the end of 1980s, automatic meteorological observation system has appeared throughout the country and obvious differences exist in the data of auto and manual observation. After American

MMTS (maximum - minimum temperature system) system replaced the manual-observed liquid thermometer, the average daily maximum temperature in large-scale areas dropped by 0.4℃, minimum temperature increased by 0.3℃, daily mean temperature dropped by 0.1℃, and daily range decreased by 0.7℃.

In China, the influence by the change of observational system has also been studied. Xiong Anyuan's research shows that the change of observational instruments has exerted certain obvious influence on the temperature data with the range of around 0.2℃ in daily, monthly and annual mean temperature. The main cause lies in the impact of solar radiation on different instruments. At the same time, there exists system observational error of 0.1℃ in the two instruments whose sensitivity to the change of surrounding temperature varies, possibly leading to the difference of 0.1- 0.15℃ in different period of a day.

This paper statistically analyzes the differences of auto and manual observation in such meteorological elements as temperature, precipitation, pressure, relative humidity, wind direction and velocity and ground surface temperature, and explores the distribution features of those differences in all elements in China as well as the causes of auto and manual observation differences in the hope of benefiting all the scientists using automatic observational data.

1. Data and Method

1.1 Data

The data from both automatic and manual meteorological observation in 700 stations of China from 2001 to 2005 have been studied in this paper.

During the two or three year parallel observational period, manual observational data is regarded as formal record in the first year while automatic observational data as formal one in the second and third year. Only when auto observational data is used as formal record, will real-time inspection and quality control be made on those data, so in this paper, all the analyses are based on the parallel data from all the auto stations when auto observational data are used as formal record.

1.2 Statistic Items and Accepted Error Range

For the main elements in contrast observations, namely temperature, extreme maximum and minimum temperature, pressure, relative humidity, ground surface temperature, 10-minuite mean wind velocity, the difference of monthly mean value in the data of auto and manual observation has been analyzed. Here "difference" refers to the manual observational value subtracted by auto observational value. The accepted error range of difference in the monthly mean value of pressure is ±0.2hPa, that of temperature is ±0.2℃, that of relative humidity is ±2%, that of 10-minuite mean wind velocity is ±0.2m/s, and that of ground surface temperature is ±0.5℃.

For the wind direction of 10-minute mean velocity, the matching rate of monthly wind direction in auto and manual observation has been analyzed. The accepted matching percentage of monthly wind direction is over 70%.

For the precipitation, the monthly percentage error of auto and manual observation has been calculated. The accepted percentage of difference of monthly manual and auto observation in the manual observation should be less than 8%.

Based on the statistics, the national distribution of all statistic items has been presented together with analysis on the distribution feature.

2. Analysis on the Differences of Auto and Manual Observation

2.1 Temperature

As to temperature, the difference of annual mean temperature, annual mean maximum temperature and annual mean minimum temperature has been calculated respectively.

There is certain difference between auto and manual observation of temperature. The stations with difference

of annual mean value over ±0.2℃ are mainly distributed in Qinghai Province, some in the province of Sichuan, Jiangxi, Xinjiang, Hunan and Shanxi. For other provinces, only a few stations get relatively large difference of annual mean value. Annual mean difference in Qinghai province turns out to be negative discrepancy and auto observational temperature is 0.2－0.6℃ higher than manual observational data.

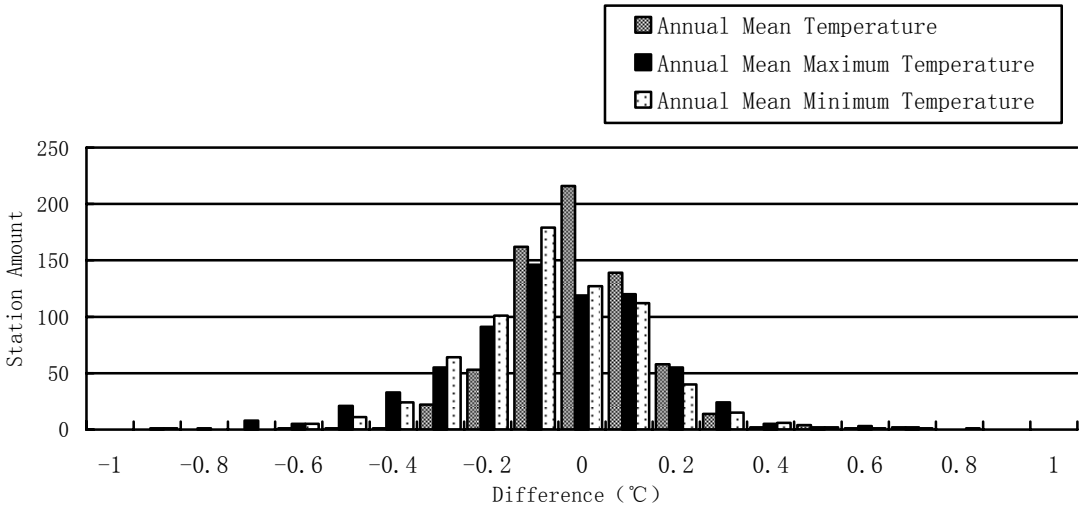

Figure 1: frequency distribution of the difference of annual mean, annual mean maximum and annual mean minimum temperature

Figure 1 is the frequency distribution of difference in annual mean, annual mean maximum and annual mean minimum temperature. From the figure, it can be seen that 76.5% stations have the difference of annual mean temperature of ±0.1℃, among which 32% stations have the difference of 0, which means there is a slight difference between auto and manual observation of temperature in most stations of China within the range of 0.1℃. There are fewer stations with the difference of annual mean maximum and minimum temperature of ±0.1℃, taking up 55.7% and 60.6% respectively. For the extreme temperature, the difference between auto and manual observation is more obvious than that of mean temperature. The stations with the difference of annual mean, annual mean maximum and minimum temperature of ±0.2℃ account for 92.9%, 76.8% and 81.0%, so for the observation of both mean and extreme value, the difference of auto and manual observational temperature falls in the accepted error range of auto observation.

For the annual mean temperature, there are 12 stations with the difference more than ±0.3℃, among which 6 stations have relative large difference of all the months in a year, which means there is a large system error in the auto observation, so problems still exist in a few stations despite the small temperature differences in most national stations. The possible reasons for those automatic meteorological stations with system errors may lie in the instruments which haven't been tested strictly or the shift of these instruments. For the other 6 of the 12 stations, more significant discrepancy occurs when the instruments go wrong. If strict real-time inspection and quality control are applied in auto stations, then this kind of problem can be tested and handled.

From figure 1, it can be shown that the frequency of difference for annual mean temperature is generally distributed around the center, only a little deflecting to negative value, which means the difference distribution of auto and manual observation is reasonable for mean temperature. The center of difference for annual mean maximum and minimum temperature lies in the area of negative values. Especially for the annual mean minimum temperature, the stations with negative difference obviously outnumber those with positive values, which indicates that most auto observational daily maximum and minimum temperatures are higher than their manual observational counterparts.

2.2 Precipitation

For precipitation, monthly percentage error is calculated, namely the percentage of difference between monthly manual and auto observational precipitation in the manual observational precipitation, followed by taking the absolute value of monthly percentage error, then obtaining the mean value of percentage error during the parallel observational period in each station.

The results show that 70 percent areas in China have the precipitation percentage error of less than 8%, mainly in the east and coast area. 30 percent areas have the precipitation percentage error of more than 8%, mainly in the Xinjiangand Qingzang plateau area. This kind of distribution indicates the precipitation percentage error in wet areas is smaller than that in dry areas. In 625 stations with comparison record, there are 447 stations with precipitation percentage error of less than 8%, occupying 71.5% of all stations. 174 stations have percentage error of 8 – 40%, accounting for 27.8%, among which 27 stations have percentage error of more than 20%.

In the 27 stations with the mean percentage error of over 20%, only 3 have annual precipitation of over 1000mm, and the rest 24 stations have annual precipitation of less than 1000mm, among which 10 stations have annual precipitation of 500 – 1000mm, 8 stations of 100-500mm, and 6 stations of less than 100mm. Therefore, if with small amount of precipitation, the percentage error is possible to be large despite the small difference in the difference between auto and manual observation. It is influenced by statistical method. For the months with little precipitation, it will be more valuable to calculate the precipitation difference of two kinds of instrument only.

Besides, there are some cases in which observation error occurs in auto stations when there is no precipitation. For example, in December of 2003, in Maduo, Qinghai, the precipitation percentage error is 350%, because the precipitation of 11.2m was observed by its auto station on 15 of this month, but actually there is no rain on that day.

There are odds for auto stations to have error data on observing precipitation, mainly because all the data are from auto and manual parallel observation record, and there is no strict quality control in those stations, thus leading to large random error in the areas or seasons with less precipitation. Since the tip ombrometer in auto precipitation stations are influenced by interfering signals, one measuring error may consequently cause the abnormality of daily and monthly precipitation. Further analysis shows that after the auto stations started functioning, the quality of precipitation data has been improved greatly comparing the data in parallel observation period due to the strict quality control from station, provincial and national department, thus eliminating most random errors. To be exact, 80% stations have controlled the percentage error of annual precipitation within 5% and only 4% stations have percentage error of over 10% in annual precipitation.

2.3 Pressure

The distribution of difference of pressure generally conforms to the geographical feature of our country. The area with pressure difference of ±0.2hPa is mainly distributed in the area with low sea level elevation in the east of China, and the area with difference of 0.2-0.6hPa is mainly in the west area with high sea level elevation. A few stations have the pressure difference of less than -0.2hPa, distributed in the east while a few others with the value of more than 0.6hPa are located in the west. Therefore, the accuracy of auto observational pressure is probably influenced by the sea level elevation of stations. In areas with lower sea level elevation, auto observational pressure is a little higher than manual observational data, but the difference is not very obvious, while in the high sea level elevation areas, the auto observational pressure is obviously lower than manual observational one. However, in the area of Tibet, there is no reflection of such features and the causes still need further analysis.

2.4 Relative Humidity

The areas in half China have the difference of ±2% for the mean relative humidity. The areas with slight difference between auto and manual observation of relative humidity are mainly distributed in the relative dry areas to the north of Changjiang River in China. A few stations have the auto observational value higher than 2%, mainly located in the middle and lower reaches of Changjiang River. The areas with the auto observational value

lower than 2% also occupy half of China, especially in the relative wet areas to the south of Changjiang River, Qingzang Plateau, and the northeast part of northeast China.

Figure 2 is the frequency distribution of difference for the relative humidity, from which it can be seen that the center of frequency is not located in the data segment with difference of 0%, stations with difference of 2% form the major part and the difference obviously inclined to the positive value area. The auto observational data in relative humidity are a little lower than manual observational ones in areas to the south of Changjiang River, Qingzang Plateau, and the northeast part of northeast China.

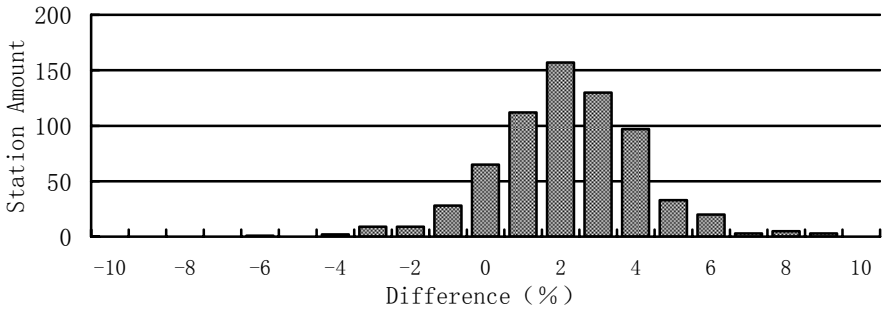

Figure 2 frequency distribution of the difference for relative humidity

In manual observation, when temperature is over −10℃, dry-and-wet-bulb hygrometer is used to observe humidity while Saussure's hygrometer is used when temperature is lower than −10℃. In automatic meteorological stations, Humicap hygrometer is used to observe relative humidity all year round, whose observational principle has great difference from manual observational one. In the summer of southern areas, the Humicap hygrometer of auto stations has obvious distortion in high temperature and high humidity, especially when the relative humidity approaches 100%. In Qingzang Plateau and the northeast part of northeast China, Saussure's hygrometer used in winter makes the observational result of relative humidity a little higher than auto observational data. In mountain stations, there are more obvious observational errors in auto stations with Humicap hygrometer and the instrument doesn't last long. For example, from Jan. to March of 2005, the Humicap hygrometer in Huangshan station lost its function, leading to a great amount of missing data.

2.5 Ground Surface Temperature

There are obvious differences between the north and the south in the difference of annual mean ground surface temperature, except a few provinces. Half areas in China have the difference of ±0.5℃ between auto and manual observation of ground surface temperature, mostly distributed in the areas with relative high temperature of China. In the north area, the lower the temperature, the higher auto observational ground surface temperature. And in the northeast areas and the north of Xinjiang Province, in average the auto observational ground surface temperature is 5℃ higher than manual observational one.

The reasons for the difference between auto and manual observation increasing with latitude lie in the difference of observational instrument and method. In winter perpetual snow covers the ground. If the thermometer is buried by snow, for manual observation, based on "surface meteorological observation rules", the thermometer should be take out of snow and horizontally set on the snow with the sensing part and thermometer body half into the snow before observation. In this case, the ground surface temperature in manual observation is snow surface temperature actually. For auto meteorological stations, platinum resistance thermometer (PRT) still functions even when it is covered by snow, so the ground surface temperature in auto observation is under snow temperature actually. This kind of different observation causes the higher ground surface temperature in auto observation when there is perpetual snow. The higher latitude, the longer time the perpetual snow stays on the ground, and the greater difference between auto and manual observation. Then inhomogeneity may exist between

manual and auto observational data in the time series of ground surface temperature for the stations with perpetual snow in winter if without proper correction.

To avoid the influence of winter perpetual snow on the auto observation, the mean difference of ground surface temperature from May to September has been calculated. The areas originally having the mean difference of less than －3℃ for ground surface temperature in the northeast and the north of Xinjiang have disappeared, and only in Qinghai Province, the auto observational ground surface temperature is obviously higher than manual observational one. In the whole nation, there are more areas with the difference between auto and manual observation in this element less than 0.5℃.

In all, there exists great difference between auto and manual observational ground surface temperature in the snowing period in the north. Due to the difference of observational instrument and method, in the snowing period of the north, auto observational ground surface temperature cannot reflect the real situation of ground surface, thus leading to great difference from manual observational data. When auto and manual observational ground surface temperature data are both used, this problem should be taken into consideration.

2.6 Wind Velocity and Direction

For the difference of 10-minute mean wind velocity, largely distributed areas in China have slight difference between auto and manual observation. Only a few areas have the difference of more than ±0.2m/s, mainly in a few provinces. The areas with auto observational wind velocity of over 0.2m/s higher than manual observational one are mainly distributed in the west of Inner Mongolia, the northeast of Xinjiang, Gansu, Sichuan, Yunnan, Jilin, Hebei, and Jiangsu provinces, while the areas with auto observational wind velocity of over 0.2m/s lower than manual observational one are mainly distributed in such provinces as Heilongjiang, Ningxia, Shandong, Anhui, and Guangdong. This kind of systematic error is possibly associated with the different manufacturer and style of auto meteorological stations in different provinces.

The matching rate of wind direction has been calculated to analyze the wind direction of 10-minute mean wind velocity. In most areas the matching rate of auto and manual observational wind direction has achieved over 70%, and nearly half areas reach the matching rate of over 90%. The areas with the wind direction matching rate of less than 70% are mainly distributed in the east of Qinghai, Tibet, the north of the northeast, the west of Xinjiang and a few other stations.

3. Possible Influence of Temperature Difference on the Continuity of Data

The official data of auto observation in national base stations have been increasing since 2002 when 46 automatic stations adopted auto observational as formal record. Before 2002 manual observational data were used and after 2002 auto observational data are used. To test the possible influence of auto stations on the continuity of temperature data, cramer's method is applied to test the difference between auto and manual station data, namely to test whether there is significant difference between the mean value of 2002-2004 and the mean value of original time series. The annual mean temperature of 618 stations from 1990 to 2004 is tested. On the significant level of 0.05, altogether 62 stations have changes in 1990s or around 2002 (due to station relocation or the start of auto observation), among which 5 stations (not accounting the influence of station relocation) are included in the 45 auto stations since 2002. Further test is made on whether there are neighboring stations of the 5 stations having interruptions and it can be found that both station 54339 and station 54342 have interruptions, but the two stations are neighbors of each other, which means the interruption is caused by the increase of annual mean temperature. There is no neighboring stations having interruptions for the other rest 3 stations, indicating the significant difference of these stations are not caused by the increasing temperature. Then the significant difference in the annual mean temperature data and long-period time series of the 3 stations in 2002-2004 is caused by the change of instrument in auto stations, occupying 6.7% of the 45 auto stations.

Table 1: automatic weather stations from 2002 with significant difference with long time series in annual

mean temperature ℃

Province	Station ID	difference with long time series	difference with parallel value
Liao Ning	54337	0.48	0.15
Hu Bei	57545	0.44	-0.03
Jiang Su	58259	0.62	-0.08

The testing result of significance level 0.05 (that is, 6.7% auto stations functioning in 2002 have interruptions in the year of 2002) shows that the change of instrument in auto stations has certain influence on annual mean temperature.

The test is only an initial one since the data of auto stations just started from 2002 and don't cover many provinces (6 stations in Liaoning, 14 stations in Anhui, 15 stations in Hubei, 1 station in Shanghai, 10 stations in Jiangsu). However, it still can be found that there is certain influence from the use of auto stations on the continuity of temperature time series, although the general difference is not significant. In some provinces, the influence can be great and may affect the analysis of temperature and climate change. When those data are used together, it calls our attention to make homogeneous test and correction for the time series.

4. Conclusion

1) Certain differences exist in all the meteorological elements between auto and manual observation, but in most areas the differences in temperature, precipitation, pressure, relative humidity, wind velocity and direction, and ground surface temperature fall in the accepted error rang of auto stations.
2) In our country, 76.5% stations have the difference of ±0.1℃ in the annual mean temperature, which means there is a little difference between auto and manual observational temperature in most stations of China. To be exact, the difference of annual mean maximum and minimum is a little larger than annual mean temperature, and the maximum and minimum temperature observed in automatic stations is a little higher than that in manual observation. More significant system error appears in the auto observation of a few stations, and when the auto observational data of temperature are used the instrument systematic error should be corrected.
3) The difference of all elements between automatic and manual observation has different distribution features in China, and the same element may vary greatly in different climatic situations. In dry areas or in the seasons with little precipitation, there is a great difference between auto and manual precipitation observation. The areas with difference of 0.2-0.6hPa in pressure are mainly distributed in the west areas with high sea level elevation. In the wet areas in the south to the Changjiang River, Qingzang Plateau, northeastern northeast area and mountain stations, great difference appears in the auto and manual observation of relative humidity. In the north during snowing period there is a significant difference between auto and manual observation of ground surface temperature.
4) Since the automatic stations are formally functioning, strict quality control has been made from station, provincial and national department to improve the quality of precipitation data. 80% stations have the percentage error within 5% in annual precipitation and only about 4% stations have the percentage error of over 10% in the annual precipitation.
5) The use of automatic stations exerts certain influence on the continuity of annual mean temperature, so it is necessary to test whether the significant difference exists in the auto and manual observation time series if manual and auto observation data are used. Homogeneity correction is needed if the significant difference appears.

The difference between auto and manual observation is unavoidable. Any instrument change in history will bring the data difference, especially the change from manual observation to automatic observation with quite different observational instrument and method. The difference is only the result of comparison, without specifying which observational instrument causes such difference.

Since the automatic stations formally functioned, strict quality control has been made from station, provincial and national department to improve the quality of automatic observation data. The peculiar value in automatic observation has been eliminated due to the quality control. For example, the difference of temperature between auto and manual observation has been greatly reduced after quality control, but difference still exist in some stations with systematic error of auto observation, so quality control is essential for the quality of automatic observational data.

The time series of automatic observation are short in China and the replacement of automatic observation is just starting, so with longer observational time series and more automatic stations further analysis is needed to know the causes for the difference between automatic and manual observation as well as correcting methods, such as the difference of hour value, daily mean value between auto and manual observation, the difference of day, season change and area difference, the influence of auto observation on extreme value. At the same time, many reasons such as the instrument change, instrument drift and the influence of instrument screen on the temperature and humidity still call for detailed analysis.

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