NOTES AND CORRESPONDENCE

Examination of Correction to Historical SST Data
Using Long-term Coastal SST Data Taken around Japan

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Abstract

Folland and Parker (1995) proposed the correction (so-called bucket correction) to historical sea surface temperature (SST) data from ship reports such as the Comprehensive Ocean-Atmosphere Data Set (COADS). In order to examine the validation of this correction, comparison is made between SST data and long-term coastal SST (CSST) data taken at nine stations around Japan. For this purpose, we extract SST data in the adjacent areas surrounding nine CSST stations, from the files of COADS and the Kobe Collection data which have been recently released by the Japan Meteorological Agency and the Japan Weather Association. As a result, it is found that the data of five CSST stations among nine stations are suitable for comparison. When Folland and Parker's correction is adopted to the historical SST data, the systematic biases in monthly mean SST anomalies have been corrected almost perfectly at three stations, and the biases at the other two stations have been reduced by 40-50%.

1. Introduction

In order to precisely detect the climate variation, climate jump or so-called regime shift and global warming, to accumulate the historically long-term data as much as possible is very important and essential. However, since the measuring instruments and methods have been changed sometimes, we have to pay careful attention on the data quality, i.e., existence of instrumental and methodological biases. For instance, before World War II, sea surface temperatures (SST) have been measured mainly by the bucket (wooden or canvas buckets) method on board, but after then the bucket method has been replaced by the intake method. For this methodological change, many researchers have already pointed out the existence of systematic biases between the two (e.g., Barnett 1984; Folland et al. 1984; Wright 1986). Therefore, based on this situation in historical SST data, correction for the historical SST data taken by the bucket method has been investigated and proposed (e.g., Folland and Parker 1995).

Recently, the Japan Meteorological Agency (JMA) and the Japan Weather Association (JWA) have released the historical marine meteorological data of approximately 1 million data by CD-ROM (Manabe 1999). Since these data have been
archived mainly by the former Kobe Marine Observatory/JMA, these are called the ‘Kobe Collection’. The released data mainly cover the data sparse era and area in the present available data set such as the Comprehensive Ocean-Atmosphere Data Set (COADS; Woodruff et al. 1984): the period from 1901 to 1932, especially in the 1910's around World War I and the North Pacific (more than 80% of the released data). See Figs. 4(a) and (b) of Manabe (1999) on the details of temporal and spatial distributions of the released Kobe Collection data. Therefore, it is expected that the Kobe Collection data can considerably contribute to the clarification of more robust climate variation in the North Pacific before World War II. Especially, these may be useful for the clarification of El Nino/Southern Oscillation (ENSO) phenomena and the decadal to interdecadal variations found in the Pacific sector (e.g., Nitta and Yamada 1989; Trenberth 1990; Tanimoto et al. 1993; 1997; Minobe 1997; Zhang et al. 1997).

However, as mentioned above, we have to pay careful attention to the treatment of SST data taken in the period of the bucket method. If some instrumental or methodological biases exist, they have to be properly corrected. The purpose of this article is to examine the validity of correction to historical SST data proposed by Folland and Parker (1995), using the independent data set of the long-term coastal SST (CSST) data taken around Japan, whose measurements have been conducted by JMA and Japan Fisheries Agency (JFA).

The remainder of this paper is organized as follows. In Section 2, the CSST and SST data used are described, and Folland and Parker’s correction and their adoption to the present data set are introduced. In Section 3, the results of validation are described. Section 4 gives summary.

2. The data used and Folland and Parker’s correction

2.1 Coastal sea surface temperature (CSST)

JMA and JFA have conducted CSST measurements at several tens number of stations around the Japan Islands as well as the coasts of the Korean Peninsula since early this century, and several stations of them are continued to the present (Tokai Regional Fisheries Research Laboratory 1982; Yoshida 1997). In the present study, we use the data at nine CSST stations as shown in Fig. 1, whose time series are relatively longer and span before and after the period of World War II. Among them, three stations of Suttsu (henceforth Station a), Miyako (e) and Ishigakijima (i) belong to JMA, and six stations of Shiokubi (b), Sirakamisaki (c), Inahozaki (d), Enoshima (f), Nojimaizaki (g) and Hachijyojima (h) belong to JFA.

From the beginning of measurements to the mid 1970s, JMA CSST data had been taken by the bucket and the stem thermometer once (10:00 am at local time) every day. After the mid 1970s, it is replaced by the electric measurement using a platinum-wire resistor. So, in the present study, we use only the data taken before 1971. On the other hand, JFA CSST data had been taken only every five days using the bucket and the stem thermometer. So, although we use monthly mean data, the JFA data may be insufficient ones in quality compared with the JMA data. Figure 2 shows time series of CSST data at nine stations presently available.

2.2 Sea surface temperature (SST)

In the present study, we use the raw (individually ship-reported) SST data archived in COADS and the Kobe Collection. The data period treated is from the beginning of the archives (1854 for COADS and 1890 for the Kobe Collection) to 1997. First, we set the circular area with the radius of 200 km surrounding each CSST station (see Fig. 1) and extract the raw SST data from the above two data sets, and then monthly mean values are computed. At this stage, to discard the outliers and erroneous ones of the raw data, we calculate the standard deviations for each calendar month using the raw data of the whole period, and the raw data exceeding two times of standard deviation are discarded. Finally, we update monthly values only when the number of raw data is greater than five in each month. Figure 3 is the time series of calculated monthly mean SST at nine circular areas surrounding nine CSST stations. The correction by Folland and Parker (1995) is not applied to these data.

2.3 Bucket correction by Folland and Parker (1995)

Here we briefly introduce the correction proposed by Folland and Parker (1995) to historical SST data based on the ship reports, and its adoption to the present SST data set. Since SST data in the bucket method are measured on the ship deck using the stem thermometer inserted in the bucket, readings of SST are influenced by the heat exchange through the side and bottom walls of the bucket as well as water surface during the measuring work. For this situation, using the idealized heat budget model for the bucket, they calculated the heat exchange quantity, and estimated temperature change during the measuring work. Since the heat exchange between the bucket (and water inside) and the surrounding air depends on the various measuring conditions such as air temperature, humidity, solar radiation as well as ship speed and material of bucket (wooden or canvas), they provided correction values to four types of measuring conditions: wooden buckets on slower or faster cruising ships and canvas buckets on slower or faster cruising ships. In addition, since the environment of marine meteorology depends on the sea areas and seasons, these correction values are functions of each calendar month and year, and
each $5^\circ \times 5^\circ$ grid points in the world's oceans (see Fig. 1). Moreover, as time goes by, measuring conditions changed from wooden bucket to canvas bucket, and from slower ship to faster ship. Therefore, actual correction values are obtained by the mixture of four types of correction values. These correction values are given from 1856 around the beginning of archive of ship reports to 1941 when World War II begun. That is, they regard all measurements since 1942 have been made by the intake method. The readers may refer to Folland and Parker (1995) on details.

For the correction of SST data taken until 1941, we use the correction values of the most adjacent grids to the CSST stations. Although CSST data have also been measured by the bucket method as mentioned above, we do not adopt this correction since the method is the same even after 1941 at least until the mid 1970s. In addition, since CSST data may be influenced by the local geographical situations, we can not expect the agreement between absolute values themselves of CSST and SST data. That is, we will make a comparison between anomaly fields of CSST and SST data.

3. Result of comparison

First, non-seasonal anomalies are calculated by subtracting the mean seasonal variation. Climatologies of mean seasonal variation are calculated using the data of 30 years from 1942 to 1971 (reference period) at both CSST stations and circular areas for SST. Here, we use only so-called "match-up" data between CSST and SST: for example, when SST data are blank at some months, then CSST data at those months are not used in calculation of climatologies, and vice verse. This 30-year period is chosen because no correction is needed for the SST data as mentioned previously before. Then, anomaly fields during the whole period are computed. Here, we prepare two SST data sets: a uncorrected one, and one corrected using the correction values proposed by Folland and Parker (1995). Figures 4 and 5 show the time-series of CSST anomalies at nine stations and those of uncorrected SST data.

![Fig. 1. Locations of nine coastal sea surface temperature (CSST) stations used in the present study. Stations are as follows: Suttsu (a), Shiokubi (b), Shirakamisaki (c), Inahozaki (d), Miyako (e), Enoshima (f), Nojimazaki (g), Hachijyojima (h), and Ishigakijima (i). Circles surrounding CSST stations denote the areas where SST data are extracted for comparison from COADS and the Kobe Collection. Symbols of cross (×) attached to every $5^\circ \times 5^\circ$ degrees denote the grid points where correction values are given by Folland and Parker (1995).](image-url)
Fig. 2. Time series of monthly CSST data at nine stations: Stations a through i.

Fig. 3. As in Fig. 2 but for monthly SST data averaged in nine circular areas surrounding nine coastal stations.
Fig. 4. As in Fig. 2 but for non-seasonal monthly CSST anomalies which are defined as the deviations from the 30-year climatologies of 1942-1971.

Fig. 5. As in Fig. 2 but for non-seasonal monthly SST anomalies. These are uncorrected ones and corrected ones using Folland and Parker's correction values are also prepared (not shown here).
anomalies at corresponding nine circular areas, respectively: those of corrected SST anomalies are not shown here.

In order to examine the validation of correction values proposed by Folland and Parker (1995), scatter plots are prepared between CSST anomalies, and corrected and uncorrected SST anomalies for the two 30-year periods of 1912-41 and 1942-71. Figures 6(a) through (c) show those at Ishigakijima station (Station i) as an example. Here Figs. 6(a) and (b) show those using the uncorrected and corrected SST anomalies for the period of 1912-1941, respectively. In each panel, a closed circle with horizontal and vertical bars denotes the mean deviations from 30-year climatologies (1942–71) and their standard deviations. Standard deviations mean the variabilities during the comparison period. Here it is natural that in Fig. 6(c), mean deviations of CSST and SST are both zero by the definition of anomalies. On the other hand, mean deviation of uncorrected SST anomalies is $-0.72^\circ$C in the period of 1912-1941, while that of corrected SST anomalies is $-0.37^\circ$C and that of CSST is also $-0.37^\circ$C. That is, the difference of $0.35^\circ$C between uncorrected and corrected SSTs comes from the correction by Folland and Parker (1995), and due to the correction, 30-year mean deviation of corrected SST in the period of 1912–1942 becomes the same as that of CSST. That is, we can say that the correction proposed by Folland and Parker functions very well at least to SST data surrounding Ishigakijima CSST station (Station i).

We made the same analysis for the other eight CSST stations (not shown here). Figures 7(a) through (b) show the summary of comparison for 9 CSST stations. Figure 7(a) shows the correlation coefficients between CSST and SST anomalies at each station. The brackets are attached to the cases which do not exceed the 98% significant level in the Student t-test for correlation coefficient. Here, we estimate the degrees of freedom using the data number (total months used in comparison) divided by the integral time scale of five months based on estimation from the auto-correlation analysis to the individual time series (e.g., Davis 1976). It is seen at four stations (Stations d, e, g, and h), among nine stations have cases in which correlation coefficients do not exceed the 98% significant level. We regard these stations as ones which are not appropriate for comparison, and therefore the results of these four stations are excluded in the later consideration. Figure 7(a) shows that in general correlation coefficients for the period of 1942–1971 are greater than those for the period of 1912–1941. This may reflect the relatively low number of SST data in the period of 1912–1941 compared with that in the period of 1942–1971.

Figure 7(b) shows the mean deviations of uncor-

![Fig. 6. Scatter plots of SST and CSST anomalies at Ishigakijima (Station i). (a) CSST versus uncorrected SST in the period of 1912 to 1941. (b) As in (a) but for corrected SST. (c) As in (a) but for in the period of 1942 to 1971. Closed circle with vertical and horizontal bars denotes mean deviation of the anomalies with standard deviations. The inclined straight line is the linear regression line. Numerals in brackets of the upper left corner are mean deviations of SST anomalies (left) and CSST anomalies (right). The coefficients (a and b) of the linear regression line and correlation coefficient (r) are also denoted in the lower right corner.](image-url)
rected SST, corrected SST and CSST in the period of 1912–1941 at each station. As mentioned before, if the present bucket correction is perfect, that is, it functions perfectly, then the difference using corrected SST (closed triangles) should coincide with that of CSST (closed stars). We can see that at Stations c, f and i those are almost the same, actually those differences are 0.03°C, 0.10°C and 0.00°C, respectively. At Stations a and b, differences between mean deviation of corrected SST and that of CSST amount to 0.25°C and 0.18°C, respectively. However, these numbers are fairly improved compared with 0.41°C and 0.36°C between that of uncorrected SST and that of CSST.

As a conclusion, based on the comparison for five CSST stations, we can say that the bucket correction proposed by Folland and Parker (1995) functions very well at least for the historical SST data set treated in the present study; that is, the systematic biases in monthly mean SST anomalies have been corrected almost perfectly at three stations, and the biases at the other two stations have been reduced by 40–50%.

4. Summary

In the present study, we have examined the validity of correction for historical SST data taken by the bucket method, which was proposed by Folland and Parker (1995), using the long-term CSST data taken at nine stations around Japan. As a result, the data of five CSST stations among nine stations were suitable for comparison. It can be concluded that the correction to the historical SST data proposed by Folland and Parker (1995) functioned very well in the historical SST data computed from COADS and the Kobe Collection, at least to the sea areas around Japan. The systematic biases in monthly mean SST anomalies have been corrected almost perfectly at three stations, and the biases at the other two stations have been reduced by 40–50%. Precisely speaking, since only the CSST data taken around Japan were used, we can not say anything
on the validity of this correction in the other sea areas. If another appropriate long-term CSST data are available in the world’s oceans, the same comparison will be useful, and the validation of the present correction will be able to be confirmed much more robustly. Further, it can be pointed out that the present method using the coastal meteorological stations as well as CSST stations can be applied for other marine elements such as sea level pressure.

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References


日本周辺の長期にわたる沿岸水温資料を用いた
歴史的海面水温資料に対する補正の検討

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Folland and Parker (1995) は、統合海洋気象データセット (COADS) のような船舶通報に基づく歴史
的海面水温 (SST) 資料に対する補正 (いわゆるバケツ補正) を提案している。この補正の妥当性を検討す
るため、SST 資料と日本周辺の 9 つの観測点で取得されてきた長期の沿岸水温 (CSST) 資料との比較を
行った。本研究では、この目的のため、9 つの沿岸水温観測点周辺の海面水温資料を、COADS と最近気
象庁/気象協会から公表された神戸コレクション資料から作成した。解析の結果、9 つの沿岸水温観測点の
うち、5 つの観測点が比較に適していることが見出された。Folland and Parker が提案した補正をこれら
歴史的 SST 資料に施すと、3 つの観測点ではほぼ完全に系統的バイアスを補正し、残り 2 つの観測点では
バイアスの 40-50 %を補正することが分かった。