The Seventeenth International Symposium on Artificial Life and Robotics 2012 (AROB 17th '12),
B-Con Plaza, Beppu, Oita, Japan, January 19-21, 2012

The maximum and minimum temperature trends in Oita

Masao Igarashi[1], Takahiro Yamazaki[2] and Eiji Nunohiro[3]

[1] College of Bioresource Sciences Nihon University, Kanagawa, Fujisawa 252-0880, Japan (Tel 0466-84-3715)
[2] Graduate School of Bioresource Sciences Nihon University, Kanagawa, Fujisawa 252-0880, Japan
[3] Tokyo University of Information Sciences, Chiba, Wakaba-ku, 265-8501 Japan

Abstract: Japan Meteorological Agency has provided various kinds of historical temperature data of local meteorological station, such as Oita since February 1887. The provided temperature data contain the maximum, the minimum and the mean records on 17 leading and 57 local meteorological stations. We apply a nonlinear curve to the datasets and estimate the trends of the maximum, the minimum and the mean temperature, especially in Oita, by a numerical iteration method.

Keywords: Nonlinear fitting, Temperature, Warmth trend, Least square method, Newton method,

1 INTRODUCTION

There are many reports concerning to the global or local trends of temperature, such as the warmth is increasing or not. In many cases, the huge datasets and a super computer are applied to the estimations. Hence the practical model and the tuning method of parameters are hardly provided, because of the complexity. We propose a simple method to conform the local temperature trends, such as local warming or not, using the Oita temperature data since January 1888.

The temperature data in Oita is provided at the following URL: `http://www.data.jma.go.jp/obd/stats/etrn/index.php`

We apply a nonlinear model $f(x)$, the variable x is month, to the data. $f(x)$ consists of two terms, that is the year trend and the month trend. Mathematica `FindFit` function is applied to determine the parameters of the model[1]. Providing a fitness criterion to the model, the parameters of $f(x)$ are practically evaluated.

Applying $f(x)$, we are able to estimate an increasing trend of the maximum and minimum temperature respectively. The program to evaluate the parameters of $f(x)$ is at most 20-line as shown in this article. The year change trend is described by a linear term of $f(x)$ and the month change trend is also described by the periodical term of $f(x)$. The results clearly show the increasing trend of the temperature and the trend is similar the report provided by NASA [2] and JMA [3]. We remark that the proposed method does not need a statistics procedure, such as Annual Mean, 5-year Running Mean or regression analysis to evaluate $f(x)$.

2 MATERIAL AND METHOD

We apply the Oita local station data from 1888 to 2010 and denote the maximum and minimum temperature data obtained from the previous URL as follows ($^\circ$C) :

max={11.2, 8.5, 14.3, 17.2, 21.4, 24.3, 28.8, 30.4, 26.3, 21.5, 17.9, 13.7, $\cdots\cdots$, 11.4, 12.9, 14.7, 17.6, 23.6, 26.6, 31.3, 34.6, 30.7, 23.1, 17.6, 13.1 }

min={1.3, -0.1, 4.6, 9.7, 12.9, 16.4, 22.0, 22.7, 18.3, 11.6, 9.4, 4.5 , $\cdots\cdots$, 2.1, 5.1, 6.8, 9.6, 13.9, 19.3, 23.8, 25.6, 22.3, 16.5, 8.2, 4.7}

For example, the first record 11.2 and the last record 13.1 in the sequence "max" are the maximum temperature of January 1888 and December 2010 respectively. And also the first record 1.3 and the last record 4.7 in the sequence "min" are the minimum temperature of January 1888 and December 2010 respectively. Both data size are $k = (2011 - 1888) \times 12 = 1476$.

We apply the following nonlinear curve to the data

$$y = f(x) = a_1 + a_2 x + a_3 \sin(\pi x/n + a_4) \qquad (1)$$

where a_1,a_2,a_3,a_4 and n are the unknown parameters. This model is simplified compared with that of NDVI [1].

We apply the least square method and the Newton iteration method to determine these parameters. For simplicity, we use Mathematic's `FindFit` function for the fixed integer n and iterate n from $n = 1$ to $n = 100$. To find the best n between them, we apply the following CR$_n$ criterion [2] to terminate the iteration.

$$\mathrm{CR}_n = \frac{\sum_{i=1}^{k} \frac{|y_i - \widehat{y_i}|}{\max\left(|y_i|, |\widehat{y_i}|\right)}}{k} \qquad (2)$$

where y_i and $\widehat{y_i}$, $i = 1, 2, \cdots, \cdots, k$ are the estimated and the observed temperatures respectively. This CR$_n$ is similar to the mean value of the relative errors between the observed temperatures and the estimated temperatures

If CR$_n$ is small, $y_i = f(x_i)$ of (1) corresponds well to the observed temperatures $\widehat{y_i}$. On the other hand, if CR$_n$ is large,

[1] Mathematica Ver.8 built in function
[2] `http://data.giss.nasa.gov/gistemp/graphs/`
[3] `http://ds.data.jma.go.jp/gmd/tcc/tcc/products/gwp/temp/ann_wld.html`

y_i does not correspond well to the observed temperatures. Hence the integer n, $1 \leqq n \leqq 100$, is chosen so as to give the smallest value CR_n.

For the max data, a program to find the best fit nonlinear curve is as follows:

```
Clear[CR, p, q, s];
q = max; k = Length[q];
Do[{Clear[f], f[x_]
= a1*Sin[(π x)/n + a2] + a3 + a4 x /.
FindFit[q,
a1*Sin[(π x)/n + a2] + a3 + a4 x,
{a1, a2, a3, a4}, {x}],
y[n, x_] = f[x],
p = Table[f[x], {x, 1, k}],
s = Abs[p - q]/Max[Abs[p], Abs[q]],
CR[n] = Sum[s[[i]], {i, 1, k}]/k},
{n, 1, 100}];
r0 = Table[CR[i], {i, 1, 100}];
n = First[Position[r0, Min[r0]][[1]]];
r1 = Table[i, {i, 1, 100}];
r2 = Transpose[{r1, r0}];
Print["y = " y[n, x]]
fig1 = ListPlot[q, PlotStyle -> {Blue},
AxesLabel -> {Month, °C}]
fig2 = Plot[y[n, x], {x, 0, k},
PlotStyle -> {Thickness[0.0001], Green},
AxesLabel -> {Month, °C}]
Show[fig1, fig2]
ListPlot[r2, PlotRange -> {0.0, 0.25},
AxesLabel -> {"n", CR}]
```

3 RESULTS

We have the following best fit function using the criterion (2) for the maximum temperature

$$f(x) = 19.16 + 0.00116x + 10.0\sin(3.93 + \pi x/6) \quad (3)$$

where $\mathrm{CR}_6 = 0.028$.

For the case of minimum temperature we have

$$g(x) = 10.23 + 0.00139x + 10.7\sin(3.92 + \pi x/6) \quad (4)$$

where $\mathrm{CR}_6 = 0.044$.

Figure 1 shows the maximum temperature data (blue dots) and $f(x)$ (red curve). Figure 2 shows the minimum case.

We consider the 12 trends of decade's periods, such as 01/1890 to 12/2010, 01/1900 to 12/2010, $\cdots\cdots$ and 01/2000 to 12/2010. Figures 3 and 4 show the maximum and the minimum trends of each decade.

Figures 5, 6 and 7 show the trends evaluated by 57 (maximum and minimum temperature), and the mean temperature trend of 17 leading stations.

The temperature up trend from 1880 to 1980 and down trend from 1980 to 2010 are similar to the Figures 3, 4 and 5.

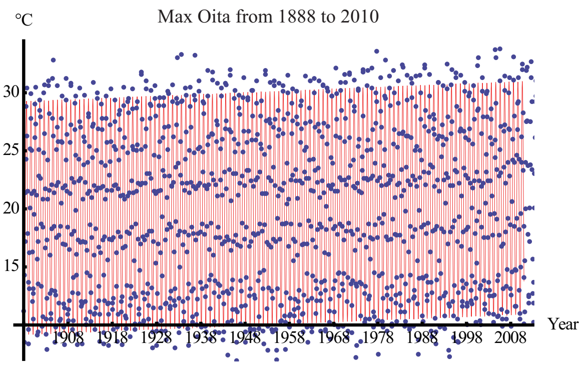

Fig. 1. The maximum data (dots) and the fitting curve

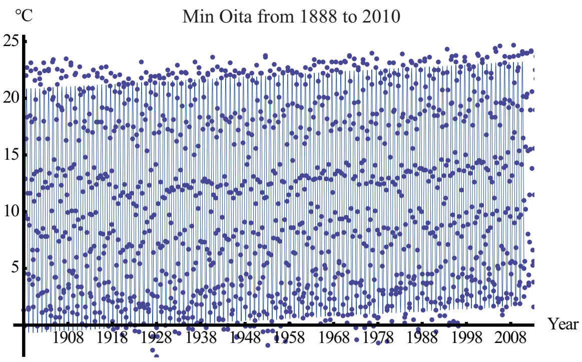

Fig. 2. The minimum data (dots) and the fitting curve

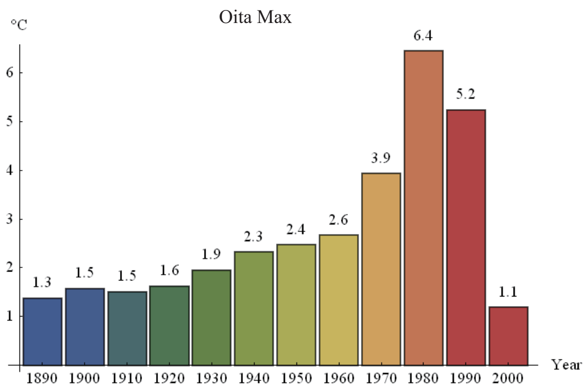

Fig. 3. The maximum trends of each decade

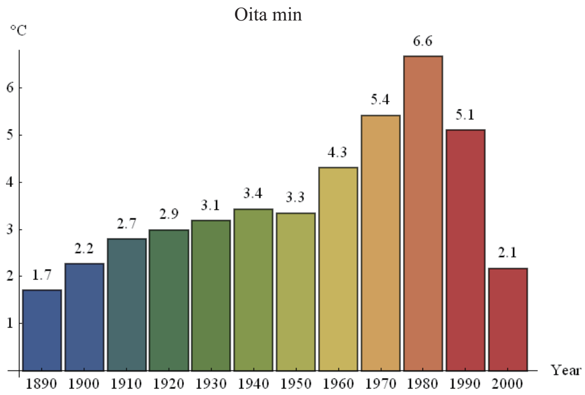

Fig. 4. The Minimum trends of each decade

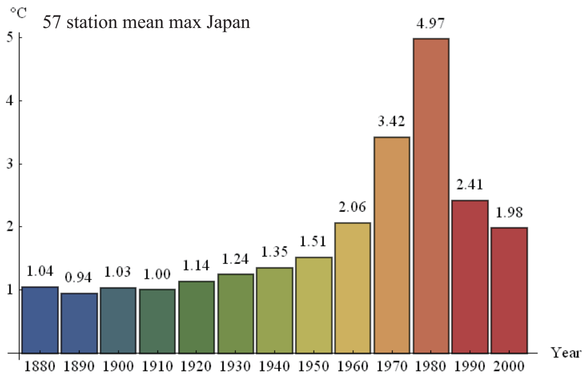

Fig. 5. The mean of maximum of 57 local stations

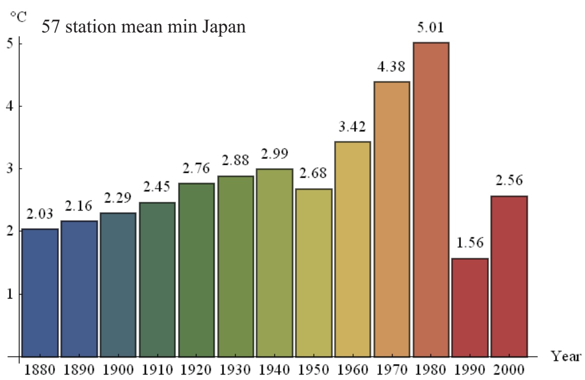

Fig. 6. The mean of minimum trend of 57 local stations

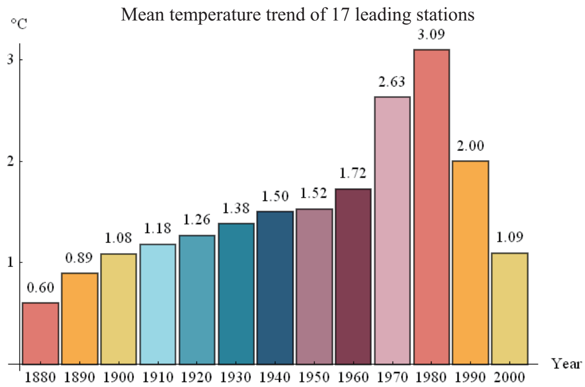

Fig. 7. The mean trend of 17 leading stations

4 DISCUSSION

The proposed criterion (2) gives $n = 6$ as the best parameter more than 200 examples. For the case of maximum temperature (3)

$$-\log_{10} \mathrm{CR}_6 = -\log_1 0.028 = 1.55$$

hence the coincident digits of y_i and $\widehat{y}_i$ are estimated more than 1.5 decimal digits in the mean for any i [3].

For the case of minimum temperature (4)

$$-\log_{10} \mathrm{CR}_6 = -\log_1 0.044 = 1.35$$

hence the coincident digits of y_i and $\widehat{y}_i$ are estimated more than 1.3 decimal digits in the mean for any i.

4.1 Year trend of max temp.

Separate f_{max} as follows:

$$f(x) = \underbrace{19.16 + 0.00116x}_{\text{Year Trend}} + \underbrace{10.0\sin(3.93 + \pi x/6)}_{\text{Month Trend}} \quad (5)$$

Ignore the Month Trend of (5), we have a following year trend

$$f_{max}(x) = 19.16 + 0.00116x$$

From

$$f_{max}(1) = 19.16 \quad \text{and} \quad f_{max}(1476) = 20.87$$

the maximum temperature increases 1.71 °C since 1888. Actually, the mean of maximum temperature from 1890 to 1894 is 19.86 °C and that of from 2006 to 2010 is 21.38 °C. Hence the difference is 1.52 °C. This shows that the estimated temperature and the actual temperature well agree and the difference is only 0.19 °C among 123 years.

4.2 Year trend of min temp.

For the case of minimum, we have followings:

$$g(x) = \underbrace{10.23 + 0.00138x}_{\text{Year Trend}} + \underbrace{10.7\sin(3.92 + \pi x/6)}_{\text{Month Trend}} \quad (6)$$

$$g_{min}(x) = 10.23 + 0.00138x$$
$$g_{min}(1) = 10.23$$
$$g_{min}(1476) = 12.26$$

Hence the minimum temperature is 2.03°C up since 1888 and the actual temperature is $13.14 - 11.36 = 1.76$(°C) up. The difference is only 0.27°C among 123 year.

4.3 Month trend of max temp.

The red dots in Figure 8 shows the mean of maximum values of each month from January 1888 to December 2010. The blue curve shows the "Month Trend" of (5) and the green curve shows the same trend from January 1998 to December 2010. Figuer 8 shows the increasing of warmth related to the maximum temperature in Oita.

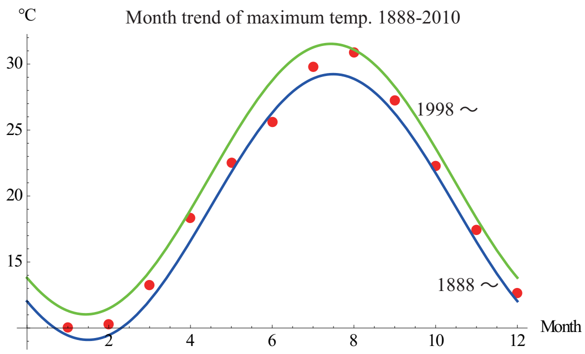

Fig. 8. The month trends of maximum temperature, the blue (green) curve is the trend since 1888 (1998)

4.4 Month trend of min temp.

The red dots in Figure 9 shows the mean of minimum values of each month from January 1888 to December 2010. The blue curve shows the "Month Trend" of (6) and the green curve shows the same trend from January 1998 to December 2010. Figure 9 also shows the increasing of warmth related to the minimum temperature in Oita.

5 CONCLUSION

The proposed model (1) is well fit the maximum and minimum temperature of Oita, because of the iteration always terminates at $n = 6$ and this means that the fundamental period of temperature change is 12 (months).

We also derive the trends of year concerning the maximum and the minimum temperature, and that the trends are described by a linear curve. The difference between the estimation and the actual temperature are 0.19 °C (maximum

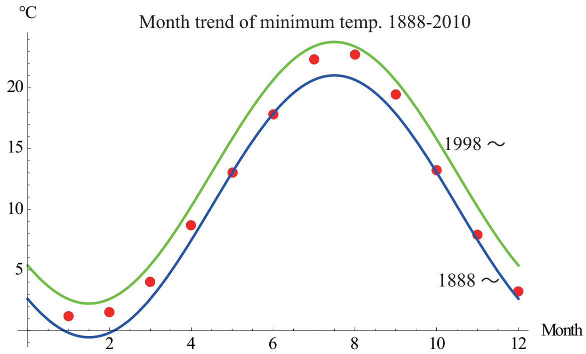

Fig. 9. The month trends of minimum temperature, the blue (green) curve is the trend since 1888 (1998)

temperature) and 0.27 °C (minimum temperature) among 123 years.

The month trends of the maximum and minimum temperatures are increasing with the increasing decade.

The estimated results of Oita are something high compared with the 17 leading [4] and 57 [5] local meteorological stations trends of Japan.

REFERENCES

[1] Masao IGARASHI, Eiji NUNOHIRO and Jong Geol PARK(2009), A Method to Fit a Nonlinear Curve to NDVI, SST and LST, International Journal of Geology, **3**: 97-100.

[2] Masao IGARASHI, Jong Geol PARK, Chen Yen Tsai, Eiji NUNOHIRO and Yukio YANAGISAWA(2010), A Fitness Criterion on Finding Nonlinear Curve for the NDVI Data, INFORMATION **13**: 601-606

[3] S. D. Conte and Carl de Boor(1972), Elementary Numerical Analysis, McGraw-Hill Book Company

[4] 1) Abashiri 2) Nemuro 3) Suttu 4) Yamagata 5) Ishinomaki 6) Fushiki 7) Nagano 8) Mito 9) Iida 10) Chousi 11) Sakai 12) Hamada 13) Hikone 14) Miyazaki 15) Tadotsu16) Nase 17) Ishigakijima.

[5] 1) Abashiri 2) Akita 3) Aomori 4) Asahikawa 5) Choshi 6) Fukushima 7) Fukui 8) Fukuoka 9) Gifu 10) Hakodate 11) Hikone 12) Hiroshima 13) Ishigakijima 14) Kagoshima 15) Kanazawa 16) Kouchi 17) Koufu 18) Koube 19) Kumagaya 20) Kumamoto 21) Kushiro 22) Kyoto 23) Maebashi 24) Maizuru 25) Matsuyama 26) Matsue 27) Minamidaitoujima 28) Mito 29) Miyakojima 30) Miyazaki 31) Morioka 32) Muroran 33) Nagano 34)Nagasaki 35) Nagoya 36) Nara 37) Niigata 38) Oita 39) Okayama 40) Okinawa 41) Osaka 42) Saga43) Sapporo 44) Sendai 45) Shimonoseki 46) Shizuoka 47) Takamatsu 48) Tokushima 49) Tokyo 50) Tottori 51) Toyama 52) Tsu 53) Utsunomiya 54) Wakayama 55) Yamagata 57) Yokohama.