Scientific Research Publishing

Atmospheric and Climate Sciences, 2024, 14, 474-483
https://www.scirp.org/journal/acs
ISSN Online: 2160-0422
ISSN Print: 2160-0414

Modeling the Seasonal Temperature from Hourly Data: Seasonal Divisions

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How to cite this paper: Djiedeu, N., Modi-Mbog, E.C. and Nana, L. (2024) Modeling the Seasonal Temperature from Hourly Data: Seasonal Divisions. *Atmospheric and Climate Sciences*, **14**, 474-483.
https://doi.org/10.4236/acs.2024.144028

Received: September 13, 2024
Accepted: October 19, 2024
Published: October 22, 2024

Abstract

In this work, we present a general theoretical study leading to analytical expression of the seasonal temperature at the near surface that is expected to evaluate any area seasonal temperature of the world using the least square method to fit the hourly data to the theoretical curve of the temperature. It is shown that the temperature is globally the result of two contributions: the contribution of the revolution movement of the terrestrial globe on its elliptical orbit around the sun, the contribution of the spin-orbit coupling for the rotation movement of the terrestrial globe around its polar axis and its revolution movement. The orbital behavior of the temperature is used to find the seasonal divisions of the climate for the local area considered. The whole expression of the temperature is very useful for the meteorological needs. The contribution of the human activities and natural instabilities are the results of discrepancies which increase errors (standard deviations).

Keywords

Seasonal Temperature, Orbital Temperature, Spin-Orbit Temperature, Hourly Data, Seasonal Divisions

1. Introduction

Nowadays, the world is facing unsuccessfully the consequences of the global climate change. The most observable manifestations of climate change are flooding [1] and heat waves having a negative impact on human activities (agriculture, tourism, etc.). Scientists are unanimous that the existing systems are not very useful for local predictions of future events. Some decision-makers think that the temperature should be maintained below a certain value and many measures are taken to reduce pollution which is one of the numerous factors increasing the temperature. One of these measures is the reduction of gazes of green house effects. In the scientific community, some questions still have no answers. The evaluation of the negative impact of Human activities and the natural contribution to climate change is still a challenging problem. How is it possible to quantify these contributions in the global warming observed around the terrestrial globe? Some answers were carried out in a recent paper [2] and the conclusion was that the climate change is mostly due to the sun activity. We think that the best variable to measure the global warming is the temperature. It is then important to study the behavior of the temperature where needed. Many efforts were done previously ([3]-[6]), but most of this work don't give a good interpretation of what happens in a small locality. Some unified models for the climate prediction exist ([7] [8]) and a decade prediction as well [9]. These predictions are generally done for a large space scale and therefore are not always in agreement with the observations in a small locality. Maybe this could be due to the inequality of the Earth surface. Local studies of climate change should then be encouraged and the study of seasonal divisions of strategic places as well (airports, agro ecological areas, etc.). A correlation between the Earth dynamics and the temperature variability was formulated some years ago and the seasonal divisions as well [10]. In this formulation, the monthly mean temperatures were used to describe the behavior of the temperature as a function of the Earth's frequency of revolution. The contribution of the Earth's rotation movement around its polar axis was not accounted for. It was shown that the seasonal temperature oscillates around the annual mean temperature like a wave with a phase and an amplitude, due to the annual periodicity of the Earth revolution around its elliptical orbit. The influence of the Earth's movement of rotation to the temperature was not accounted for. In a recent work, using the daily mean temperature as experimental points, an effort was made to account the contribution of the Earth's frequency of rotation to the temperature [11]. The perturbation function used was periodic and its period was wrongly chosen as 12 hours instead of 24 hours. Unfortunately, the daily behavior of the temperature can not be observed when the daily mean temperatures are used as experimental points. We remind that the data used accounts for the natural and the Human activity contributions to the temperature and can not be dissociated. In this paper, we have used an oscillating function of time with a period of 24 hours suitable to model the daily temperature, because the temperature moves from a relative minimum to another relative minimum every day, crossing a relative maximum. This function was used to create a perturbation of the amplitude of expression of the temperature used previously ([10] [11]). This theory is determinist compared with those used previously in the literature. Section 2 is Material and method. Here, the expression of the temperature is linearized. Both the orbital and the spin-orbit coupling of the temperature are derived and the period of the seasonal temperature as well. The differential equation of the temperature is also established. The numerical results are presented in section 3 followed with the seasonal divisions of the studied area. This paper ends with discussions in section 4 and the summary and conclusion in section 5.

2. Materials and Methods

We are introducing a new oscillating function in the expression of the temperature to assure that the temperature moves from a relative minimum to another relative minimum after crossing a relative maximum each day of the year. This new oscillating function is periodic. Its period is 24 hours. The new expression of the temperature can then be rewritten as:

$$T(t) = a_1\left(a_2 \sin \omega t + a_3 \cos \omega t + 1\right)\sin \omega_0 t + a_4\left(a_5 \sin \omega t + a_6 \cos \omega t + 1\right)\sin \omega_0 t + a_7. \tag{1}$$

Developing Equation (1) leads to:

$$T(t) = a_1 \sin \omega_0 t + a_4 \cos \omega_0 t + a_1 a_2 \sin \omega t \sin \omega_0 t + a_1 a_3 \cos \omega t \sin \omega_0 t + a_4 a_5 \sin \omega t \cos \omega_0 t + a_4 a_6 \cos \omega t \cos \omega_0 t + a_7. \tag{2}$$

The coefficients a_i, i changing from 1 to 7 can be obtained from Equation (2) using the nonlinear least square method but, Equation (2) should be linearized first of all.

2.1. Linearized Temperature

The linearized temperature can be rewritten as:

$$T(t) = c_1 \sin \omega_0 t + c_2 \cos \omega_0 t + c_3 \sin(\omega + \omega_0)t + c_4 \cos(\omega + \omega_0)t + c_5 \sin(\omega - \omega_0)t + c_6 \cos(\omega - \omega_0)t + c_7, \tag{3}$$

where

$$c_1 = a_1, c_2 = a_4, c_3 = \frac{1}{2}(a_1 a_3 + a_4 a_5), c_4 = \frac{1}{2}(a_4 a_6 - a_1 a_2), c_5 = \frac{1}{2}(a_4 a_5 - a_1 a_3), c_6 = \frac{1}{2}(a_1 a_2 - a_4 a_6), c_7 = a_7. \tag{4}$$

The coefficients of the temperature a_i can then be deduced as:

$$a_1 = c_1, a_2 = \frac{c_6 - c_4}{c_1}, a_3 = \frac{c_3 - c_5}{c_1}, a_4 = c_2, a_5 = \frac{c_3 + c_5}{c_2}, a_6 = \frac{c_6 + c_4}{c_2}, a_7 = c_7. \tag{5}$$

The origin of time is the first January at midnight (12 AM). At this time, the terrestrial globe is two days to the perihelion. Let t_0 be the time for the terrestrial globe to travel from its initial position (1^{st} January) to the perihelion (2^{nd} January). Equation (3) can then be rewritten as:

$$T(t) = c_1 \sin \omega_0 (t - t_0) + c_2 \cos \omega_0 (t - t_0) + c_3 \sin(\omega + \omega_0)(t - t_0) + c_4 \cos(\omega + \omega_0)(t - t_0) + c_5 \sin(\omega - \omega_0)(t - t_0) + c_6 \cos(\omega - \omega_0)(t - t_0) + c_7. \tag{6}$$

where $t_0 = 2$ days. The temperature oscillates with the three types of frequency: ω_0, $\omega + \omega_0$ and $\omega - \omega_0$. The corresponding periods of oscillation are:

$$T_0 = \frac{2\pi}{\omega_0}, \tag{7}$$

$$T_1 = \frac{T_0 T}{T_0 + T}, \tag{8}$$

$$T_2 = \frac{T_0 T}{T_0 - T}, \tag{9}$$

respectively. The period of the temperature T_{temp} is the common multiplier of the three periods, that is:

$$T_{temp} = LCM\left(T_0, T_1, T_2\right) = LCM\left(T_0, \frac{T_0 \cdot T}{T_0 + T}, \frac{T_0 \cdot T}{T_0 - T}\right). \tag{10}$$

where T is the period of rotation of the terrestrial globe around its polar axis. The Lower common multiplier of T_0, T_1 and T_2 can be written as:

$$LCM\left(T_0, T_1, T_2\right) = mT_0 = n\frac{T \cdot T_0}{T + T_0} = k\frac{T_0 \cdot T}{T_0 - T}, \tag{11}$$

where m, n and k are the smallest integer which satisfy Equation (11). Substituting T and T_0 in Equation (11), we obtain:

$$\frac{m}{n} = \frac{4}{1465}. \tag{12}$$

and

$$\frac{m}{k} = \frac{4}{1457}. \tag{13}$$

The LCM is then obtained for $m = 4$, $n = 1465$ and $k = 1457$. The LCM is then:

$$LCM\left(T_0, T_1, T_2\right) = 4T_0. \tag{14}$$

where T_1 = 23h56mn04s and T_2 = 24h03mn57s. T_1 is slightly lower than the period of rotation of the terrestrial globe $T = 24\ \text{h}$. The period T_1 corresponds exactly to the sidereal day measured from the Earth's rotation nominal mean velocity. T_2 is slightly higher than the period of rotation of the terrestrial globe $T = 24\ \text{h}$. The period of the temperature is then 4 years, that is:

$$T_{temp} = 4T_0 \tag{15}$$

2.2. Differential Equation of the Temperature

We are now curious to know the differential equation satisfies by the seasonal temperature. The second derivative of Equation (6) leads to the following differential equation of the second order:

$$\frac{\partial^2 T(t)}{\partial t^2} + \omega_0^2 T(t) = \omega_0^2 c_7 - \omega^2 T_{spin-orb}(t) - 2\omega\omega_0\left(x_2(t) - x_3(t)\right), \tag{16}$$

where

$$x_2(t) = c_3 \sin(\omega + \omega_0)(t - t_0) + c_4 \cos(\omega + \omega_0)(t - t_0), \tag{17}$$

and

$$x_3(t) = c_5 \sin(\omega - \omega_0)(t - t_0) + c_6 \cos(\omega - \omega_0)(t - t_0). \tag{18}$$

Equation (16) shows that the temperature at the near surface of the terrestrial globe oscillates with the Earth frequency of revolution. This oscillation is influenced externally by the spin-orbit coupling of the both rotation and revolution movements of the terrestrial globe. This coupling of the movements creates the instantaneous perturbation of the orbital temperature.

2.3. Data Acquisitions and Analysis

The data used were extracted from hourly meteorological database of Cameroon station P30 for the year 2008. If the number of experimental points used correspond to the number of hours in a year, it would be too big and the fluctuation that is the standard deviation would also increase. This is the reason why we have chosen only three values of the measured temperatures for each day of the year. Therefore, we build three vectors to record the daily temperature data at 9 AM, 12 AM and 3 PM. These three vectors were concatenated chronologically in one vector during the computation. The least square method was used to fit the curve of the temperature to the hourly data considered as experimental points. The residue R is defined as:

$$R = \sum_{i=1}^{N} \left(T(t_i) - T_i\right)^2, \tag{19}$$

where N is the number of experimental points (T_i, t_i) used and T_i is the measured temperature at the time t_i. The system of algebraic equations containing the unknown coefficients c_i of the temperature is found using the consideration that the residue is minimum for each of the coefficient c_i that is:

$$\frac{\partial R}{\partial c_i} = 0. \tag{20}$$

We then obtain a system of 7 algebraic equations which is triangulated and solved using the Gauss pivot method. The standard deviation (*SE*) from any individual hourly measured temperature is obtained as:

$$SE = \sqrt{\frac{R}{N}}. \tag{21}$$

The standard deviation (σ) from the annual mean temperature is obtained as:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}\left(T(t_i) - \bar{T}\right)^2}{N}}. \tag{22}$$

where $\bar{T}$ is the annual mean temperature. The seasonal divisions of the studied locality were obtained using the orbital temperature. These seasonal divisions are obtained from the variability of the seasonal temperature over a year. When the seasonal temperature crosses the up-line temperature, the annual mean temperature and the down-line temperature, the transition times can be derived [10].

3. Numerical Results

The numerical results concern the coefficients of the temperature, the transition times and the seasonal divisions. The transition times presented in Table 2 are obtained in a thirteen-month calendar: the universal standard calendar [12]. Same are the dates used for the seasonal divisions presented in Table 3.

3.1. Tables

Table 1 presents the coefficients of the temperature. Table 2 presents the transition dates between the different seasons and Table 3 presents the seasonal divisions. In Table 3, the abbreviations correspond to the different season's names, that is; ds: dry season, eds: ending dry season, srs: starting raining season, rs: raining season, ers: ending raining season, sds: starting dry season. Also, letters are used to indicate the beginning or the end of a season. The letters used are: D—December, A—April, M—May, J—June, O—October, N—November.

Table 1. Temperature coefficients.

c_1	c_2	c_3	c_4	c_5	c_6	c_7
1.04065	1.17585	2.062858E−02	0.118228	9.408806E−02	−0.381317	28.8668

Table 2. Transition dates between seasons.

Transition	t_{12}	t_{23}	t_{34}	t_{45}	t_{56}	t_{61}
Date	3.68	4.77	5.85	10.20	11.29	12.37

Table 3. Seasonal divisions.

Season	ds	eds	srs	rs	ers	sds
Period	11 D 19 A	19 A 22 M	22 M 24 J	24 J 06 O	06 O 09 N	09 N 11 D
Duration	4.35	1.09	1.09	4.35	1.09	1.09

3.2. Graphical Representations

Figure 1 displays the seasonal temperature over a year. The horizontal lines represent the up-line temperature (temperature at the transition time t_{12}), the annual mean temperature and the down-line temperature (temperature at the transition time t_{34}) respectively. These transition times where plotted on all the figures. The daily oscillations due to the spin-orbit coupling are not visible here. The maximum and minimum temperatures observed over a year are $T_{\max} = 30.10$, $T_{\min} = 27.04$ respectively. The standard deviation from the annual mean temperature and the standard deviation from individual measured temperatures are $\sigma = 1.07$, $SE = 0.07$ respectively. Figure 2 displays the seasonal temperature from the beginning of the year up to the first transition time. This figure shows how the seasonal temperature oscillates around the orbital temperature. The daily oscillations due to the spin-orbit coupling are then visible here. Figure 3 displays the curve of the seasonal temperature in an interval corresponding to its period that

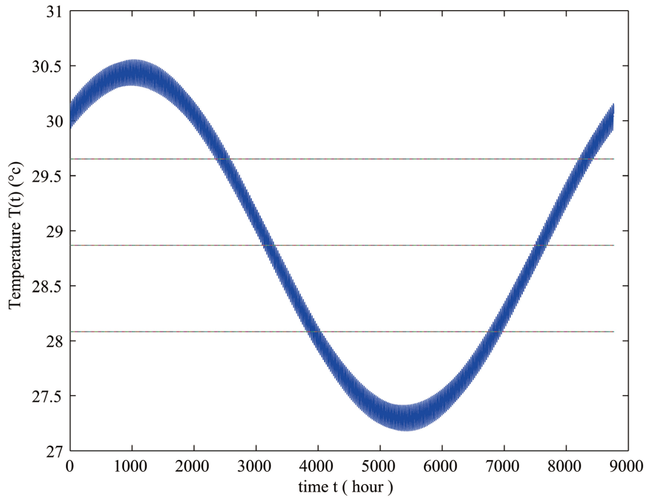

Figure 1. Seasonal temperature over a year.

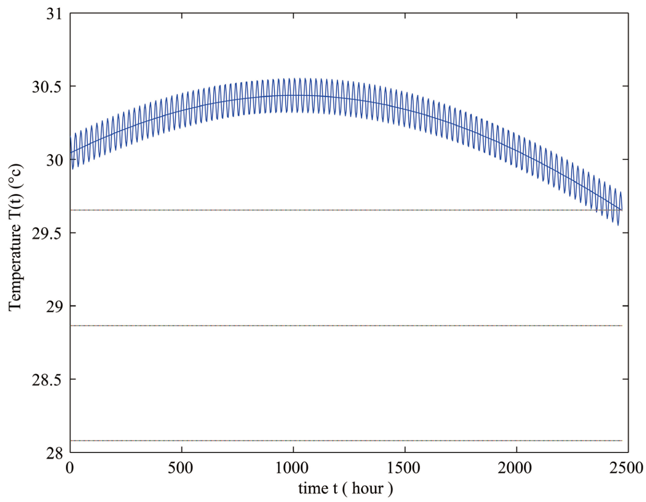

Figure 2. Seasonal temperature from January up to the transition time t_{12}.

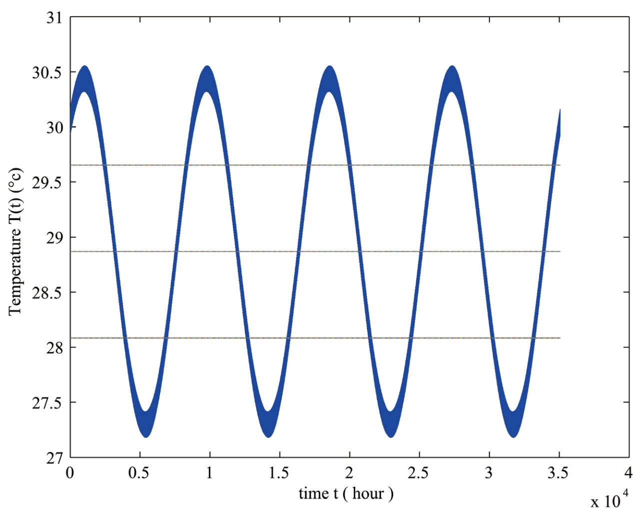

Figure 3. Seasonal temperature for a period of 4 years.

is 4 years. It seems like this curve has a period of one year. This is due to the fact that the spin-orbit temperature is weak compared to the orbital temperature. Therefore, the temperature can be studied in an interval of one year.

4. Discussion

Three vectors were used to record the daily temperature data at (9 AM, 12 AM and 3 PM). We observed that the contribution of the spin-orbit temperature is low. The use of 5 vectors to record these data at (6 AM, 9 AM, 12 AM, 3 PM and 6 PM) instead of three vectors could help to improve the spin-orbit contribution and globally the fit. It is sure that the human activities and the numerous perturbations from the Earth and from the solar system modify the behavior of the temperature. This modifies the coefficients of the temperature and consequently increases the standard deviations. Though the established temperature has a period of 4 years, it is important to use annual data to find the expression of the temperature every year because of the permanent perturbations affecting the dynamics of the terrestrial globe. In previous work, it was difficult to study the variability of seasonality [13]. Using our approach, we obtained the seasonal divisions in a fix temporal frame of reference: the universal standard calendar [12]. Therefore, it becomes easier to observe the fluctuations of seasonal divisions. We are convinced that there is a correlation between the dynamics of the terrestrial globe and many natural phenomena happening around the world. Our approach could help to describe the correlation between the Earth's surface temperature and the atmospheric temperature as initiated in [14]. It could also be helpful for the study of local moisture and the wind velocity or Potential and then compared with existing literature ([15] [16]).

5. Summary and Conclusions

We have established in this work a theoretical analysis for the temporal determination of the temperature for any area of the world. We have shown that this expression depends on the Earth's frequency of revolution and the Earth's frequency of rotation. This temporal expression of the temperature was expressed as the sum of two contributions. The orbital contribution and the spin-orbit coupling of the temperature. The least square method was used to fit the curve of the linearized temperature to the hourly data used as experimental points. The orbital part of the temperature was used to deduce the seasonal divisions of the studied locality. The established temperature oscillates everyday around the orbital temperature. Its period of oscillation is 4 years, but its shape doesn't change much from a year to another because the spin-orbit temperature is weak. Given that we used hourly data over a year, we can then conclude that this expression of the temperature can be used as prevision for up to the 3 following years, but the curve of the temperature can be plotted each year to correct the previsions. The method presented in this work can help to save time and money because low coast materials are used for data acquisitions. It would be interesting for further investigations to study the spatial distribution of the temperature in the atmosphere.

Acknowledgements

The authors wish to thank the agency for the Safety of Air Navigation in Africa and Madagascar (ASECNA) for making the station-based temperature data freely available. The first author acknowledge support for this work from the Abdus Salam International Centre for Theoretical Physics (ICTP, Trieste Italy) under the OEA-12 projects.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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