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A Harmonic Analysis in Seasonal Oscillation of Surface Air Temperature over Assam

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Abstract: *The present study is done with the data series of surface air temperature for the period of (1969-2013) for 45 years. The result of the study shows the climatic classification or the seasonal variation pattern of the five different studied locations over Assam. The harmonic analysis shows the variation pattern of seasonal oscillation, that there observed different three types of variation pattern and different four types of range of variation pattern. Thus it is clear that seasonal oscillation is responsible for climatic classification of a location. The seasonal oscillation depends on the amplitude of the harmonics of studied location, in the present study amplitude varies from location to location significantly, the range of amplitude of first harmonic (annual oscillation) lies between in (6.47°c and -4.89°c) where Dibrugarh shows the both maximum and minimum amplitude; Dhubri, Guwahati, Silchar and Tezpur show the range of (5.52°c to -3.23°c), (6.1°c to -3.55°c), (5.46°c to -3.72°c) and (5.71°c to -4.23°c) respectively. While second and third harmonic shows the range (1.87°c to -1.44°c) and (0.60°c to -1.13°c) respectively where tertiary oscillation or third harmonic shows considerably low amplitude so annual and semi-annual oscillation are most significantly suitable than tertiary oscillation to study seasonal variation of surface air temperature.*

Keywords: *amplitude, harmonic, seasonal oscillation, temperature , variance*

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I. INTRODUCTION:

According to the latest estimates by IPCC (2007), Earth' linearly averaged surface temperature has increased by 0.074 during the period 1901- 2005 [1]. Assessing to the impact urbanization and land use change on mean surface air temperature is a challenging task. Increasing temperature and changing pattern of patterns of precipitation are among the consequences, which are attributed to climate change. Regional variance can be much wider and considerable spatial and temporal variance may exist between climatically different regions. Temperature difference from day to night and from season to season are consequence of intensity of sunlight falling to the surface and into the earth's atmosphere . It effects on seasonal variation of surface air temperature. Where seasonal oscillation or seasonal variation of surface air temperature one of the fundamental features of thermal environment and is major factor climatic classification. It is the reflection of seasonal variation of isolation or solar incoming radiation throughout the year, which sinusoidal in nature. But the local factors significantly perturb normal and sooth variation pattern. Hence the pattern of seasonal variation of surface air temperature is not the same, even at different location in small region where the effects of the local factors are heterogeneous.

Several researchers studied on the seasonal variation temperature as well as other meteorological parameters (e.g. pressure, rainfall etc.) in different part of the world. Namely Yan and Martinson (2000) [2]; Fyfe et al. (2007) [3]; Jastino and Peltier (2008) [4]; F. Jastino [5] . In India also this type of study carried out by some researchers like Chen and Yen (1994) [6]; Sperber and Palmer (1996) [7]; Shukla et al. (2000) [8]; Saha et al. (2014) [9]; Pattanaik and Kumar (2014) [10]; Sahai et al. (2013) [11]; Borah et al. (2013) [12]; Abhilash et al. (2014) [13]; Pattanaik (2014) [14]; L. S. Rathore (2016) [15] etc., . Same type of study carried out Kalita (1984) [16] for Brahmaputra valley and Goswami (2000) [17] for the Brahmaputra and Barak valley.

The objective of the present research is also to study the nature of seasonal oscillation of surface air temperature over Assam at different five studied locations.

II. METHODOLOGY

The present research is studied for the five different locations of Assam. The study area Assam is located south of the eastern Himalayas. It comprises the Brahmaputra and Barak river valleys along with the Karbi Aanglong and the Dima Hasao district. Guwahati (26°11/N, 91°47/E) city is in between the southern bank of Brahmaputra River and the foothills of the Shillong Pleatue. Tezpur(26°37/N, 92°50/E) is on the banks of the Brahmaputra River. The town of the Dibrugarh (Mohanbari), (27°48/N, 95°02/) is situated in the southern part of the Assam. Silchar (Kumbhigram) (24°50/N, 82°51/E) town is located in the southern part of Assam and is belongs to Barak valley. Dhubri (26°01/N, 89°59/E) is situated on western Assam near West Bangal

The local factors including geographical position, variation in elevation, continental, marine and topographic influences, etc may have considerable impact on surface air temperature over Assam.

The data were collected from the meteorological department of studied locations.

2.1 The method of Harmonic Analysis:

Various researchers of climatology and meteorology have suggested that the harmonic analysis is advantageous to study the seasonal variation or oscillation of meteorological or climatological parameters. The development and the mathematical formulation of the method of harmonic analysis have been discussed by a good number of researchers in study of different climatological parameters like as Azzali and Menenti (2001) [18], Yuan and Li (2008) [19], van Loon (1967) [20], Meehl (2006) [21], Goswami (2000) [17], and many others.

Harmonic analysis is based on the series of trigonometric function (Wilks, 1995) [22]. The basic principle of harmonic analysis is that any curve representing periodic phenomena may be expressed as the sum of a large number of sine and cosine curves, called Harmonics or the Fundamental, which makes use of Fourier's Series, as describe below:

$$f(t) = a_0 + \sum_{n=1}^{\infty}(a_n \sin(n\omega t) + b_n \cos(n\omega t)) \ldots\ldots\ldots\ldots (2)$$

Where a_0, a_n and b_n are coefficients of flourier series is the frequency of periodic oscillation of phenomena.

As discussed by Aslan et al. (1997) [23], the Fourier transformation or a harmonic analysis decomposes a time dependent periodic phenomena into a series of sinusoidal function, each defined by unique amplitude and phase values. The proportion of variance in the original time-series dataset accounted for by each term of the harmonic analysis can also be calculated (Jakubauskas *et al*. (2001)) [24]. The first order harmonics of meteorological parameters show long-term effects, while higher order harmonics show the effects of short-term fluctuations. Using phase angle, the time occurrence of maximum and minimum of the seasonal variation or oscillation can be determined. As Conard and Pollak, (1950) [25]; Rao and Rao, (1971) [26]; Goswami (2000) [17] and many others, the seasonal profile of surface air temperature can be expressed in terms of Fourier's expansion, i.e.

$$T = T_n + \sum_{k=1}^{\infty} \{H_k \sin(k\,\theta + \epsilon_k)\} \ldots\ldots\ldots\ldots (3)$$

Where, T_n = observed daily temperature (period mean of daily mean temperature).

T_o = annual mean of T_n.

H_k = amplitude of the k^{th} harmonic.

ϵ_k = phase angle of the k^{th} harmonic.

θ = jz or time angle, j = 1, 2, 3, ………, (N-1);

z = $2\pi/p$, p = length of the period.

The amplitude and the phase angle for each harmonics are obtained as,

$$|H_k| = (A_k^2 + B_k^2)^{1/2} \ldots\ldots\ldots\ldots (4)$$

And $\epsilon_k = \tan^{-1}(A_k/B_k) \ldots\ldots\ldots\ldots (5)$

Where, $A_k = 2/n\sum_{n=1}^{N}[(Tn - To)\cos\{(n-1)kz\}] \ldots\ldots (6)$

$B_k = 2/n\sum_{n=1}^{N}[(Tn - To)\sin\{(n-1)kz\}] \ldots\ldots (7)$

Where N is the number of data points.

The numerical value of harmonic is depends upon on T_O. On the other hand To varies from location to location, so to compare the harmonic of different locations, amplitude must be free from the influence of T_O. Therefore, the amplitudes are expressed in percentage of T_O on amplitude and to get relative amplitude. Thus the relative amplitude may be expressed as,

$$H_{R,k}(\%) = 100H_k/T_O \ldots\ldots\ldots\ldots (8)$$

The contributions of different harmonics to constitute to the seasonal profile of temperature are different. The percentage of contribution of k^{th} harmonic to the total variance of the periodic process is given by the equation.

$$(V_{ar})_k = \{H_k^2 / \sum_{k=1}^{N/2} H_k^2\}100 \ldots\ldots\ldots\ldots (9)$$

For harmonics $k \leq N/2$.

III. RESULTS AND DISCUSSION:.

3.1 Harmonic Analysis:

From study on harmonic analysis of surface air temperature across five studied locations over Assam some results are obtained. In this study the harmonics above the third is found generally insignificant. As such the time series characteristics in respect the amplitude of the harmonics only up to the third harmonics have been discussed here. These are discussed below:

I Harmonics:

The first harmonics can be described in the case of annual oscillation of surface air temperature (Fig.1). The 1st order harmonic of meteorological parameters show long term effects, while higher order harmonics shows short term fluctuation . Using phase angle the month of occurrence of maximum and minimum temperature can be determined. The first harmonic shows a variation from 6.47°c to 5.46°c over locations; the maximum being at Dibrugarh and minimum being at Silchar. The relative amplitude of this harmonics varies from 21.51% to 27.11%; which maximum at Dibrugarh and minimum at Silchar (Table 1). From these investigations, it is observed that higher amplitude of first harmonic has higher index of seasonality . The average relative amplitude of the first harmonic contributes about 93.15% of the total variance. Dibrugarh shows the highest variance about (95.91) of the total variance and Dhubri shows the minimum variance (89.28%) of the total variance (Table 2). The amplitude of the first harmonics occurs in the month of August and minimum in the month of January which both are observed at Dibrugarh, so it is clear that range of first harmonics lies the range of Dibrugarh which is (6.47°c to -4.89°c). Guwahati shows the maximum range of first harmonics (6.1°c to -3.55°c); Dhubri (5.52°c to -3.23°c), Tezpur (5.71°c to -4.23°c) and Sichar shows (5.46°c to -3.72°c) range of first harmonics respectively which under the studied locations (Table 5).

II Harmonics:

The amplitude of the second harmonic is less than the first harmonics, but it is suitable for the discussion of climatic classification of the present study, because the amplitude of the second harmonic is not considerably low (Fig 2). Thus second harmonic can be described as semi- annual oscillation of surface air temperature. Table 1 shows the amplitude of the second harmonics, where Dhubri (1.87°c to -0.99°c) and Silchar (1.47°c to -1.4°c) show maximum and minimum range of second harmonics over studied locations. Tezpur, Guwahati and Dibrugarh show the range of first harmonics (1.38°c to -0.97°c), (1.54°c to -1.44°c) and (1.29°c to -1.21°c). As a whole (1.87°c to -1.44°c) is the range of amplitude of the second harmonics or the semi-annual oscillation of monthly mean temperature. The amplitude of this harmonic occurs in the month of August and is minimum in the month of January as a whole. Dhubri shows maximum in the month of August, Guwahati and Silchar in July, Tezpur in May respectively. The relative amplitude of this harmonic varies from location to location (Table 2). It shows amplitude of this harmonic is about of 6.09% to the total variance. It is obtained highest at Dhubri and minimum at Dibrugarh, thus the range of variation is in between these two locations which is (5.40% to 7.54%). While it is observed that at Guwahati, Silchar and Tezpur 6.21%, 5.79% and 5.55% respectively.

Table(1): Amplitudes (H_k) and phase (ϵ_k) of first three harmonics of seasonal variation curves of monthly mean temperature across five different studied locations over Assam.

Locations	Annual oscillation		Semi- annual oscillation		Tertiary oscillation	
	Amplitude	Phase	Amplitude	Phase	Amplitude	Phase
	(H_1)	(ϵ_1)	(H_2)	(ϵ_2)	(H_3)	(ϵ_3)
Dhubri	5.52	59.85	1.87	77.59	0.40	85.68
Guwahati	6.1	56.82	1.54	61.27	0.33	89.23
Silchar	5.46	65.09	1.47	66.35	0.39	87.81
Tezpur	5.71	52.93	1.38	54.24	0.32	89.95
Dibrugarh	6.47	52.30	1.29	86.87	0.34	88.96

Table (2): Relative amplitudes ($H_{R,k}$) and variances [$(V_{ar})_k$] of the first three harmonics for different five locations over Assam.

Locations	Annual oscillation		Semi- annual oscillation		Tertiary oscillation		Total variance in (%)
	$H_{R,1}$ in (%)	$(V_{ar})_1$ in (%)	$H_{R,2}$ in (%)	$(V_{ar})_2$ in (%)	$H_{R,3}$ in (%)	$(V_{ar})_3$ in (%)	
Dhubri	22.26	89.28	7.54	10.24	1.61	0.016	99.53
Guwahati	24.62	93.70	6.21	5.91	1.33	0.27	99.88
Silchar	21.51	92.71	5.79	6.70	1.53	0.42	99.83
Tezpur	22.99	94.18	5.55	5.46	1.28	0.29	99.93
Dibrugarh	27.11	95.91	5.40	5.78	1.42	0.26	99.95

III Harmonics:

The amplitude of the third harmonic is considerably low as comparing to that of first and second harmonics, therefore the occurrence period of third harmonic is also low (Fig.3) . Thus third harmonic is described as a tertiary oscillation of seasonal oscillation pattern. The amplitude of this harmonic lies between 0.60°c and -1.13°c among the locations. It occurs maximum at Dhubri and minimum at Guwahati. The range of amplitude of third harmonic or tertiary oscillation shows maximum at Guwahati (0.33°c to -1.37°c) and it minimum at Tezpur (0.32°c to -0.33°c); Dhubri, Silchar and Dibrugarh show (0.60°c to -0.53°c), (0.39°c to -0.27°c) and (0.34°c to -0.30°c). in case of relative amplitude the range of relative amplitude lies between the location Dhubri and Tezpur which about of 1.61% and 1.28% to the total variance (Table 2).

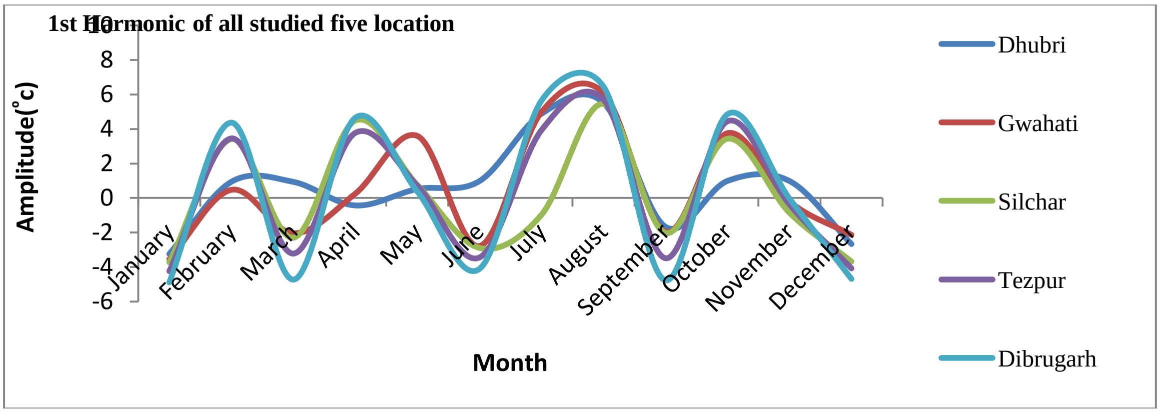

Figure: (1) I Harmonic component of seasonal variation of mean monthly temperature observed at studied locations.

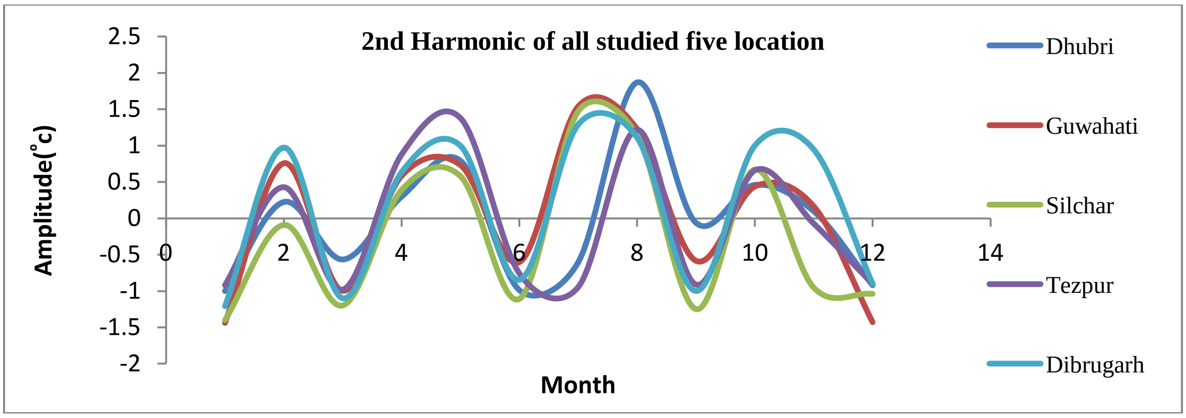

Figure: (2) II Harmonic component of seasonal variation of mean monthly temperature observed at studied locations.

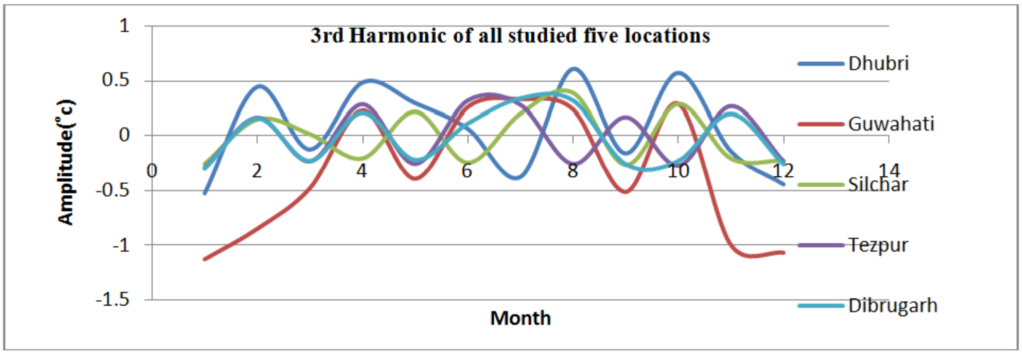

Figure: (3) III Harmonic component of seasonal variation of mean monthly temperature observed at studied locations.

IV. CONCLUSIONS:

From the analysis of the seasonal variation pattern the following points are may be drown-

Over the studied location in Assam, January is the coldest month of the year. The entire variation pattern may result of local factors which is influence the seasonal solar radiation balance, so it is clear that it is due to change in temperature or the temperature trend of increasing and decreasing.The monthly mean temperature shows a high variation in two harmonics. It is interesting to know that other researchers are found that only first harmonic is significant responsible for seasonal variation of monthly or daily surface air temperature, but in this study both two harmonics i.e., first and second harmonics significantly or mostly suitable for study of seasonal variation of monthly mean temperature as they contribute about 93.15% and 6.81% to the total variance respectively. While third harmonic shows only 0.28% to the total variance. Thus it is clear that the low considerable variation, so only first and second these two harmonics are suitable for study of seasonal variation of monthly mean temperature.The most characteristics of seasonal variations are can be drown with the help of first harmonic or the annual oscillation. The range of amplitude of first harmonics is 6.47^{o}c to -4.89^{o}c ; Which are both observed at Dibrugarh. The maximum and minimum amplitude of second harmonic occurs at Dhubri (1.87^{o}c) and Guwahati (-1.44^{o}c). While is observed in third harmonic maximum at Dhubri (0.60^{o}c) and minimum at Guwahati (-1.13^{o}c).

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