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Estimate of Change in Temperature over the Last Fifty Years in the Context of Assam

Dhritikesh Chakrabarty

Independent Researcher, Ex Associate Professor, Department of Statistics, Handique Girls' College, Guwahati – 781001, Assam, India

ABSTRACT: Pythagorean geometric mean can suitably be applied in finding a measure of average (overall) relative change in a group of variables over two different situations. This art has recently been applied in deriving a measure, termed as **temperature index**, of overall relative change in temperature over two different situations. This measure has here been applied in estimating temperature index at the five cities Dhubri , Dibrugarh , Guwahat , Silchar & Tezpur in order to obtain estimate of change in temperature over the last 50 years at these five cities. It has been found that the tendency of surface air temperature at these five cities in Assam have increased by the amounts (in Degree Celsius) of 1.5406, 7.3586, 6.898, 4.7615 & 2.6807 respectively over the last 50 years (from the year 1973 to the year 2023).

KEYWORDS*:* Temperature index, ssurface air temperature, index of change, five stations in Assam

I. INTRODUCTION

Temperature a location/place changes over time continuously. It occurs due to two types of causes namely assignable cause (or causes) and chance cause. The change is insignificant if it occurs due to chance cause only while the change is significant if it occurs due to some assignable cause(s) in addition to change cause [6 , 7 , 10 , 39]. There had been several studies on identifying the significance of change in temperature at a location/place as well as on its central tendency [6 , 7 , 11 , 12 , 21 , 54 , 57 , 59] and its confidence interval (also natural extrema) within a temperature periodic year [6 – 9 , 13 , 43 , 53 , 55 – 58]. However, it is also essential to know the degree or amount of change in temperature at a location over time. Due to this necessity, one concept namely "**temperature** i**ndex**" has recently been defined with the help of the concept of average in order to measure the overall change in temperature at a location over time [42]. Attempt has been made on defining this concept with the help of the concept of average [4 , 15 , 16 , 18 – 20 , 40 , 51]which is a single number taken as representative of a non-empty list of numbers (including a large set of numbers) and which describes any characteristic of an aggregate / population / class of individuals overall but not of an individual in the aggregate / population / class in particular.

The great mathematician Pythagoras, the pioneer of defining average, defined the three most common measures of average namely arithmetic mean, geometric mean and harmonic mean which were given the name "Pythagorean Means" as a mark of honour to him [5 , 14]. Later on, a number of definitions / formulations of average had been derived due to necessity of handling different situations. Some of them are quadratic mean or root mean square, square root mean , cubic mean, cube root mean, generalized p *mean* & generalized p^{th} root mean etc. in addition to Arithmetic Mean , Geometric Mean & Harmonic Mean [5 , 15 , 16 , 18 – 20 , 23 , 36 , 40]. Recently, four formulations of average have been derived from the three Pythagorean means which are Arithmetic-Geometric Mean, Arithmetic-Harmonic Mean, Geometric-Harmonic Mean and Arithmetic-Geometric-Harmonic respectively [22 , 23].

In statistics, these three means are used in measuring the central tendency of data [1 – 3 , 34 , 37 , 44 – 46 , 48 – 50 , 60 , 61]. Recently, it has been established that in addition to the three Pythagorean means, the four formulations of average derived from them can also be used as mathematical measures of central tendency of data. [24 –33 , 35 , 38] which implies that average is a basis of mathematical measures of central tendency of data. Moreover, Pythagorean means can be hypothesized as a tool of constructing measures of various characteristics of data [17]. One common characteristic of data, in addition to central tendency, is dispersion [1 – 3 , 44 – 49 , 52 , 60]. Recently, it has been shown that average is also a basis of mathematical measures of dispersion of data [41]. In another study, an art was

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shown on how to apply Pythagorean geometric mean in finding a suitable measure of average relative change in a group of variables [17]. This art has recently been applied in deriving a measure, termed as **temperature index**, of overall relative change in temperature over two different situations [42]. This measure has here been applied in estimating temperature index at the five cities Dhubri , Dibrugarh , Guwahat , Silchar & Tezpur in order to obtain estimate of change in temperature over the last 50 years at these five cities. .

II. TEMPERATURE INDEX

Let

$$X_1 , X_2 , \ldots\ldots\ldots , X_n$$

be n variables and

$$x_{1b} , x_{2b} , \ldots\ldots\ldots , x_{nb}$$

the values of the respective variables in the situation 'b'
as well as

$$x_{1c} , x_{2c} , \ldots\ldots\ldots , x_{nc}$$

the values of the respective variables in the situation 'c'.
Then the average (overall) relative change of the variables in the situation 'c' with respect to the situation 'b'is defined by

$$\text{Average Relative Change} = \left\{ \frac{(x_{1c}\, x_{2c} \ldots\ldots\ldots\ldots x_{nc})}{(x_{1b}\, x_{2b} \ldots\ldots\ldots\ldots x_{nb})} \right\}^{1/n} \qquad (2.1)$$

which implies, the overall change in the variables can be interpreted as increasing or decreasing according to its values is greater than 1 or less than 1 [42].

Average Relative Change is called **Change Index** when it is expressed as percentage.
Thus the Chain Index of the variables in the situation 'c' with respect to the situation 'b', is defined by

$$\text{Change Index} = \left\{ \frac{(x_{1c}\, x_{2c} \ldots\ldots\ldots\ldots x_{nc})}{(x_{1b}\, x_{2b} \ldots\ldots\ldots\ldots x_{nb})} \right\}^{1/n} \times 100 \qquad (2.2)$$

which implies, the overall change in the variables can be interpreted as icreasing or decreasing according to the values of Change Index is greater than 100 or less than 100 [42].

Now let us consider some characteristic (like tendency, extremum, etc.) of temperature at a place/location/station.
Suppose,

$$T_1 , T_2 , \ldots\ldots\ldots , T_n$$

are n variables representing the characteristic in a group of n period and

$$T_{1b} , T_{2b} , \ldots\ldots\ldots , T_{nb}$$

are the values of the respective variables in the situation 'b'
as well as

$$T_{1c} , T_{2c} , \ldots\ldots\ldots , T_{nc}$$

are the values of the respective variables in the situation 'c'.
Then the change index (describing the overall relative change) of these variables, which can be termed/interpreted as **Temperature Index**, in the situation 'c' with respect to the situation 'b' can be given by

$$\text{Temperature Index} = \left\{ \frac{(T_{1c}\, T_{2c} \ldots\ldots\ldots\ldots T_{nc})}{(T_{1b}\, T_{2b} \ldots\ldots\ldots\ldots T_{nb})} \right\}^{1/n} \times 100 = I_{bc} \text{ , say} \qquad (2.3)$$

which implies, the overall change in the group of temperature variables

$$T_1 , T_2 , \ldots\ldots\ldots , T_n$$

can be interpreted as increasing or decreasing according to the values of Change Index is greater than 100 or less than 100 [42].

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III. CHANGE IN TEMPERATURE IN ASSAM

Median is a measure of central tendency of data suitable to be used in data of continuous type [1 , 3 , 50]. Accordingly, it has been planned to estimate index of median of surface air temperature. The formulation of temperature index, described above, has been applied in estimating temperature index of monthly median of surface air temperature at the five cities

Dhubri , Dibrugarh , Guwahat , Silchar & Tezpur

in order to obtain estimate of change in temperature, described by its tendency, over the last 50 years at these five cities. Median of temperature during a period of time can describe/explain the tendency of warm in the period. Accordingly, values of median of temperature have been calculated from monthly data on maximum & minimum of surface air temperature collected from Indian Meteorological Department for the year 1973 and from the websites

Dhubri, Assam, India Monthly Weather ...

Dibrugarh, Assam, India Monthly Weather ...

Guwahati, Assam, India Monthly Weather ...

Silchar, Assam, India Monthly Weather ...

Tezpur, Assam, India Monthly Weather ...

for the year 2023.

Values of median (monthly) obtained from the data on maximum (monthly) & minimum (monthly) have been shown in **Table – 3.1**. Then temperature index of median (monthly) have been calculated by the application of the formulation (2.3) from the values of median. Values of temperature index of median along with overall relative change & overall % of change, obtained by the application of the formulation (2.3), have been shown in **Table – 3.2**. Also, values of annual median obtained from the data on maximum (monthly) & minimum (monthly) have been shown in **Table – 3.3**. Values of amount of change in annual median over last 50 years have also been presents in this table.

Table – 3.1
(Median of Surface Air Temperature at 5 stations in Assam)

Month	Value of Median (in Degree Celsius)									
	Dhubri		Dibrugarh		Guwahati		Silchar		Tezpur	
	1973	2023	1973	2023	1973	2023	1973	2023	1973	2023
January	17.2	19.5	15.8	18.885	16.55	19.5	18.3	19.5	17.6	18.5
February	20.85	20.5	18.85	20.55	18.2	20.5	19.8	20.0	20.7	20.0
March	24.75	25.0	23.75	23.61	23.85	24.5	24.25	25.0	24.8	25.0
April	29.5	27.5	25.55	23.61	28.0	27.5	26.95	27.5	28.25	27.5
May	26.7	28.5	27.15	28.33	26.9	29.0	26.7	28.5	27.35	28.5
June	27.85	31.0	28.6	29.72	29.3	30.5	27.3	31.0	28.8	31.0
July	30.05	31.5	26.75	30.83	30.1	31.5	29.95	31.5	30.2	31.5
August	30.25	31.0	29.55	30.55	30.1	31.5	28.65	31.0	29.9	31.0
September	30.85	25.0	28.35	30.83	28.95	30.5	28.5	30.5	29.45	30.5
October	26.8	27.0	25.5	26.38	25.75	26.5	26.0	26.5	25.75	26.5
November	22.7	23.5	19.55	22.495	21.1	23.5	21.6	23.5	22.35	24.5
December	18.85	20.0	16.6	19.44	17.85	20.0	17.5	16.5	20.05	19.5

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Table – 3.2
(Index of Median of Surface Air Temperature in the year 2023 with 1973 as Base Year)

Station	Median of Temperature		
	Index	Overall Relative Change	Overall % of Change
Dhubri	101.5406	1.015406	1.5406
Dibrugarh	107.3586	1.073586	7.3586
Guwahati	106.898	1.06898	6.898
Silchar	104.7615	1.047615	4.7615
Tezpur	102.6807	1.026807	2.6807

Table – 3.3
(Change in Annual Median of Surface Air Temperature)

Station	Annual Median (in Degree Celsius)		
	1973	2023	Amount of Change
Dhubri	24.4	24.0	– 0.4
Dibrugarh	21.15	23.33	2.18
Guwahati	22.0	24.0	2.0
Silchar	22.5	24.0	1.5
Tezpur	23.6	24.0	0.4

IV. DISCUSSION AND CONCLUSION

Temperature Index, defined by equation (2.3), is as follows:
The overall (average) change of temperature in the situation 'c' is

$$\frac{I_{bc}}{100}$$

times with respect to the temperature in the situation 'b' and the amount of that change is

$$(I_{bc} - 100)\%$$

The index of median temperature at Dhubri over the last 50 years has been found to be 101.5406 which means, the overall change over this period is 1.5406 % . Since median is a measure of central tendency of data suitable to be used in data of continuous type , the findings on the index of median temperature implies that the tendency of surface air temperature at Dhubri has increased by 1.5406 % over the last 50 years (from the year from 1973 to the year 2023).

Similarly, the tendency of surface air temperature at Dibrugarh , Guwahat , Silchar & Tezpur has been found to be increased by 7.3586 % , 6.898 % , 4.7615 % & 2.6807 % respectively over the last 50 years (from the year from 1973 to the year 2023).

The estimated amounts of increase (in Degree Celsius) in the tendency at Dhubri, Dibrugarh, Guwahat , Silchar & Tezpur are found to be are respectively 1.5406, 7.3586, 6.898, 4.7615 & 2.6807 respectively.

However, it is observed in **Table – 3.3** that the change in annual median is increasing at each of the four cities
Dibrugarh , Guwahat , Silchar & Tezpur
but not increasing at Dhubri. The interpretation of this findings is to be studied.

The findings have shown that the highest increase in the tendency of surface air temperature has occurred at Dibrugarh among the five stations considered in the study while the lowest increase of this has occurred at Dhubri. The ranks of the stations as per the increase in change have been shown in the following table (**Table – 4.1**):

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Table – 4.1
(Rank of Index of Surface Air Temperature)

Rank in Degree of Change	1	2	3	4	5
Station	Dibrugarh	Guwahati	Silchar	Tezpur	Dhubri

Finally on the basis of the findings obtained, it can be concluded that there is necessity of initiating action on reducing the temperature at these five stations by

1.5406 % at Dhubri , 7.3586 % at Dibrugarh , 6.898 % at Guwahati , 4.7615 % at Silchar & 2.6807 % at Tezpur.

or a little bit more for the interest of restoring the warming level at what was 50 years ago.

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AUTHOR'S BIOGRAPHY

Dr. Dhritikesh Chakrabarty passed B.Sc. (with Honours in Statistics) Examination from Darrang College, Gauhati University, in 1981 securing 1st class &1st position. He passed M.Sc. Examination (in Statistics) from the same university in the year 1983 securing 1st class & 1st position and successively passed M.Sc. Examination (in Mathematics) from the same university in 1987 securing 1st class (5th position). He obtained the degree of Ph.D. (in Statistics) in the year 1993 from Gauhati University. Later on, he obtained the degree of Sangeet Visharad (inVocal Music) in the year 2000 from Bhatkhande Sangeet vidyapith securing 1st class, the degree of Sangeet Visharad (in Tabla) from Pracheen Kala Kendra in 2010 securing 2nd class, the degree of Sangeet Pravakar (in Tabla) from Prayag

(Dr. Dhritikesh Chakrabarty, at the left, with his nephew Sri Mahaatmaan Chakrabarty and brother Sri Pulak Chakrabarty in a family festival on March 21, 2024)

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Sangeet Samiti in 2012 securing 1st class, the degree of Sangeet Bhaskar (in Tabla) from Pracheen Kala Kendra in 2014 securing 1st class and Sangeet Pravakar (in Guitar) from Prayag Sangeet Samiti in 2021 securing 1st class. He obtained Jawaharlal Nehru Award for securing 1st position in Degree Examination in the year 1981. He also obtained Academic Gold Medal of Gauhati University and Prof. V. D. Thawani Academic Award for securing 1st position in Post Graduate Examination in the year 1983.

Dr. Dhritikesh Chakrabarty, currently an independent researcher, served Handique Girls' College, Gauhati University, during the period of 34 years from December 09, 1987 to December 31, 2021, as Professor (first Assistant and then Associate) in the Department of Statistics along with Head of the Department for 9 years and also as Vice Principal of the college. He also served the National Institute of Pharmaceutical Education & Research (NIPER) Guwahati, as guest faculty (teacher cum research guide), during the period from May, 2010 to December, 2016. Moreover, he is a Research Guide (Ph.D. Guide) in the Department of Statistics of Gauhati University and also a Research Guide (Ph.D. Guide) in the Department of Statistics of Assam Down Town University. He has been guiding a number of Ph.D. students in the two universities. He acted as Guest Faculty in the Department of Statistics and also in the Department of Physics of Gauhati University. He also acted as Guest Faculty cum Resource Person in the Ph.D. Course work Programme in the Department of Computer Science and also in the Department of Biotechnology of the same University for the last six years.

Dr. Chakrabarty has been working as an independent researcher for the last more than thirty years. He has already been an author of 260 published research items namely research papers, chapter in books / conference proceedings, books etc. He visited U.S.A. in 2007, Canada in 2011, U.K. in 2014 and Taiwan in 2017. He has already completed one post doctoral research project (2002 – 05) and one minor research project (2010 – 11). He is an active life member of the academic cum research organizations namely (1) Assam Science Society (ASS), (2) Assam Statistical Review (ASR), (3) Indian Statistical Association (ISA), (4) Indian Society for Probability & Statistics (ISPS), (5) Forum for Interdisciplinary Mathematics (FIM), (6) Electronics Scientists & Engineers Society (ESES) and (7) International Association of Engineers (IAENG). Moreover, he is a Reviewer/Referee of (1) Journal of Assam Science Society (JASS) & (2) Biometrics & Biostatistics International Journal (BBIJ); a member of the executive committee of Electronic Scientists and Engineers Society (ESES); and a Member of the Editorial Board of (1) Journal of Environmental Science, Computer Science and Engineering & Technology (JECET), (2) Journal of Mathematics and System Science (JMSS) & (3) Partners Universal International Research Journal (PUIRJ). Dr. Chakrabarty acted as members (at various capacities) of the organizing committees of a number of conferences/seminars already held.

Dr. Chakrabarty was awarded with the prestigious SAS Eminent Fellow Membership (SEFM) with membership ID No. SAS/SEFM/132/2022 by Scholars Academic and Scientific Society (SAS Society) on March 27, 2022.

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