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CONFIDENCE INTERVAL OF ANNUAL EXTREMUM OF AMBIENT AIR TEMPERATURE AT DHUBRI

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ABSTRACT

Confidence intervals (of 95%, 99% & 99.73% degrees of confidence) have been determined for each of annual maximum & annual minimum of ambient air temperature at Dhubri. The determination is based on the data from 1969 onwards collected from the Regional Meteorological Centre at Tezpur. This paper describes the method of determination of them and the numerical findings on them.

KEYWORDS: *Ambient Air Temperature at Dhubri, Annual Extremum, Confidence Interval*

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I. INTRODUCTION

Observations or data collected from experiments or survey suffer from chance error (which is unavoidable or uncontrollable) even if all the assignable (or intentional) causes or the sources of errors are controlled or eliminated and consequently the findings obtained by analyzing the observations or data which are free from the assignable errors are also subject to errors due to the presence of chance error in the observations (D.Chakrabarty2014) (R. Sarmah Bordoloiand and D. Chakrabarty 2016). Determination of parameters, in different situations, based on the observations is also subject to error due to the same reason. Searching for mathematical models describing the association of a chance error with the observations is necessary for analyzing the errors. There are innumerable situations/forms corresponding to the scientific experiments. The simplest one is that where observations are composed of some parameter and chance errors (D.Chakrabarty2014, 2015,2008). The existing methods of estimation namely least squares method, maximum likelihood method, minimum variance unbiased method, method of moment and method of minimum chi-square (Ivory1825, G.A.Barnard1949, Lucien Le Cam, Birnbaum Allan 1962, Erich L. Lehmann 1990, Anders Hold 1999) provides the estimator of the parameter which suffers from some error. In other words, none of these methods can provide the true value of the parameter. However, An analytical method has been developed, by Chakrabarty [D.Chakrabarty2014] for determining the true value of the parameter from observed data in the situation where the observations consist of a single parameter chance error but any assignable error. The method has already been successfully applied in determining the central tendency of each of annual maximum and annual minimum of the ambient air temperature at Guwahati

(D.Chakrabarty2014).Again the method has already been successfully applied in determining the central tendency of each of annual maximum and annual minimum of the ambient air temperature at Tezpur (Ramani Sarmah Bordoloi 2016). This paper deals with the determination of the central tendency of each of annual maximum and annual minimum of the ambient air temperature at Tezpur by the same method. The study was carried out using the data since 1969 onwards.

2. GAUSSIAN DISCOVERY

In the year 1809, German mathematician *Carl Friedrich Gauss* discovered the most significant probability distribution in the theory of statistics popularly known as normal distribution, the credit for which discovery is also given by some authors to a French mathematician *Abraham De Moivre* who published a paper in 1738 that showed the normal distribution as an approximation to the binomial distribution discovered by *James Bernoulli* in 1713 {*Bernoulli* (1713), *Chakrabarty* (2005*b*, 2008), *De Moivre* (1711, 1718), *Gauss* (_____), *Kendall* and *Stuart* (1977, 1979), *Walker* and *Lev* (1965), *Walker* (1985), *Brye* (1995), *Hazewinkel* (2001), *Marsagilia* (2004), *Stigler* (1982), *Weisstein* (--------) et al}. The normal probability distribution plays the key role in the theory of statistics as well as in the application of statistics. There are innumerable situations where one can think of applying the theory of normal probability distribution to handle the situations.

The probability density function of normal probability distribution discovered by *Gauss* is described by the probability density function

$$f(x : \mu, \sigma) = \{ \sigma (2\pi) ½\}. \exp [-½ \{(x-\mu)/\sigma\}^2], \quad (2.1)$$

$-\infty < x < \infty, -\infty < \mu < \infty, 0 < \sigma < \infty.$

where (i) X is the associated normal variable,

(ii) μ & σ are the two parameters of the distribution

and (iii) Mean of X = μ & Standard Deviation of X = σ.

Note: If $\mu = 0$ & $\sigma = 1$, the density is standardized and X then becomes a standard normal variable.

Area Property of Gaussian Distribution:

If $X \sim N(\mu, \sigma)$, then

(i) $P(\mu - 1.96\,\sigma < X < \mu + 1.96\,\sigma) = 0.95,$ (2.2)

(ii) $P(\mu - 2.58\,\sigma < X < \mu + 2.58\,\sigma) = 0.99$ (2.3)

& (iii) $P(\mu - 3\,\sigma < X < \mu + 3\,\sigma) = 0.9973.$ (2.4)

If X is a standard normal variable then

(i) $P(-1.96 < X < 1.96) = 0.95,$ (2.5)

(ii) $P(-2.58 < X < 2.58) = 0.99$ (2.6)

& (iii) $P(-3 < X < 3) = 0.9973.$ (2.7)

3. CONFIDENCE INTERVAL

If X_1, X_2, …………, X_n are n observations on μ (some characteristic / measure / parameter whose value is to be determined).

In this situation, each observation X_i is composed of the true value of μ and an error ε_i (occurring due to chance).

Thus the observations, in such types of situations, satisfy the model

$X_i = T(\mu) + \varepsilon_i$

where (i) X_i is the i^{th} observation on μ,

(ii) T (μ) is the true value of μ

& (iii) ε_i is the chance error associated with X_i.

Let X_1, X_2, …………, X_n be, n observations on μ (some characteristic / measure / parameter whose value is to be determined).

T (μ), the true value μ is unique.

But the observed values on μ are different.

The variation in the observed values occurs due to two types of causes/errors namely

1. Assignable Cause(s) that is (are) avoidable / controllable

& 2. Chance, Cause/Error that is unavoidable / uncontrollable

The values X_i (i = 1, 2, ……….., n) should be constant if there exists no cause of variation among them over i.

However, the chance cause of variation exists always.

Thus, if no assignable cause of variation exists in X_i (i = 1, 2, ……….., n), we have

$X_i = T(\mu) + \varepsilon_i$, (i = 1, 2, ……….., n)

where (i) X_i is the i^{th} observation on μ,

(ii) T(μ) is the true value of μ

& (iii) ε_i is the chance error associated to X_i.

(i = 1, 2, 3, …………..).

Here ε_1, ε_2, ……….., ε_n are values of the chance error variable ε associated to X_1, X_2, …………, X_n respectively.

It is to be noted that

- X_1, X_2, …………, X_n are known,
- T(μ), ε_1, ε_2, …………, ε_n are unknown
- The number of linear equations in (3.1) is n with n + 1 unknowns implying that the equations are not solvable mathematically.

Reasonable Facts Regarding ε_i :

- $\varepsilon_1, \varepsilon_2, \ldots\ldots\ldots, \varepsilon_n$ are unknown values of the variables ε.
- The values $\varepsilon_1, \varepsilon_2, \ldots\ldots\ldots, \varepsilon_n$ are very small relative to the values $X_1, X_2, \ldots\ldots\ldots, X_n$.
- The variable ε assumes both positive and negative values.
- P(ε = a) = P(ε = − a) for every a assumed by ε.
- Sum of all possible values of each ε is 0 (zero).
- Standard deviation of ε is unknown and small, say σ_ε.
- ε obeys the normal probability law. Thus $\varepsilon \sim N(0, \sigma_\varepsilon)$.

3.1. Confidence Interval of Error 'ε':

Since $\varepsilon \sim N(0, \sigma_\varepsilon)$,

By the area property of Gaussian distribution given by the equation (2.5),

$$P(-1.96\ \sigma_\varepsilon < \varepsilon < 1.,96\ \sigma_\varepsilon) = 0.95 \quad (3.1)$$

i.e. the interval

$$(-1.96\ \sigma_\varepsilon\ 1.96\ \sigma_\varepsilon) \quad (3.2)$$

is the 95% confidence interval of ε.

This means that out of 100 random observations on ε (unknown), maximum 5 observations fall outside this interval.

Again by the area property of Gaussian distribution given by the equations (2.6) and (2.7),

$$P(-2.58\ \sigma_\varepsilon < \varepsilon < 2.58\ \sigma_\varepsilon) = 0.99 \quad (3.3)$$

$$\&\ P(-3\sigma_\varepsilon < \varepsilon < 3\sigma_\varepsilon) = 0.9973 \quad (3.4)$$

Respectively which implies that the intervals

$$(-2.58\ \sigma_\varepsilon, 2.58\ \sigma_\varepsilon) \quad (3.5)$$

$$\&\ (-3\sigma_\varepsilon, 3\sigma_\varepsilon) \quad (3.6)$$

are respectively the 99% & 99.73% confidence intervals of ε.

These respectively mean that out of 100 random observations on ε (unknown), maximum 1 observation falls outside the interval $(-2.58\ \sigma_\varepsilon, 2.58\ \sigma_\varepsilon)$ and out of 10000 random observations on ε (unknown), maximum 27 observations fall outside the interval

$$(-3\sigma_\varepsilon, 3\sigma_\varepsilon).$$

3.2. Confidence Interval of Parameter 'μ':

Also under the assumption number (7),

$X - \mu \sim N(0, \sigma_\varepsilon)$

or equivalently $X \sim N(\mu, \sigma_\varepsilon)$.

Thus, by the same area property of Gaussian distribution mentioned above,

(i) $P(X - 1.96\,\sigma_\varepsilon < \mu < X + 1.96\,\sigma_\varepsilon) = 0.95$, (3.7)

` i.e. the interval

$(X - 1.96\,\sigma_\varepsilon, X + 1.96\,\sigma_\varepsilon)$ (3.8)

is the 95% confidence interval .

This means that out of 100 random intervals corresponding to each random observation, the value of μ will fall outside a maximum 5 such intervals.

(ii) $P(X - 2.58\,\sigma_\varepsilon < \mu < X + 2.58\,\sigma_\varepsilon) = 0.99$ (3.9)

i.e. the interval

$(X - 2.58\,\sigma_\varepsilon, X + 2.58\,\sigma_\varepsilon)$ (3.10)

is the 99% confidence interval of μ.

This means that out of 100 random intervals corresponding to each random observation, the value of μ will fall outside a maximum 1 such intervals.

& (iii) $P(X - 3\sigma_\varepsilon < \mu < X + 3\sigma_\varepsilon) = 0.9973$
\(3.11)

i.e. the interval

$(X - 3\sigma_\varepsilon, X + 3\sigma_\varepsilon)$ (3.12)

is the 99.73% confidence interval of μ.

This means that out of 10000 random intervals corresponding to each random observation, the value of μ will fall outside a maximum 27 such intervals.

3.3. Confidence Interval of Observation Variable 'X ':

Also under the assumption number (7),

$X - \mu \sim N(0, \sigma_\varepsilon)$

or equivalently $X \sim N(\mu, \sigma_\varepsilon)$.

Thus, by the same area property of Gaussian distribution mentioned above,

(i) $P(\mu - 1.96\,\sigma_\varepsilon < X < \mu + 1.96\,\sigma_\varepsilon) = 0.95$, (3.13)

i.e. the interval

$(\mu - 1.96\,\sigma_\varepsilon, \mu + 1.96\,\sigma_\varepsilon)$ (3.14)

is the 95% confidence interval of X.

This means that out of 100 random observations, maximum 5 observations fall outside this interval.

(ii) $P(\mu - 2.58\ \sigma_\varepsilon < X < \mu + 2.58\ \sigma_\varepsilon) = 0.99$ (3.15)

i.e. the interval

$(\mu - 2.58\ \sigma_\varepsilon, \mu + 2.58\ \sigma_\varepsilon)$ (3.16)

is the 99% confidence interval of X.

This means that out of 100 random observations, maximum 1 observations fall outside this interval.

& (iii) $P(\mu - 3\sigma_\varepsilon < X < \mu + 3\sigma_\varepsilon) = 0.9973$ (3.16)

i.e. the interval

$(\mu - 3\sigma_\varepsilon, \mu + 3\sigma_\varepsilon)$ (3.17)

is the 99.73% confidence interval of X.

This means that out of 10000 observations, maximum 27 observations fall outside the interval.

Note

The set of observations

$X_1, X_2, \ldots\ldots\ldots, X_i, \ldots\ldots.., X_n$

constitute the population for the period from the year '1' to the year 'n'.

Thus, μ = Arithmetic Mean of $(X_1, X_2, \ldots\ldots\ldots, X_i, \ldots\ldots.., X_n)$ (3.18)

and σ_ε^2 = Variance of $(X_1, X_2, \ldots\ldots, X_i, \ldots.., X_n)$ (3.19)

Table 1

Year No	Observed Value (X_i)	$(X_i - 36.3)^2$	Year No	Observed Value	$(X_i - 36.3)^2$
1	36.5	0.04	13	35.8	0.25
2	36.1	0.04	14	35.3	1.00
3	36.2	0.01	15	35.8	0.25
4	35.2	1.21	16	35.5	0.64
5	39.6	10.89	17	35.3	1.00
6	35.7	0.36	18	36.4	0.01
7	37.8	2.25	19	36.8	0.25
8	38.4	4.41	20	35.2	1.21
9	35.7	0.36	21	36.3	00
10	35.1	1.44	22	35.5	0.64
11	38.7	5.76	23	35.0	1.69
12	37.5	1.44	24	36.2	0.01
			25	36.0	0.09

$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} Xi$

$= \frac{1}{25} \times 907.6$

$= 36.304$

$\sigma^2 = = \frac{1}{n}\sum_{i=1}^{n}(Xi\text{-}\bar{X})^2$

$= \frac{1}{25} \times 35.25$

= 1.41

σ = 1.874342087

Confidence interval for µ

95% confidence interval for µ

$(\bar{X} - 1.96\frac{\sigma}{\sqrt{25}}, \bar{X} + 1.96\frac{\sigma}{\sqrt{25}})$

$= (36.304 - 1.96\times\frac{1.874342087}{\sqrt{25}}, 36.304 + 1.96\times\frac{1.874342087}{\sqrt{25}})$

= (35.5692579019, 37.0387420981)

Therefore, at 95% confidence interval of µ the ambient temperature at Dhubri is

(35.5692579019, 37.0387420981)

99% confidence interval for µ

$(\bar{X} - 2.58\times\frac{\sigma}{\sqrt{25}}, \bar{X} + 2.58\times\frac{\sigma}{\sqrt{25}})$

$= (36.304 - 2.58\times\frac{1.874342087}{\sqrt{25}}, 36.304 + 2.58\times\frac{1.874342087}{\sqrt{25}})$

= (35.3368394832, 37.2711605168)

Therefore, at 99% confidence interval of µ the ambient temperature at Dhubri is

(35.3368394832, 37.2711605168)

99.73% confidence interval for µ

$(\bar{X} - 3\times\frac{\sigma}{\sqrt{25}}, \bar{X} + 3\times\frac{\sigma}{\sqrt{25}})$

$= (36.304 - 3\times\frac{1.874342087}{\sqrt{25}}, 36.304 + 3\times\frac{1.874342087}{\sqrt{25}})$

= (35.1793947478, 37.4286052522)

Therefore, at 99.73% confidence interval of µ the ambient temperature at Dhubri is

(35.1793947478, 37.4286052522)

CONFIDENCE INTERVAL OF X

95% Confidence interval for X

$(\mu - 1.96\,\sigma, \mu + 1.96\,\sigma)$

= (36.3 – 1.96 × 1.874342087, 36.3 + 1.96 × 1.874342087)

= (32.6262895095, 39.9737104905)

Therefore at 95% confidence interval of X the ambient temperature at Dhubri is

(32.6262895095, 39.9737104905)

99% Confidence interval for X

(μ - 2.58× σ, μ + 2.58× σ)

= (36.3 – 2.58 × 1.874342087, 36.3 + 2.58 × 1.874342087)

= (31.4641974156, 41.1358025844)

Therefore, at 99% confidence interval of X the ambient temperature at Dhubri is

99.73% Confidence interval for X

(μ - 2.58× σ, μ + 2.58× σ)

= (36.3 – 3 × 1.874342087, 36.3 + 3 × 1.874342087)

= (30.676973739, 41.923026261)

Therefore, at 99.73% confidence interval of X the ambient temperature at Dhubri is

(30.676973739, 41.923026261)

5. ANALYSIS OF ANNUAL MINIMUM TEMPERATURE AT DHUBRI

Table 2

Year No	Observed Value	$(X_i - 8.8)^2$	Year No	Observed Value	$(X_i - 8.8)^2$
1	8.1	0.49	13	6.1	7.29
2	7.3	2.25	14	10.0	1.44
3	8.8	00	15	9.5	0.49
4	9.2	0.16	16	10.5	2.89
5	9.3	0.25	17	8.9	0.01
6	9.6	0.64	18	9.1	0.09
7	8.6	0.04	19	12.2	11.56
8	7.6	1.44	20	10.0	1.44
9	8.9	0.01	21	9.0	0.04
10	8.4	0.16	22	7.8	1.00
11	9.4	0.36	23	5.8	9.00
12	8.8	00			

$\bar{X} = \frac{1}{23} \sum_{i=1}^{36} X_{\text{i}}$

$= \frac{1}{23} \times 202.9$

= 8.82173913043

$\sigma^2 = \frac{1}{23} \sum_{i=1}^{23} (X - \mu)^2$

$= \frac{1}{23} \times 41.05$

= 1.78478260869

$б = \sqrt{1.78478260869}$

= 1.33595756245

<u>Confidence interval for µ</u>

<u>95% confidence interval of µ</u>

$(\overline{X} - 1.96 \frac{ó}{\sqrt{n}}, \overline{X} + 1.96 \frac{ó}{\sqrt{n}})$

$= (8.82173913043 - 1.96 \times \frac{1.33595756245}{\sqrt{23}}, 8.82173913043 + 1.96 \times \frac{1.33595756245}{\sqrt{23}})$

= (8.27574897011, 9.36772929075)

Therefore, at 95% confidence interval of µ the ambient temperature at Dhubri is

(8.27574897011, 9.36772929075)

<u>99% confidence interval of µ</u>

$(\overline{X} - 2.58 \frac{ó}{\sqrt{n}}, \overline{X} + 2.58 \frac{ó}{\sqrt{n}})$

$= (8.82173913043 - 2.58 \times \frac{1.33595756245}{\sqrt{23}}, 8.82173913043 + 2.58 \times \frac{1.33595756245}{\sqrt{23}})$

= (8.10303779694, 9.54044046392)

Therefore, at 99% confidence interval of µ the ambient temperature at Dhubri is (8.10303779694, 9.54044046392)

<u>99.73% confidence interval of µ</u>

$(\overline{X} - 2.58 \frac{ó}{\sqrt{n}}, \overline{X} + 2.58 \frac{ó}{\sqrt{n}})$

$= (8.82173913043 - 3 \times \frac{1.33595756245}{\sqrt{23}}, 8.82173913043 + 3 \times \frac{1.33595756245}{\sqrt{23}})$

= (7.98603990544, 9.65743835542)

Therefore, at 99.73% confidence interval of µ the ambient temperature at Dhubri is

(7.98603990544, 9.65743835542)

<u>Confidence interval for X</u>

<u>95% confidence interval of X</u>

(µ - 1.96 σ, µ + 1.96 σ)

= (8.8 – 1.96 × 1.33595756245, 8.8 – 1.96 × 1.33595756245)

= (6.1815231776, 11.4184768224)

Therefore, at 95% confidence interval of X the ambient temperature at Dhubri is

(6.1815231776, 11.4184768224)

99% confidence interval of X

(μ - 2.58 σ, μ + 2.58 σ)

= (8.8 – 2.58 × 1.33595756245, 8.8 + 2.58 × 1.33595756245)

= (5.35322948888,12.2467705111)

Therefore, at 99% confidence interval of X the ambient temperature at Dhubri is

(5.35322948888,12.2467705111)

99.73% confidence interval of X

(μ - 3 σ, μ + 3 σ)

= (8.8 – 3 × 1.33595756245, 8.8 + 3 × 1.33595756245)

= (4.79212731265, 12.8078726873)

Therefore, at 99.73% confidence interval of X the ambient temperature at Dhubri is

(4.79212731265, 12.8078726873)

6. CONCLUSIONS

The existing statistical methods of estimation yield estimates which are not free from error.

However, the method developed by Chakra artist [8] can yield the estimate which is free from error (i.e. exactly equal to the true value of the parameter). Thus the central tendency of the annual maximum as well as an annual minimum of the ambient air temperature at Dibrugarh as the available data yield, can be taken as 36.3 Degree Celsius and 8.8 Degrees Celsius respectively. Based on these two central tendency Confidence intervals (of 95%, 99% & 99.73% degrees of confidence) have been determined for each of annual maximum & annual minimum of ambient air temperature in Dibrugarh.

The determination of these two is based on the assumption that the data recorded by the Indian Meteorological Department have been recorded correctly. If there is an error in recording the data, the determined value(s) will not be accurate. The determination of these two is based on another assumption that the change in temperature at Dibrugarh during the period whose data have been used in computation has not been influenced by any assignable cause(s). If in this period, some assignable cause has influenced significantly on the change in temperature at this location, the findings are bound to be inaccurate.

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