# "Analysing Climatological Time Series of Temperature and Rainfall for Southern Districts of West Bengal over the period 1901-2011"

Synopsis of the Thesis submitted for the
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by

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Climatology is an integrative interdisciplinary science that deals with the relationship among Climatological parameters through temporal and spatial scale. This science is very complex because several variables within the Earth's atmosphere, such as temperature, rainfall, barometric pressure, humidity, wind velocity, clouds etc. are interacting with each other and maintains a nonlinear structure for a particular geographical area. The activeness and performance of these parameters has made often randomly ordered outlier due to uneven correlation of climatic parameters through frequency domain as well as time domain. Spatial inference of the climatic parameters is also an influencing character for climatological analysis. This study deals with the regional analysis of Climatological parameters like ambient atmospheric temperature and rainfall series. The authenticated and approved datasets are collected from India Meteorological Department (IMD, Alipur, Kolkata) and Indian Water Portal Department (www.**indiawaterportal**.org). The attribute of the implanted data series combines Mean Monthly Maximum ($TMin$) Temperature, Mean Monthly Minimum ($TMin$) Temperature and Average Monthly Rainfall series. Annual average and seasonal series is also considered for this analysis and these series has been confirmed from monthly average series. The considered temperature data being the SI unit of ℃ and rainfall data unit is millimeter respectively. Remarkably, the considered time series maintained consistency while used in this study and the nearest distance covers 5 km and the far distance of the data network has been covered 101 km from the farthest station. The temporal span has confirmed 111 years (1901-2011) and there is no such temporal gap over the considered time series.

**The main objectives of this study are:**

1. Quality Check and Change Point detection over the time series.
2. Variability analysis over the time series.
3. Potential Change Point detection over the time series.
4. Homogeneity construction of the time series.
5. Monotonic Trend detection.
6. Magnitude of Change and Pattern establishment.

The study area has been confirmed by 13 weather observatories location spread over the southern part of West Bengal. Primarily, the data quality control has been checked for proper analysis of the climatic system. Quality assurance or quality control is a system of routine technical activity, to measure and control the quality of the inventory while it is being developed. So, the quality control system has been designed with a particular process consisting continuous check to ensure the data integrity, correctness and sequential completeness. Data quality depends primarily on the location of a climatological station for data acquisition and its adjoining surroundings. Often encountered inconveniences in terms of data homogeneity due to changes in the immediate surroundings over temporal spell as well as changes of the observatory location and exchanges of the data observational techniques. Moreover, new techniques about the proper observation time, changes or replacements of the high performance instruments, different active observing practices, and formulae is used to calculate the mean of the series which can cause artificial discontinuities from the prior time. In primary step the data has been processed by correlation method. After that, some statistical method has been adopted for the assessment of homogeneity nature of the considered dataset. Both parametric and non-parametric statistical techniques has been selected for this analysis like Cumulative Deviation (CD), Standard Normal Homogeneity Test-I (SNHT-I), Pettitt Test, Buishand Range Test (BRT), Von-Neuman Ratio Test and CUSUM and Bootstrapping. To complete these inspections, different software has been used to find out the inhomogeneity, abruptness, variability, randomness, outlier etc. over the considered time series of $TMax$, $TMin$, $ATMax$, $ATMin$, $STMax$, $STMin$, monthly rainfall, annual rainfall and seasonal rainfall separately. The used software's are XLSTAT, Change Point Analyzer, AnClim , Regime Shift Detection, TREND, MAKESENS_1_0 and SPSS_20.1. Moreover the anthropogenic variability like data acquisition error, error made by the observer and data transmission error has been detected by these strong statistical methods. In accordance to these methods, the considered time series has always assumed as normal distribution and primarily a Null Hypothesis ($H_o$) has considered.

After that the Alternative Hypothesis ($H_1$) has been argued at $\alpha = 0.05$ level of significance. If the value statistic has defend at chosen level of significance and if it is situated $\geq$ critical level as a function of, then the Null Hypothesis has rejected and Alternative Hypothesis has accepted. Always $n$ is considered as the number of observations. Adjusted Partial Sums (APS) and Re-Scaled Adjusted Partial Sums (RAPS) have detected the variability and break point in the middle of the considered period. Single abruptness over the considered time series has been detected by Pettitt test. The ratio of mean square successive difference (year to year) has identified the randomness over the considered time series. One interesting statistical technique has implanted here like CUSUM and Bootstrapping. This method confirms the level of change at a particular point and bootstrapping has been confirmed by its associated interval limit over the considered period. Ultimately, inhomogeneity characters of the considered time series has established and their effect (Number of Null Hypothesis rejection) has been categorized by "$Useful$" , "$Doubtfull$" and "$Suspected$" group.

Homogenization of climatic parameters like temperature and rainfall series is a challenge to climate change researches, especially in cases where metadata are not always available. So, the reference series building was a difficult challenge in this concern. The quality check assessment has indicated that, there is no one considered series which has been considered as homogeneous. The result of the quality check has revealed uncertain frequency, outlier, abnormality, variability as well as significant change point over the considered period. Ultimately, Multiple Analysis of Series for Homogenization ($MASH\ v\ 2.03$) has been used to conduct the homogenization process for considered time series. This process has been developed by the Hungarian Meteorological Service. This procedure has been performed by "$DOS$" based programme. This method is called relative homogeneity construction procedures that do not assume any reference series as homogeneous. The possible break points and change (Shift) on the time series can be detected and adjusted through mutual comparisons (with replacement or without

replacement of sample shift value) of considered series within the same climatic area.

The candidate series has been chosen from the available considered series. In the mean time the remaining series has been considered as reference series. The climatic variability has analyzed from two types of main frequency domain such as temperature record as well as rainfall record. So, additive and multiplicative model has been used comparatively. According to the basic function of this method, additive model has considered for temperature series and on the other hand, multiplicative model has considered for rainfall series. According to "$base-2\,numeral$" system, zero (0) amount of rainfall converted to 1 numeric value consideration where needed. Serial number of considered observatories with proper name, co-ordinates, nearest distance of the considered series has been implanted carefully into the MASH method to operate the process properly. Every series has been employed through $CSV\ (Comma\ Separated\ Values)$ format. The candidate series has been confirmed by manually inputs of series serial commend. The adjustment of every frequency has noticed a particular weighted reference series and displayed several difference series. The optimal weighted value is determined by minimizing the variance of the difference series, in order to increase the efficiency of the statistical test. After the relative homogenization process, several statistical tests has been conducted for significant climatic break point analysis (Sequential Mann-Kendall Test), trend analysis (Mann-Kendall Test), magnitude of Change analysis (Sen's Slope Estimator) and periodicity estimation (ACFs & PACFs). The major findings of this study are:

1. The increasing trend of the $TMax$ series from the middle of the considered series.
2. The positive increasing trend of the $TMax$ series from March to July for every observatory.
3. The ling upward outlier whisker from the median for South 24 Pargana observatory.
4. The cyclic pattern of $TMax$ and $TMin$ series by ACFs and PACFs.
5. Gentle positive trend for $ATMax$ time series after Mann-Kendall test.

6. The potential statistically significant change points in between two temporal span, according to Sequential Mann-Kendall test. These two spans are since 1954 to 1965 and 1982 to 1993.
7. The most uncommon seasonal noise signals and very low auto-correlation between adjacent and near adjacent observation.
8. The increasing winter temperature over every decade.
9. “Spike” and “Step Jump” character for annual average temperature time series.
10. The exception of “Phase Diffusion” structure for annual series.
11. Regular fluctuations of noise signal frequency domain after every twenty years (with high positive auto-correlation function) and after every twenty eight years (with high negative autocorrelation function).
12. The negative trend of rainfall series over the time period.
13. The cyclic pattern of annual rainfall series with inference noise components.
14. The prediction of increasing temperature (ACFs & PACFs) for coming twenty years.
15. 0.003 ℃ is the decadal growth of $ATMax$.