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A Novel approach based on Curvelet Transform for Detecting Climate Signal using Time Series

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Abstract: Climate Signal identifying and attribution of observed record plays vital role in incorporate information of the climate system. Traditional techniques for detecting and attributing changes due to statistical forcing require for large number of general circulation model statistically results of various primary conditions and forcing scenarios, and these have been completed with a average number of GCMs. In this paper, we proposed a novel approach based on Curvelet Transform to identify the climate change in time series statistics. The parameters like auto-correlation and maximum likelihood ratio through global mean temperature are estimated for statistical climate detection of climate change. The object of this paper is discussed about natural climate variability; It is various claims of anthropogenic signal detection. Numerical results illustrate that our proposed method is self-consistent, accurate and quantitative results than established methods. The detection and attribution analysis can be further extended to recognize the effects of non climatic localized effects like land use and land cover changes, urbanization.

Keywords: Curvelet Transform, Time Series, Attribution, Detection, Climate signal, Statistical analysis.

I. INTRODUCTION

Climate change is most observed for the century to increase in the normal temperature of the Earth's climate and its similar effects of the climate. Several effects of scientific facts investigate that the climate system is warming. The group of surface near to us atmospheric temperature is increase global warming often notified in the legendary press, lot of the additional information stored in the climate system [1]. Melted ice also heated the continents and atmosphere regularly. So many changes are occurred during thousands of years. Due to all this climate changes are linked and impacts will differ from region to region around the globe. These powerful effects include such things warming global temperature, rising ocean levels, changeable precipitation, and expansion of deserts in the globe and Ocean humans include the threat to food security from drop crop yields and the abandonment of populated locations due to rising sea levels. The climate system has a vast pollution and CO_2 will continue in the atmosphere for a long time, many of these effects existing for decades but will continue for thousands of years [2].

Efficient studies have acceptable facts to support the regular perception that climatic variables and associated natural resources and human systems are being affected by extraneous forcing. Detection and attribution of climate change carry a proper mechanism to decipher the complex logic of climate change [3]. Numerically detect such climatic change signals and present climate change is the effort to systematically established systems is responsible for current climate changes on Earth, usually known as global warming. The effort has focused on changes inspected during the period of instrumental temperature record. The leading mechanisms are anthropogenic of the outcome of human activity. The raising of atmospheric concentration of greenhouse gases, Global changes to land surface. There are also natural systems for variation including climate oscillations, adjustments in solar activity, and volcanic activity [4]. More lines of facts support attribution of present climate change to human activities:

- A basic physical understanding of the climate methods like greenhouse gases and their warming properties.
- Historical estimates of past climate changes suggest that the current changes in global surface temperature are notable.
- Natural forces simply, cannot explain the practical warming.

Curvelet Transform (CT) is a well mechanism suited for multi scale process phenomenon over spatial and time domains. This Transform finds and developed by Candes and Donoho decades ago; It is a well established tool for different fields of Science, signal detection and image processing [5]. The earth climate preparations rapidly process the cited characteristics, mostly in research CT was using for climate signal detection and analysis process. It provides high performance of results in all directions.

This paper is investigated as follows. In next section, we discussed about the related work, Section 3 discusses scope of research, section 4 describes proposed method for climate signal detection, Section 5 presents simulation results and Section 6 concludes the paper.

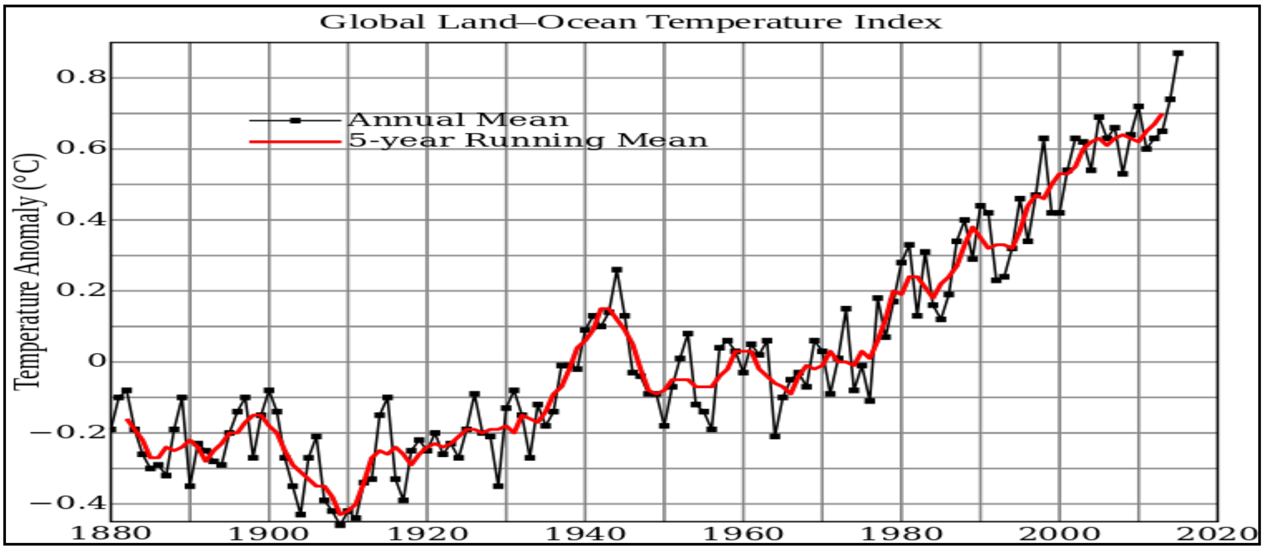


Figure 1. Global and Ocean Temperature Index

II. RELATED WORK

The objective of climate system shows to better clarification of the Earth's information of present and past, and to estimate future climate response to changes in natural and human life factors, such as the Sun, greenhouse gases and aerosols. Climate analysis studies are frequently carried out using a mix of data from different resources including historical climate data, present and past field campaigns and results from regional and global statistical analysis.

- Chithra N R et.al (2015) introduced an ANN based models for detection and attribution (D&A) of climate change facilitate a tool to decode the complex reasons of climate change. Statistically significant such climatic change signals and review the factors grant it. GCMs were statistically downscaled to river basin scale using ANN based established models for Rainfall information and the correlation coefficient analysis using for finding possible predictors. The t- test at 99% assurance interval was performed on the downscaled monthly rainfall data and Results are consistency for notice [6].
- K. M Lau et.al (1995) proposed new application for climate time series analyses using an analogy of the wavelet transform (WT). WT applied on climate data analysis and presented using analytic signals as well as genuine climate time series. The results of WT applied data are taken monthly basis for better understanding. In the presence of huge data timescales, common features in time-frequency of wavelet transform are best results. These variations of the earth's climate are consistent with those presented by a nonlinear dynamical system under external forcing [7].
- Aurelien Ribes et.al (2010) proposed temporal pattern give integration forcing of different climate changes. Optimal fingerprint method is different from temporal pattern scheme. It grants inferring the spatial distribution of the detected signal information. The effectiveness of the method is illustrated by employing it on real similar datasets of temperatures and other aerosols. Different model detection is performed by means of an ensemble of atmosphere-ocean general circulation models (GCM) for calculating the temporal pattern of the temperature. Novel results are generated for temperature and the method also grants to detecting a climate change signal in rainfall affects and the spatial distribution of the precipitation more than the mean of the domain [8].
- Edward S Epstein et.al (1982) proposed the likelihood ratio of data for a hypothesis of a some changes, similar to the hypothesis of no change. It is a correct statistical measure for detection of climate changes in different situations. Future values of likelihood ratios generate potential values to calculate probabilities of attaining pivot on the postulated future climate change. Increase of atmosphericCO_2 is a modest and effect climate change, it is expected to happen from detected from global mean surface temperature within ten years. The combination of multiple behaviors of troposphere and stratosphere is to distinguish between climate change and no climate change than are surface temperatures [9].

III. SCOPE OF RESEARCH

Climate change is one of the burning challenges for human civilization and animal life from globe. As the climate continues to change, the risk is involved in the climate system. Changes in the climate, 20th century has been linked to anthropogenic expansion in greenhouse gases and Co_2. The present climate evaluations have given that observed changes in the climate organism are hugely affected to human activities. First, estimate the natural climate variability detection of climate signal and attribution. In this situation control of global climate models may offer the finest estimates of natural variability on a global foundation. Surface air temperature affected by climate change results of global temperature. The report is made by specific natural and anthropogenic forcing to notice the climate change. One of the important reasons is that fully realistic simulations of climate change due to the effects of all anthropogenic and natural forgings processes have to be computed.

In climate research, challenging is the combination of physical processes and analysis of results whose evolution in time can be estimate well into the future. The Earth's climate with various models of how the climate is changing and it takes into report this inherent lack of predictability, sometimes it is called climate noise. Climate data analysis deals with the separation of climate signals generated from noise and other polluted resources. Filter out climate noise from signal using different Methods, among these methods best weighting of observations and simplify models from the climate system. Compare climate change predictions with noticed changes.

IV. PROPOSED METHOD

Curvelet Transform is powerful tool; it multi dimensional scale and non-stationary processes happening over finite spatial and time domains. CT is well suitable for application using in various fields of sciences, Such as signal detection and image processing. The earth climate organism indisputably processes the above specified characteristics of different fields. The CT is merely a classy process used by arithmetic experts for pure academic search and generates narrow academic practical application in climate research. Curvelet analyses are investiture to make discover the climate signal analysis properly. This paper gives brief description and to call attention to the usefulness of CT as a powerful tool for climate research, that can give a new acceptable understanding of the earth's climate.

A. Detecting climate Signal based on Curvelet

Curvelet analysis is the multi dimensional scale and non-stationary processed transform in the superior of the multi scale geometric information like curvedly formed features during the modeling procedure of the signal analysis. It permits for optimal non-adaptive sparse representation of object with edges [12]. It has generated increasing interest in the association of applied mathematics and signal processing. Our passionate in two dimensions, i.e., R^2, with spatial variable y, with ¥ a frequency field variable, and with r and θ polar coordinates in the frequency domain. We make two windows δ(r) and γ(t), which we will call together radial and angular window, respectively [10, 11]. These windows are value in real with nonnegative, with δ consider positive real arguments with supported on r ∈ (1/2, 2) and γ accept real arguments with supported on t ∈ [-1, 1]. These windows accept the conditions all time:

$$\sum_{j=-\infty}^{\infty} \delta^2 (2^j r) = 1, \; r \in (3/4, 3/2)$$

$$\gamma^2 (t- l) = 1, \; r \in (3/4, 3/2)$$

For each j ≥ j_0, then to start frequency window U_j defined in the Fourier domain by

$$V_j(r, \theta) = 2^{-3j/4}\, \delta(2^{-j} r)\, \gamma\left(\frac{2^{\lfloor j/2 \rfloor}\theta}{2\pi}\right)$$

That $\lfloor j/2 \rfloor$ is an integer part of j/2. Thus V_j is a polar wedge give clarity for Support of δ and γ, both windows, applied window widths with scale-dependent in every direction. We may think of $¥_j$ as a look after curvelet in the intelligence that every curvelet at scale 2^{-j} are obtained by rotations and translations of φ_j.

1. The equivalent series of rotation angles $\theta_l = 2\pi \cdot 2^{\lfloor -j/2 \rfloor} \cdot l$, with l = 0,1….. Such that $0 \le \theta_l \le 2\pi$

2. The sequence of conversion parameters $k = (K_1, K_2)^2 Z_2$.

A curvelet coefficient is the internal product between an element $f \in L^2(R^2)$ and a Curvelet $\varphi_{j,l,k}$;

$$c(j,l,k) := \langle f, \varphi_{j,l,k} \rangle = \int_{R^2} f(x)\, \overline{\varphi_{j,l,k(y)}}\, dx$$

Actually digital curvelet transforms apply in the frequency domain, it will helpful to use Plancherel's theorem and state this internal product as the integral over the frequency plane

$$C(_{j,l,k}) = \frac{1}{(2\pi)^2} := \int \hat{f}(¥)\, \overline{\hat{\varphi}_{j,l,k(\omega)}}\, d¥$$

$$= \frac{1}{(2\pi)^2} \int \hat{f}(¥) V_j (R_{\theta_l}\omega) e^{i\langle y_k^{(j,l)}, \omega \rangle} d¥$$

As in wavelet, we also have scale elements. We start the low-pass window δ_0 accept the

$|\delta o(r)|^2 + \sum_{j \ge 0} |\delta(2^{-j} r)|^2 = 1$ with for $k_1, k_2 \in Z$,

describe scale curvelet as

$$\varphi_{jo,k}(y) = \varphi_{jo}(y - 2^{-jo} k), \; \hat{\varphi}_{jo}(¥) = 2^{-jo}\, \delta o(2^{-jo} |¥|).$$

The curvelet transform made up of the well scale directional elements $(\varphi_{j,l,k})_{j \ge j_{o,l,k}}$ and of the isotropic wavelets is $(\Phi_{jo,k})_k$.

B. Statistical detection of climate change

We will assume that they ε_i are normally distributed with constant variance σ^2. It is conceivable that a climate change could be demonstrate by a change in variance, rather than only a change in mean, but we will not examine that possibility in this analysis. The fundamental measure use to calculate the credibility of various hypotheses about δ the likelihood ratio. The likelihood of obtaining a particular value of T_i in the i^{th} year is:

$$H(\delta_i, U_i, \sigma) = (2\pi)^{-1/2} \sigma^{-1} \exp(-\varepsilon^2 / 2\sigma^2),$$

$$= (2\pi)^{-1/2} \sigma^{-1} \exp[-(U_i - \mu_i - \delta_i)^2 / 2\sigma^2].$$

The likelihood set the n values of U_i, i = 1… n, where $\boldsymbol{\varepsilon}_i$ are uncorrelated, is

$$H(\delta_i; U_i, \mu_i, \sigma, i = 1, \ldots, n)$$

$$= (2\pi)^{-1/2} \sigma^{-1} \exp[-\textstyle\sum_{i=1}^{n} (U_i - \mu_i - \delta_i)^2 / 2\sigma^2].$$

Assume $\mu_i = \mu_0$ for all i, this likelihood is maximized if

$$\hat{\mu}_0 = (\textstyle\sum_{i=1}^{n} U_i - (\sum_{i=1}^{n} \delta_i) / n = \overline{U} - \overline{\delta}$$

And $$\hat{\sigma}^2 = \frac{1}{n} \sum_{i=1}^{n} (U_i - \delta_i - \hat{\mu}_0)^2$$

Are used as estimates of the parameters μ_0 and σ^2. The maximum likelihood for the remarks, under a particular hypothesis concerning the values of δ_i, is the

$$H(\delta_i; U_i, \ldots, U_n) = (2\pi)^{-1/2} \hat{\sigma}^{-n} \exp[-\textstyle\sum_{i=1}^{n} (U_i - \overline{U} - \delta_i + \overline{\delta})^2 / 2\hat{\sigma}^2] = (2\pi)^{-1/2} \hat{\sigma}^{-n} e^{-n/2}$$

By replacing in the exponential, the maximum likelihood solution for σ^2 and μ. The relative likelihood of achieving the data, given a particular hypothesis concerning δ_0, compared to that for the hypothesis $\delta_i = 0$ is $\lambda = \left[\frac{\sum_{i=1}^{n} (Ui - \overline{U} - \delta i + \overline{\delta})2}{\sum_{i=1}^{n} (Ui - \overline{U})2\,] - n/2}\right]^{-\frac{n}{2}}$

$$= 1 + \frac{\left(\overline{\delta^2} - \overline{\delta}^2 - 2(\overline{\delta U} - \overline{\delta}\,\overline{U})\right)^{-n/2}}{\overline{U^2} - \overline{T}^2}$$

Given any hypothesis about the δ_i, one can calculate the corresponding value of λ. If the processed value of λ is large (say > 100), ones complete that is much more credible hypothesis about δ and δ = 0. On the other hand, if λ is small (say <0.01), one would be integrated to reject the notation of the particular behavior of δ in favor of the hypothesis that λ = 0.

C. Test of Significance

It is used for testing of hypothesis when the sample size is small and population S.D. σ is not known. If $\{ y_1, y_2, \ldots\ldots y_n \}$ be any random sample of size n drawn from a normal population with mean μ and variance σ^2, then the test statistics t is defined by $t=\frac{y'-\mu}{\frac{S}{\sqrt{n}}}$ Where y' = sample mean and $S^2 = \frac{1}{n-1}\sum_{i=1}^{n}(yi-y')$ is an unbiased estimated off σ^2. The test statistic t = $\frac{y'-\mu}{S\sqrt{n}}$ is a random variable having the t- distribution with v = n-1 degrees of freedom and with probability density function f (t) = x_0 (1+ t^2 / v) $^{(v+1)/2}$ where v = 1-n and x_0 is a constant got by $\int_{-\infty}^{\infty} f(t)$dt = 1. This is known as "Student's t-Distribution" or simply "t-distribution".

The above result is more general than the central limit theorem, since it is does not require the knowledge of σ, and since population is imagined to be normal it is fewer ordinary than the central limit theorem.

Step1: **Null hypothesis**

There is no significance difference between sample and population mean.

i.e. H_0: $\Upsilon_1 = \Upsilon_2$

Step2: **Alternative Hypothesis**

There is significance difference between sample and population mean.

i.e. H_1: Υ_1 # Υ_2

Step3: **Level of significance**

The level of significance can be assume that

β= 95% or β =0.05 or β = 5% (or) β = 99% or β =0.01 or β = 1%

Step4: **Test Statistics**

The test statistic can be calculated using the following expression

T= (y_1- y_2)/sqrt (sd_1/ n_1 + sd_2/ n_2)

Step5: **Critical Region**

The calculated value is greater than the table value. We can refuse the null hypothesis H_0. Otherwise, we can believe the null hypothesis.

D. Climate Signal Processing

In signal processing, given a signal *f(t)*, the autocorrelation $S_{ff}(\tau)$ is the majority defined as the continuous cross-correlation integral of *f(t)*, with itself, at lag τ.

$$S_{ff}(\tau) = \left(f * g_{-1}(\overline{f})\right)(\tau) = \int_{-\infty}^{\infty} f(u+\tau)\overline{f}(u)du = \int_{-\infty}^{\infty} f(u)\overline{f}(u-\tau)du$$

The parameter *u* in the integral of a temporary variable and is only essential to compute the integral. It has no detailed sense. The discrete autocorrelation S at lag l for a discrete signal *y (n)* is

$$S_{yy}(l) = \sum_{n\in Z} y(n)\overline{y}(n-l)$$

For wide-sense-stationary random processes, the autocorrelations are defined as

$$S_{ff}(\tau) = E\left[f(t)\overline{f}(t-\tau)\right]$$
$$S_{yy}(l) = E[y(n)\overline{y}(n-l)]$$

For computes that are also ergodic, the hope can be replaced by the limit of a time is normal. The autocorrelation of an ergodic process is sometimes defined as or equal to

$$S_{ff}(\tau) = \lim_{T\to\infty}\frac{1}{T}\int_0^T f(t+\tau)\overline{f}(t)dt$$

$$S_{yy}(l) = \lim_{N\to\infty}\frac{1}{N}\sum_{n=0}^{N-1} y(n)\overline{y}(n-l)$$

In three dimensions the autocorrelation of squares summed with discrete signal would be

$$S(j,k,l) = \sum_{n,q,r} x_{n,q,r}x_{n-j,q-k,r-l}$$

When indicated values are subtracted from signals before processing an autocorrelation function, the resultant function is frequently called an auto-covariance function [13].

V. SIMULATION RESULTS

In this paper, we presented a novel method through Curvelet Transform to find climate change in time series data. The parameters like auto-correlation and maximum likelihood ratio based global mean temperature are expected for statistical detection of climate change using MATLAB. In training of Bayesian statistics, the likelihood is the ratio of the probability allocate to a hypothesis after the data are inspected (the posterior probability) to that allocated to the hypothesis before the data are inspected (the prior probability). To the extent there are no strong prior preferences for one hypothesis to another; λ is a measure of relative posterior credibility of the hypothesis. On the other hand, if strong prior prediction exists and various criterions should be adopted. For example, the author would allocated prior probability in case 1, for δ > 0.1 relative to δ =0, of < 0.01. Therefore for case 1, he would place more stringent criteria on δ before he would be vulnerable to accept the validity of a hypothesis that δ > 0.1.

Computations of λ can be made on the source of data presently unavailable and different such calculations are exhibit below. Calculations will also be obtainable in future years after more data are acquired. It is predicted, in probabilistic sense, what the results of this future calculation will be, if one assumes some particular true activities of δ. Such calculations yield estimation of the probability that some true effect will or will not be accepted a few years hence, and, on the other hand, the probability of being mistakenly let to conclude that an influence is genuine when it is really not so.

Predictions of the T_i are more than is implied simply by the estimate σ^2 of the variance of the procedure. If the variance of the procedure were known to be given by σ^2 and the mean was known to be accurately equal to $\mu_{0,}$ then indeed one would use a normal distribution to produce predictions of future values of U_i. However uncertain in the cost of σ^2, and in the cost of μ_0 must also be factored into probability statements about future $T_{i.}$ It is shown by Raiffa and Schailfer (1968, P. 303) that under these environment, with all the information about μ_0 and σ^2 contained in the n previous years interpretation, the quantities (U_i – δ_i – $\overline{U}$ + $\overline{\delta}$) / V, i>n, have independent Student – t distributions with n-1 degrees of freedom, where

$$V= \frac{n+1}{n-1}\frac{1}{n}\sum_{i=1}^{n}(U_i - \delta_i - \overline{U}+\overline{\delta})^2$$

By means of Monte Carlo Calculations large number(1000) possible future realization of the climate record for n* = 1,2,5 and 10 into the future have been calculated for each model of $\delta_{i,}$ and for values of past parameters. A time series is similar to a set {x_1, x_2… x_n } of annotations taken over a series of equally spaced time intervals. The time series data begins with a plot of the points. The graphs positions display the autocorrelations of the time series. A time series of data that represent recorded values of a happening over time. Time series data constitutes a huge part of the data stored in real world databases [Agrawal et al. 1993]. These graphs are used to recognize the type of diverse models for describing the development of the time series. The Time Series exhibit lets you search, analyze, and forecast in different directions.

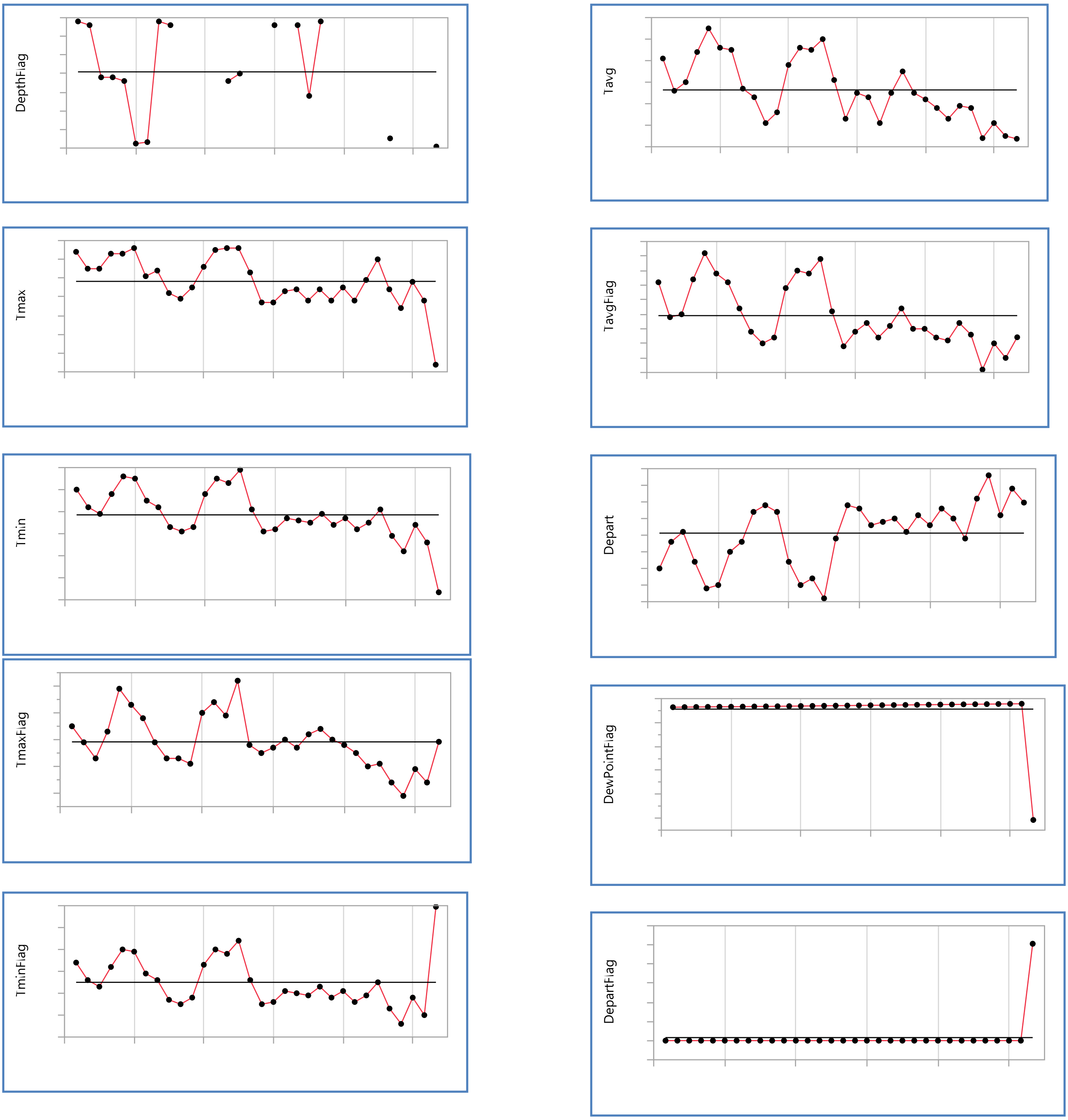
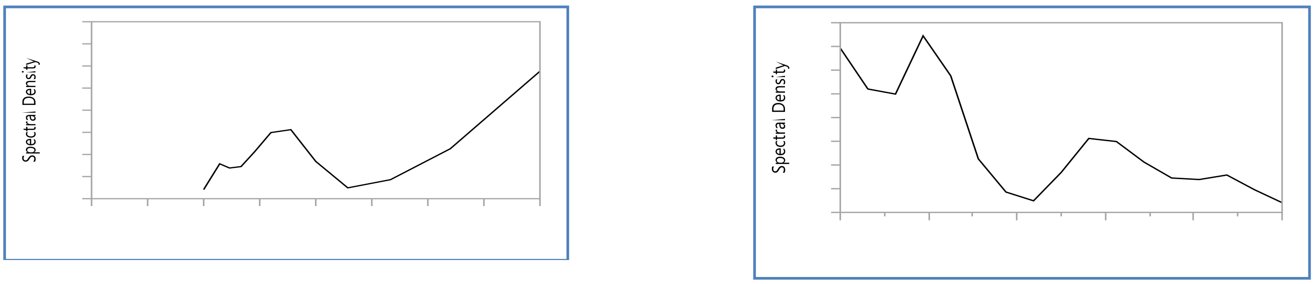


Figure 2.Describing Model Parameters Using Time series Analysis



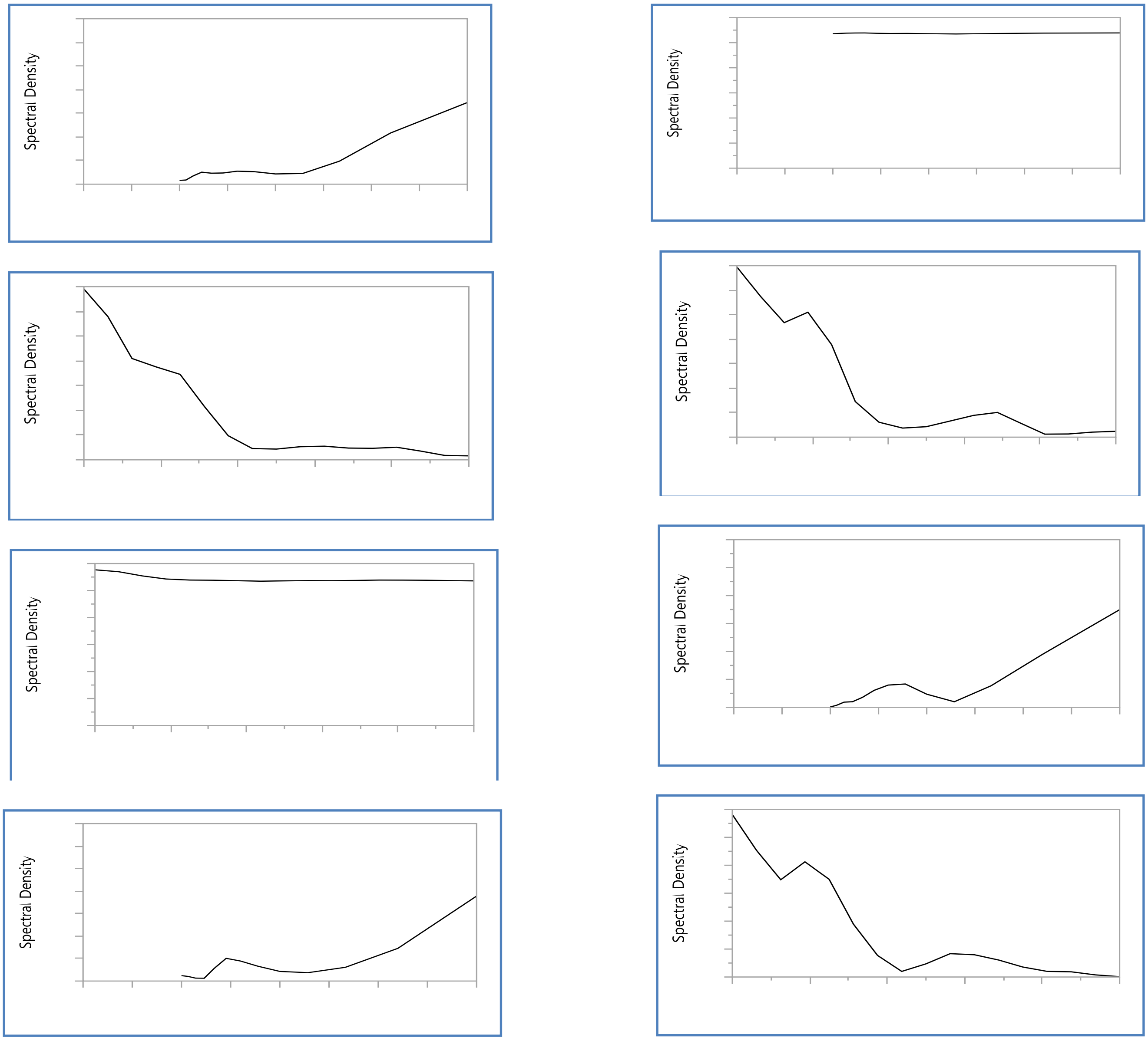


Figure 3. Describing Model Parameters Using Time series Analysis

VI. CONCLUSION

Detecting Climate Signal plays an important role in synthesizing data of the climate system. Traditional approaches for detecting and attributing changes due to statistical forcings feel require for huge number of general circulation model statistically results of various primary conditions and forcing scenarios, and these have been completed with a modest number of GCMs. In this paper, we propose a novel method through Curvelet Transform to find out the climate change in time series data. The parameters like auto-correlation and maximum likelihood ratio based global mean temperature are estimated for statistical detection of climate change using MATLAB. Our aim is to calculate natural climate variability, versus assertion of anthropogenic signal detection. Simulation results illustrate that our projected technique is self-consistent, precise and qualitative results than traditional methods. The attribution and detection analysis can be more extended to consider the things of non climatic localized effects like land use and land cover changes, urbanization.

VII. ACKNOWLEDGEMENT

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