Study of Arabian Seawater Temperature Fluctuations

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Abstract: It is well known that the ocean has an important role in climate variability and change. To study the variations in sea-surface temperature (SST) of Arabian sea near Karachi coastal region, we apply the probability distributions theory as it gives more insights of SST fluctuating behavior. In this regard the adequacy of Normal. Gamma, and Lognormal probability distributions is tested with the help of Kolmogorov-Smirnov *D*-test. It is found that most of the months of the year follow Normal probability distribution, whereas April, August, October, and November follow Lognormal probability distribution. Further, using the distribution parameters mean and standard deviations of monthly SST are also calculated, which come out to be (23.33 ± 0.316), (23.19 ± 0.300), (24.36 ± 0.312), (26.27 ± 0.360), (28.31 ± 0.325), (29.19 ± 0.347), (28.64 ± 0.346), (27.38 ± 0.364), (27.34 ± 0.322), (27.61 ± 0.311), (26.43 ± 0.352), (24.65 ± 0.380).

Keywords: Sea-Surface Temperature (SST) Average Seawater Temperature Data (AVTD), Arabian Monthly Average Seawater Temperature (AMAST).

1. INTRODUCTION

According to IPCC report [1] the ocean has an important role in climate variability and change, which is becoming warmer due to global warming. The ocean's heat capacity is about 1,000 times larger than that of the atmosphere, and the oceans net heat uptake since 1960 is around 20 times greater than that of the atmosphere. This large amount of heat, which has been mainly stored in the upper layers of the ocean, plays a crucial role in climate change, in particular variations on seasonal to decadal time scales. Moreover, latitude exerts a strong control on the surface temperature of the ocean, because the amount of insolation decreases pole-ward [1]. Surface water temperatures, therefore, are highest in the tropics and decrease with distance from the equator. Isotherms, the imaginary contour lines that connect points of equal water temperature, generally trend east-ward, parallel to the lines of latitude [2].

Furthermore, depletion of ozone layer over Pakistan region has statistically significant impact on Arabian Sea [3]. It is also important to note that the eleven years sun sunspots cycles and ozone layer depletion over arctic region have significant correlations [4-5]. Global warming has shown acceleration in its fluctuations [6]. Variability of sea surface temperature is important as the duration and intensity of SST provides the basis for studies related to climatic change scenario. Increasing trend of SST is observed throughout all the seasons in the northern Arabian Sea extending from Oman to Karachi and Mumbai and further south to Salalah and Colombo [7]. It corroborates the result found in [8] with reference to local and global climatic parameters interactions. The relationship between cyclones and SST is also well known [9], which in turn, may affect coastal areas.

The present paper attempts to show the type of trends in the twentieth century Arabian seawater monthly average temperature data series. Section 2 gives data and methodological approach in this paper and in Section 3 we find the probability distributions of seawater temperature fluctuations. Section 4 concludes this communication.

2. MATERIAL AND METHODS

This communication uses the data from the period 1871-2009 from the *Hadley British Climate Centre*, UK. Data used in the analysis covers the following Arabian sea coordinates which are close to the Karachi coastal region:

(23N,68E), (23N,67E), (23N,66E), (23N,65E), (23N,64E), (23N,63E), (23N,62E), (24N,67E), (24N,66E), (24N,65E), (24N,64E), (24N,63E), (24N,62E), (25N,66E), (25N,65E), (25N,64E) and (24N,66E).

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It is well known that the study of statistical distributions of climatic parameters generally gives more insights of the physical processes. In general, atmospheric temperature fluctuations follow Normal distribution. However, environmental parameters also show right skewed distributions [10].

In assessing the nature of the distribution obeyed by real-time data, we check for the deviation from normality using KST [Kolmogorov-Smirnov *D*-test], which tests whether the statistic

$$D = \max|F(x) - G(x)| \tag{2.1}$$

exceeds a critical value in the K-S table, $G(x)$ and $F(x)$ are respectively the sample cumulative distribution and the predetermined cumulative distribution corresponding to a given a sample of size n.

We know that the normal distribution is the most important distribution of continuous variables applied to symmetrically distributed data. Mathematically it can be expressed as follows:

$$f_X(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} \quad (-\infty < x < +\infty), \tag{2.2}$$

where, σ is the standard deviation and μ is the mean of the sample.

Similarly the gamma distribution is expressed as,

$$f_X(x) = \frac{\lambda^\eta}{\Gamma(\eta)} x^{\eta-1} e^{-\lambda x}, \ (x \geq 0,\ \eta > 0,\ \lambda > 0), \tag{2.3a}$$

$$E[X] = \frac{\eta}{\lambda}, \ \mathrm{Var}(X) = \frac{\eta}{\lambda^2}, \tag{2.3b}$$

And the mathematical form of lognormal distribution is,

$$f_X(x) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{\ln x-\mu}{\sigma}\right)^2}, \ (-\infty < x < +\infty), \tag{2.4a}$$

$$E[X] = e^{\mu+\frac{\sigma^2}{2}}, \ \mathrm{Var}(X) = e^{2\mu+\sigma^2}\left(e^{\sigma^2} - 1\right) \tag{2.4b}$$

In equations (2.3b) and (2.4b), $E[X]$ and Var (X) represent mean and variance of samples respectively [11]. A lognormal process being one in which the random variable of interest results from the product of many independent random variables multiplied together, whereas the normal process is one in which the random variable of interest results from the sum of many independent random variables [12].

3. RESULTS AND DISCUSSIONS

3.1. Probability Distributions of Sea-Surface Temperature Data

As reliable mathematical modeling of climatic parameters is necessary for any forecast, monitoring and management of sustainable urban development, this section tests the distribution models to serve as a guide in the assessment of impact of the global warming due to the heat absorption in the ocean. *STATISTICA* 5 was utilized for the test of underlying distributions and parameter estimations. Tables **1** and **3** depicts the final distributions obeyed by the monthly series of SST.

Table 1: Probability Distributions of Twentieth Century Arabian seawater Monthly Temperature Series (1871-2009)

Months	Distribution	KST-value (α = 0.05)
January	Normal	0.048
February	Normal	0.024
March	Normal	0.029
April	Log normal	0.033
May	Normal	0.033
June	Normal	0.048
July	Normal	0.037
August	Log normal	0.061
September	Normal	0.026
October	Log normal	0.024
November	Log normal	0.034
December	Normal	0.050

As we see from the calculations carried out above, the set of monthly series of SST follows different distributions. In particular, the changes in distribution from normal to lognormal indicate that the distribution is becoming increasingly heavy tailed. Further, the gradual growth of the right-skewed structure of the distributions obtained here shows that there exist multiplicative processes, which are making the SST fluctuation multiplicative one. This gives a higher time-rate of increase in SST. This is indicative of presence of factors like global warming consequences, impact of mega-city (Karachi) industrial activities, etc. To sum up, the annual unfolding of the process considered here is important in that it reflects site-specific peculiarities of the process and so is particularly capable of catching information concerning the variability on annual to decadal time scales.

Table 2: Mean and Standard Deviations of SST Series Obtained Using Probability Distributions Parameters

Months	Mean values	Standard deviation
January	23.33	0.316
February	23.19	0.300
March	24.36	0.312
April	26.27	0.360
May	28.31	0.325
June	29.19	0.347
July	28.64	0.346
August	27.38	0.364
September	27.34	0.322
October	27.61	0.311
November	26.43	0.352
December	24.65	0.380

Tables **2** and **4** shows the estimated long-term mean and standard deviations of monthly SST series. Next, we conclude this work.

Table 3: Probability Distributions of Urban Monthly Maximum Temperature Series (1961-2009)

Months	Distribution	KST-value ($\alpha = 0.05$)
January	Normal	0.042
February	Normal	0.026
March	Normal	0.026
April	Log normal	0.033
May	Normal	0.033
June	Normal	0.046
July	Normal	0.034
August	Log normal	0.061
September	Normal	0.028
October	Log normal	0.024
November	Log normal	0.036
December	Normal	0.048

Table 4: Mean and Standard Deviations of Urban Land Maximum Monthly Temperature Using Probability Distributions Parameters

Months	Mean values	Standard deviation
January	25.33	0.351
February	23.19	0.320
March	26.36	0.342
April	26.27	0.360
May	28.31	0.355
June	31.19	0.357
July	29.64	0.366
August	29.38	0.384
September	27.34	0.342
October	29.61	0.331
November	27.43	0.372
December	28.65	0.380

4. CONCLUSION AND OUTLOOK

Section 1 demonstrates the reasons of overheating Arabian SST. In Section 2, we discussed the SST data series utilized in this study and the probability distributions followed by the SST. Section 3 demonstrated that most of the months follow Normal distribution; whereas, April, August, October, and November follow Lognormal probability. This findings based on Kolmogorov-Smirnov adequacy tests reveal that the monthly SST fluctuations are a multiplicative processes. The distribution parameters give the long-term mean and standard deviations of the monthly SST series, which appeared to be (23.33 ± 0.316), (23.19 ± 0.300), (24.36 ± 0.312), (26.27 ± 0.360), (28.31 ± 0.325), (29.19 ± 0.347), (28.64 ± 0.346), (27.38 ± 0.364), (27.34 ± 0.322), (27.61 ± 0.311), (26.43 ± 0.352), (24.65 ± 0.380). Knowledge of long-term mean monthly temperature values can be useful for maintenance managers of thermal power plants near coastal areas as efficiency of heat exchangers depends on seawater temperature. The probabilistic modeling of temperature fluctuations of sea-surface performed here gave long-term behavior of temperature trends. For more accurate forecasts of temperature fluctuations, time series analysis and Hurst exponent calculations will be attempted in the next communication.

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