Arabian Seawater Temperature Fluctuations in the Twentieth Century

M.A. Hussain*[,1], Shaheen Abbas[2] and M.R.K. Ansari[2]

[1]*Institute of Business and Technology (BIZTEK), Karachi, Pakistan*

[2]*Federal Urdu University of Arts, Sciences and Technology, Karachi, Pakistan*

Abstract: It is well known that in the twentieth century anthropogenic activities have changed the climatic natural variability to some extent, which resulted in statistically significant increase in the global average temperature. Global warming has increased both atmospheric and sea-surface temperatures around the world. To study the seawater temperature fluctuations in the Arabian sea, this communication performs linear trend analysis of Arabian seawater monthly average temperature data (1871-2009) obtained from *Hadley British Climate Centre*, UK. The warming trends (positive for every month) of average seawater temperature data show that the ocean has gained heat from the atmosphere over the last 150 years. The trend analysis also shows that the ocean rate of heat absorption in the first half of the twentieth century is higher as compared to the second half. It is clear from the trend values that the winter warming rate is higher than the summer warming rate. It has also been shown that the Karachi urban monthly maximum temperature trends are, more or less, similar to the twentieth century Arabian monthly average seawater temperature fluctuation trends. Its decadal trend values are, more or less, ten times higher than the sea surface temperature trend values.

Keywords: Global Average Temperature (GAT), Average Seawater Temperature Data (AVTD), Arabian Monthly Average Seawater Temperature (AMAST).

1. INTRODUCTION

Anthropogenic activities have significant contribution to global warming [1]. Estimates show that the average temperature of Earth's near surface air and oceans has raised by 0.74 ± 0.18°C during last 100 years [2]. Also in the last 100 years global average temperature has increased about 0.74°C (IPCC, 2005). In case of oceans, we know that latitude exerts a strong control on the surface temperature of the ocean, because the amount of insolation decreases pole-ward [3]. Sea surface water temperatures, therefore, are highest in the tropics and decrease with distance from the equator. Isotherms, imaginary contour lines that connect points of equal water temperature, generally trend east-ward, parallel to the lines of latitude [4].

Research elsewhere shows that depletion of ozone layer over Pakistan region has statistically significant impact on Arabian Sea [5]. In general, eleven years sun spots cycles and ozone layer depletion over arctic region has significant correlation [6] So, the global warming is responsible for the expansion of the seawater volume with list of other consequences. Moreover, presence of positive trend in global warming makes the quantity of seawater increase due to increasing input from the lakes, underground water, and polar region glaciers. It is also important to note that global warming has acceleration in its fluctuations [7]. Comparing with the global average sea level, regional changing of the sea levels (in case of Arabian and Indian oceans) has comparable result. Other regions show some differences because of different geology, that is, structure, different climatic conditions, and different conditions of the oceans. Therefore, they have different consequences [8].

Variability of sea surface temperature is important as the duration and intensity of sea surface temperature (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 [9]. It corroborates the result found in [10] with reference to local and global climatic parameters interactions. The relationship between cyclones and SST is also well known [11], which in turn, may affect coastal areas.

The upper 10m of the ocean has complex and variable vertical temperature stratification. This variation in stratification occurs more frequently under conditions in which the ocean surface fluxes cause gains or losses of heat or freshwater or in situations of strong horizontal exchange. Surface fluxes are responsible for a distinct diurnal cycle in the temperature in the uppermost few meters over wide areas of the ocean when winds are weak and solar

*Address corresponding to this author at the Institute of Business and Technology (BIZTEK), Karachi, Pakistan; Tel: +92-21-36322563;
E-mail: wmarif2002@yahoo.com

ISSN: 1814-8085 / E-ISSN: 1927-5129/12

heating is strong [12]. The influence of urban areas on air temperature has also been widely presented in many works, but it was considered mainly in mesoscale, e.g. the urban heat island or heat balance of urban canyon. The present paper attempts to show the type of trends in the twentieth century Arabian seawater monthly average temperature data series.

Section 2 gives the data analysis approach and in Section 3 we discuss the results of trend analysis. Section 4 concludes this communication.

2. MATERIAL AND METHODS

The presented analysis is based on 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:

(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).

Trends, variances, etc., in the data set are important parameters, which could be helpful in forecasting future values [13]. This section develops trend models to serve as a guide in the assessment of impact of the global warming due to the heat absorption in the ocean. To do the linear trend analysis we define the following linear model

$$y(t) = \alpha\ t + \beta \tag{1}$$

where parameters α and β are estimated using least squares method, which gives following formulae

$$\alpha = \frac{\sum y_i \sum t_i^2 - \sum t_i \sum t_i y_i}{n\sum t_i^2 - \left(\sum t_i\right)^2} \tag{2}$$

$$\beta = \frac{n\sum y_i t_i - \sum t_i \sum y_i}{n\sum t_i^2 - \left(\sum t_i\right)^2} \tag{3}$$

t_0 represents years in the temperature series considered with t_0 = 1871. Similarly, y_i denotes Arabian seawater monthly average temperature. We implement the above model to temperature series and obtain the following models for twelve months of the year in the first half, second half, and then taking the complete data for 139 years. *MINITAB* 14 was utilized for the estimation of model parameters. Results are summarized in the next section

3. RESULTS AND DISCUSSIONS

Trend analysis shows that on global scale the oceans have gained heat from the atmosphere over the last one and half century possibly due to anthropogenic activities. Table **1** depicts the annual linear trend analysis (in °C/decade) performed on the complete set of twentieth century Arabian seawater monthly temperature series (1871 – 2009). P-values analysis [14] at α = 5% shows that the trends for all the months are statistically significant. It is important to note that the trend values for the months of November and December are highest. It is showing that the rate of warming during winter is higher as compared to summer warming rate with exception for the month of July, which shows higher increasing rate. The trend models and the time plots are shown in the Figures **1-3**. These figures also show the higher winter warming.

Table 1: Annual Linear Trend Analysis (in °C/decade) Performed on the Twentieth Century Arabian Seawater Monthly Temperature Series (1871 – 2009)

Months	Linear Trend Model	Coefficient of Determination
January	23.08 + 0.034 t	0.206
February	22.95 + 0.034 t	0.208
March	24.09 + 0.038 t	0.242
April	25.98 + 0.037 t	0.169
June	28.97 + 0.032 t	0.134
July	28.34 + 0.043 t	0.249
August	27.11 + 0.039 t	0.188
September	27.07 + 0.038 t	0.225
October	27.31 + 0.030 t	0.341
November	26.06 + 0.053 t	0.365
December	24.31 + 0.049 t	0.262

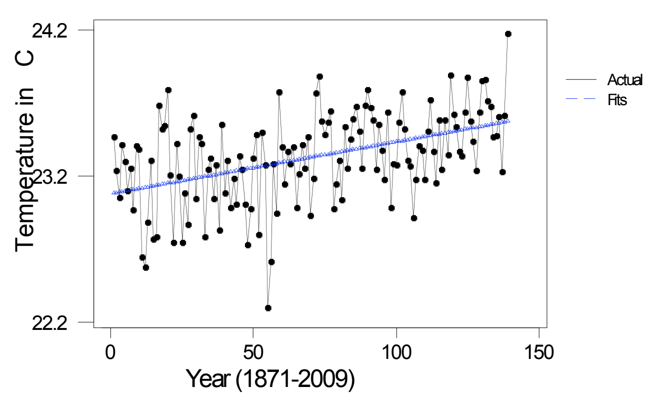

Figure 1: Time plot of Arabian seawater temperatures for the month of January with fitted linear trend model (1871-2009). Pleas see text for detail.

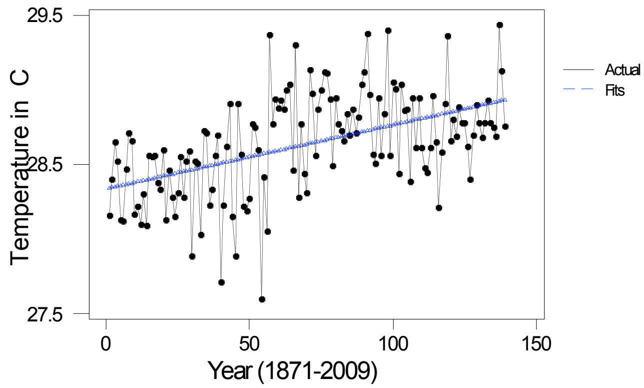

Figure 2: Time plot of Arabian seawater temperatures for the month of July with fitted linear trend model (1871-2009). Pleas see text for detail.

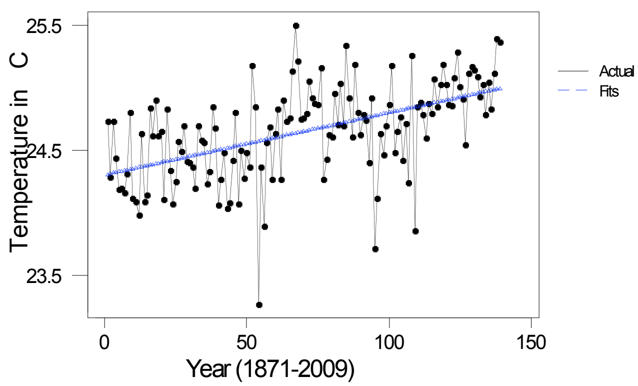

Figure 3: Time plot of Arabian seawater temperatures for the month of December with fitted linear trend model (1871-2009). Pleas see text for detail.

Table 2: Annual Linear Trend Analyses (in °C/decade) Performed on the First Half of Twentieth Century Arabian Seawater Monthly Temperature Series (1871 – 1948)

Months	Linear Trend Model	Coefficient of Determination
January	23.11 + 0.027 *t*	0.035 *
February	23.07 − 0.001 *t*	0.00009 *
March	24.19 + 0.006 *t*	0.0018 *
April	26.02 + 0.024 *t*	0.031 *
May	27.98 + 0.054 *t*	0.135
June	28.81 + 0.079 *t*	0.240
July	28.21 + 0.074 *t*	0.212
August	27.11 + 0.033 *t*	0.051
September	27.10 + 0.027 *t*	0.037 *
October	27.24 + 0.065 *t*	0.319
November	26.01 + 0.066 *t*	0.209
December	24.28 + 0.060 *t*	0.134

*Statistically not significant trends as revealed by P-value analysis.

It is clear from Tables **2** and **3** that warming trends during summer were higher in the first half of previous century temperature data as compared to the second half data. It is also important to note that the trends of only three months (December, January and February) are statistically significant in the second half century temperature data. Next, Table **4** compares the trends of the monthly maximum Karachi urban region with the twentieth century Arabian seawater monthly temperature series.

Table 3: Annual Linear Trend Analysis (in °C/decade) Performed on the Second Half of Twentieth Century Arabian Seawater Monthly Temperature Series (1949 – 2009)

Months	Linear Trend Model	Coefficient of Determination
January	23.34 + 0.045 *t*	0.106
February	23.21 + 0.044 *t*	0.107
March	24.47 + 0.024 *t*	0.032 *
April	26.31 + 0.031 *t*	0.022 *
May	28.51 − 0.020 *t*	0.018 *
June	29.36 − 0.018 *t*	0.012 *
July	28.80 − 0.002 *t*	0.00012 *
August	27.58 − 0.005 *t*	0.00073*
September	27.44 + 0.020 *t*	0.021 *
October	27.68 + 0.030 *t*	0.047 *
November	26.53 + 0.034 *t*	0.044 *
December	24.62 + 0.066 *t*	0.126

*Statistically not significant trends as revealed by P-value analysis.

The two temperature series (Karachi urban maximum and Arabian seawater) in Table **4** show, more or less, similar increasing trends except for the month of July. In July, Karachi urban maximum temperature series reveal almost zero trend [15], that is, the temperature evolution seems to be steady. The decadal increasing trends in case of Karachi urban maximum temperature are almost ten times higher as compared to Arabian seawater monthly temperatures in the twentieth century. This higher rate of urban maximum temperature (due to rapid industrialization, large urban traffic volume, etc.) affects SST near Karachi region. It also results in increase in air temperature and low precipitation [16].

4. CONCLUSION AND OUTLOOK

As Section 1 demonstrates, human activities are responsible for the warming of both Arabian SST and local atmospheric temperature. Section 2 discussed

Table 4: Comparison of Annual Linear Trends (in °C/decade) of the Twentieth Century Arabian Seawater Monthly Temperature Series and the Monthly Maximum Karachi Urban Temperatures

Months	Linear Trend Karachi Urban Max. Temp.	Linear Trend Arabian Seawater Temp.
January	0.22	0.034
February	0.30	0.034
March	0.27	0.037
April	0.31	0.036
May	0.13	0.036
June	0.31	0.032
July	−0.0029	0.043
August	0.12	0.039
September	0.29	0.037
October	0.37	0.044
November	0.37	0.053
December	0.39	0.049

data source and demonstrated the modeling approach adopted in the present work. As analyzed in Section 3, the trends of seawater temperature in the first half of the twentieth century are higher during summer as compared to the trends of the second half of the twentieth century temperature showing higher rate of oceanic heat uptake in the first half as compared to the second half of the twentieth century. Temperature linear trend models are statistically significant for each month for the complete data sets as revealed by P-value analysis. It also shows that the local (Karachi) urban maximum monthly temperature trends have much similar trends as depicted by the twentieth century Arabian SST trends. The trend values for the urban maximum monthly temperature are, more or less, ten times higher than the trends shown by the twentieth century Arabian SST. This shows the impact of urban activities on the local extreme temperature fluctuations.

The reliable trend modeling is necessary for any forecast, monitoring and management of local and global greenhouse emissions. It can help urban planners in managing sustainable urban growth in future. It will also help maintenance managers of thermal power plants near coastal areas as efficiency of heat exchangers depends on seawater temperature. The trend values reported in this communication can be used to estimate the average future temperatures of sea-surface water in future. The application of probabilistic modeling will also be helpful in long-term forecasts of temperature fluctuations of both atmospheric and sea-surface, which will, in turn, give more insights of the temperature evolutionary process. This will be attempted in the next communication.

ACKNOWLEDGEMENTS

We thank the *Hadley British Weather Centre*, UK, for providing us Arabian seawater temperature data. The contents of this paper form part of the second author's doctoral thesis.

REFERENCES

[1] Hussain MA. Mathematical Aspects of Impact of Urban Greenhouse Gas Emissions on Global Warming. Ph. D. Thesis. Federal Urdu University, Karachi, Pakistan 2008.

[2] Naeem A, Qureshi MS. Climatic Variability and Linear Trend Models for the Five Major Cities of Pakistan. J Geogr Geol 2010; 2(1): 83-2.

[3] Briggs D, *et al*. Fundamentals of the Physical Environment, 2nd ed. Routledge, London 1997.

[4] Pinet PR. Invitation to Oceanography. Jones and Bartlett, Boston 1998.

[5] Yousufzai MAK. A Quantitative Study of Effects of Ozone Layer Depletion On Marine Organism with Reference to Coastal Regions of Pakistan. Ph. D. Thesis. University of Karachi, Pakistan 2003.

[6] Yousufzai MAK, Ansari MRK, Iqbal J, Hussain MA. Wavelet Characterization of ozone layer depletion for atmospheric region of Pakistan. Proceedings of 35th All Pakistan Science Conference, University of Karachi, Pakistan, 2008; from 20-23 Dec.

[7] Hussain MA, Ansari MRK, Statistical Aspects of Global Warming Dynamics. Arabian Journal for Science and Engg Saudi Arabia 2007; 32(2A): 189.

[8] Hussain MA, Ansari MRK. Some Insights of Local And Global Temperatures Dynamics. Arabian Journal for Science and Engg Saudi Arabia 2009; 31(2A): 178-186.

[9] Krishna KM. Coastal upwelling along the West Coast of India – ENSO Modulation. Ocean Sci Discuss 2008; 5: 123-134. Maggie L IPCC. IPCC Fourth Assessment Report, Working Group 1 2008.

[10] Khan TMA, *et al*. Seasonal and Interannual Sea Surface Temperature Variability in the Coastal Cities of Arabian Sea and Bay of Bengal. Natural Hazards 2004; 31(2): 549. http://dx.doi.org/10.1023/B:NHAZ.0000023367.66009.1d

[11] Khan TMA, *et al*. Recent Sea level and Sea Surface Temperature Trends along Bangladesh Coast in Relation to the Frequency of Intense Cyclones. Mar Geodesy 2004; 23(2): 103-116.

[12] Folland CK, Coauthors. Observed climate variability and change. Climate Change 2001: The Scientific Basis: Contribution of the Intergovernmental Panel on Climate Change. J. T. Houghton et al., Eds, Cambridge University Press, Cambridge: 2001.

[13] Gille, Sarah T. Decadal-Scale Temperature Trends in the Southern Hemisphere Ocean. J Climate 2008; 21: 4749-4765. http://dx.doi.org/10.1175/2008JCLI2131.1

[14] Hothorn LA. Trend Tests in Epidemiology: P-Values or Confidence Intervals?' Biometrical J 1999; 41(7): 817-825. http://dx.doi.org/10.1002/(SICI)1521-4036(199911)41:7<817::AID-BIMJ817>3.0.CO;2-C

[15] Hussain MA, *et al*. Forecast Models for Urban Extreme Temperatures: Karachi Region as a Case Study. NUCLEUS 2010; 47(4): pp. 301-311.

[16] Khan TMA, *et al*. Sea Surface Temperature Variability Along Pakistan Coast and its Relation to El Nino-Southern Oscillation. J Basic Appl Sci 2008; 4(2): pp 67-72, ISSN: 1814-8085.

Received on 22-01-2012 Accepted on 12-02-2012 Published on 28-02-2012

DOI: http://dx.doi.org/10.6000/1927-5129.2012.08.01.24