Proceedings of the Pakistan Academy of Sciences 50 (3): 235–245 (2013)

ISSN: 0377 - 2969 (print), 2306 - 1448 (online)

Pakistan Academy of Sciences

Research Article

Perturbations of Modeling and Forecast of Karachi Coastal Region Seawater

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Abstract: Global warming is now a stark reality affecting the humanity in many hazardous ways. Continuous floods in Pakistan in past two years are an eye opener in this regard. A great loss of property, agriculture and life as a result of these floods suggests for an intelligent monitoring of the future projections of climate change and global warming. This is necessary because the harmful impacts of natural hazards can be coped and alleviated with a good planning in advance. This monitoring demands for enhanced forecasting capabilities, use of better analytical techniques and a clear determination and study of the controlling factors. Karachi is a coastal city which is also the industrial hub of Pakistan. Moreover, it is among one of the largest metropolitans of the world. So expectedly is most suitable for the study of high level of complex natural and anthropogenic activities. It is peculiar in the sense that it has two summer seasons, a situation scarcely observable on the globe. Here, summer season seawater temperature fluctuations are studied with the help of Seasonal Autoregressive Integrated Moving Average (SARIMA) models and short- and long-term forecasts are made. Our short-term forecasts determine months for the summer wise temperature extremes. It appears that the months of May, June, July and August are the months of extreme temperature for the first summer and October is the month of extreme temperature for the second summer. The long-term forecasts predict that 2014, 2016, 2018, and 2019 will be the years of warm summers. The analysis appearing here would be useful for coastal-urban planners in emphasizing the impact of seawater extreme temperatures on urban industrial activities, etc.

Keywords: Seawater extreme temperatures, global warming, SARIMA model, Karachi

1. INTRODUCTION

Environmental scientists are now getting consensus that in the current decade human activity is responsible for a considerable increase in the concentration of greenhouse gases in the atmosphere causing a climate change [1]. A brief review shows that the global mean sea level temperature has been rising at an average rate of 1.7 mm/year (plus or minus 0.5 mm) over the past 100 years [10-12]. This significant increase averaged over the last several thousand years made the sea level to raise by 0.18 to 0.59 meters, lower level greenhouse gases produce lower level of increase and higher level greenhouse gases produce higher level of increase [9-11]. The temperature rise over the 100 years period from 1906-2005 has been 0.74 °C (0.56 to 0.92 °C) with a confidence interval of 90% [The Fourth Assessment Report (AR4) by IPCC]. The current global temperature increase ranges between 1.8 to 4.0°C. An increase in the extremes ranging between 1.1 and 6.4°C is expected by 2100. It is predicted that this global average will integrate

Received, December 2012; Accepted, July 2013
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widely varying regional responses (warming of land areas much faster than the oceans) [13, 14, 18, 23]. The rate of increase of temperature in northern hemisphere is significantly higher as compared to southern hemisphere. Arabian Sea is lying in the northern hemisphere. Therefore, the Sea Surface Temperature (SST) of Arabian Sea is increasing at a higher rate as compared to other oceans in the region. Global warming induced tropical sea water evaporation and other physical processes make the situation complex.

Latitude exerts a strong control on the surface temperature of the ocean, because the amount of insulation decreases pole-ward. Surface water temperatures, therefore, are highest in the tropics and decreases 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 [29]. The upper space 10 m 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 heating is strong [25, 27]. Data sets of more than fifty data points are scale invariant and usually give useful results [7, 27]. Trends and variances of data sets are important parameters for making useful forecasts of future values. Time series models are considered a popular and power tool for forecasting in many areas [11, 16]. A variety of time series models are in use. Since Autoregressive Integrated Moving Average (ARIMA) models have been successful in forecasting global temperatures [24] so we have preferred to employ the same for forecasting the study of Arabian seawater temperature variations near Karachi. However, in view of the seasonality involved its modified form Seasonal Autoregressive Integrated Moving Average (SARIMA).

In the global perspective, when one probes into the temperature anomalies of the recent past in view of the 14 ^{o}C global average, it is realized that the year 1998 was the warmest during the last decade of the past century and the year 2005 was warmest during the first decade of the new century. Despite a fall in the increase in temperature in the forthcoming years a rinse in the increase in the temperature is again observed in the year 2010 Table 9. In case the global temperature anomaly approaches + 0.30°C or higher, sea-water and river-water temperatures also go high. As predicted by the UK met office the year 2010 appeared to be the warmest in the history. We can observe the following Fig. 1.0 [27], which shows the probable global temperatures in the next 20 years and it is clear from the Fig. that most of the years in the next twenty years would show high temperatures, especially in year 2010, 2012, 2014, 2016, 2018, and 2019. It means that current decade is poised to be the warmest on record, globally.

Emphasizing the links of latitude and sea surface temperature once again, we notice that the rate of increase of temperature in northern hemisphere is significantly higher as compared to southern hemisphere. Arabian Sea is lying in the northern hemisphere. Therefore, the Sea Surface Temperature (SST) of Arabian Sea is increasing at a higher rate as compared to other oceans in the region. Global warming induced tropical sea water evaporation and other physical processes make the situation very complex. We have already noticed in Section 1 that coastal seawater temperature at Karachi is increasing due to many reasons. In this section we analyze and contrast the global temperature records during last two decades with that of extreme seawater temperatures. During nineties, year 1998 was the warmest as far as high temperatures record is concerned. Similarly, during the last decade ,years 2005 and 2009 were observed to be the warm years globally in which sea-water and river-water temperatures were also high and showed problems to the efficiency of thermal power plants. Table 2 reveals global high temperatures in descending order in the two decades. It seems that whenever global temperature anomaly approaches +0.30°C or higher sea-water and river-water temperatures also go high.

It is the perspective in which we emphasize on the existence of maxima in the temperature records of Karachi, the mega-city alongside the Arabian Sea. It is peculiar that Karachi region experiences double summers. The months of April to July form

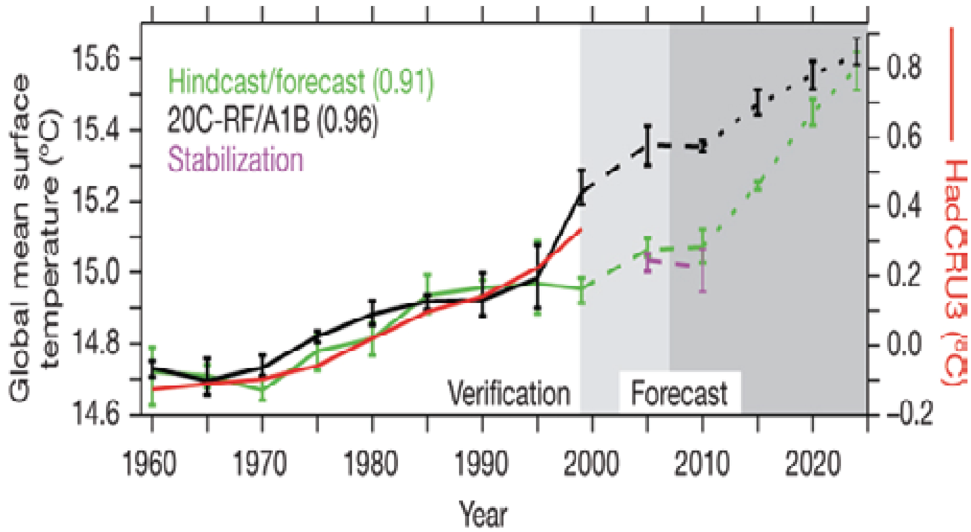

Fig. 1 Global temperature variations as forecasted by several global circulation models, show that the rate of increase of temperature would be higher during 2010 and 2020.

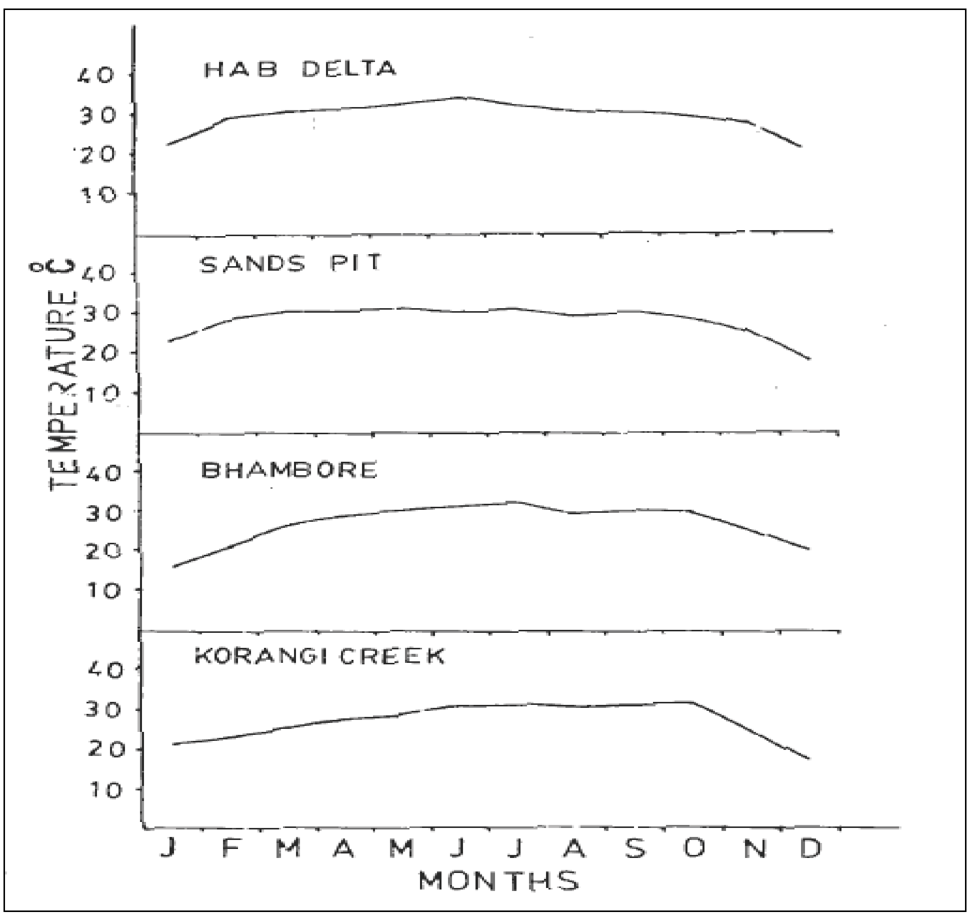

Fig. 2 Temperature variations of Karachi coastal water at different locations during different months.

the first summer whereas the month of October is considered as the second summer. It is interesting to note that current decade (2010-2020) comes under the maximum sunspots cycle [2], therefore, it is more likely that this decade will reveal high frequency of extreme temperature summer days in several years [10]. Seawater temperature near the coast remains higher as compared to offshore water due to its shallowness. Coastal water temperatures at different locations of Karachi coasts show slight variations as depicted in Fig. 1 [20]. It seems that coastal water temperatures at Hub-Delta and Sands Pit remain higher as compared to Korangi Creek. During summer season the temperature near Hub-Delta water remains at 30 °C or higher.

Here, summer season seawater temperature fluctuations are studied with the help of SARIMA models and short- and long-term forecasts are made. Our short-term forecasts determine that months of May, June, July and August are the months of extreme temperatures in the first summer and the month of October is the month of extreme temperature in the second summer. Comparing the temperature extremes in the two summers it appears that temperature in the first summer attains a higher value than the temperature in the second summer. For the long-term our forecasts predict warm summers in 2014, 2016, 2018, and 2019. The analysis carried out here would be useful for coastal urban planners in emphasizing the impact of seawater extreme temperatures on urban industrial activities, etc.

2. MATERIALS AND METHODS

This study analyses the seawater extreme temperatures in the Arabian Sea near Karachi and the urban industrial activities in the city. We will attempt to develop some reliable models using monthly average temperature data of the Arabian seawater ranging over 139 years (1871-2009). The data under consideration relates to 17 Arabian Sea locations near Karachi having coordinates in terms of longitudes and latitudes(23N, 68E),(23 N,67 E), (23 N,66 E), (23 N,65 E), (23 N,64 E), (23N,63 E), (23 N,62 E), (24 N,67 E), (24 N,66 E), (24 N,65 E), (24 N,64 E), (24 N,63 E), (24 N,62 E), (25 N,66 E), (25 N,65 E), (25N,64 E) and (25 N, 63 E). The Hadley Weather Centre, UK) is acknowledged for providing the data.

2.1 Modeling and Analysis of Seawater Temperature Fluctuations

Since we intend to study the summer season seawater temperature fluctuations with the help of SARIMA models so first we briefly describe ARIMA models then SARIMA models. ARIMA models, initially developed by Box and Jenkins (1976) and further enhanced by Box (1994) are a class of time series models which are considered suitable for time correlated modeling and forecasting [3, 4 5, 22, 25, 29]. The method tries to extract the predictable movements from the observed data. The data is passed through three linear filters, the autoregressive filter, the integration filter and the moving average filter. An unpredictable white noise is left out as the end result of the application of these filters [22, 21, 25]. ARIMA suits to work with non-stationary data where an initial differencing step (corresponding to the integrated part of the model) can be applied to remove the non-stationary. The ARIMA (*p, d, q*) × (*P, D, Q*)$_s$ model (where *p* is thee order of the non-seasonal autoregressive process, *d* the number of consecutive differencing, *q* the order of the non-seasonal moving average process, *P* the order of the seasonal autoregressive process, *D* the number of seasonal differencing, *Q* the order of the seasonal moving average process, and *s* the span of the seasonality) is represented as

$$\Phi(B)\nabla^d Y_t = \theta(B)Z_t \quad (1)$$

$$\nabla^d = (1-B)^d \quad (2)$$

$$\theta(B) = 1 + \theta_1 B + \theta_2 B^2 + ... + \theta_q B^q \quad (3)$$

$$\phi(B) = 1 - \phi_1 B - \phi_2 B^2 - \cdots - \phi_p \mathrm{B}^p \quad (4)$$

$$(1 - \mathrm{B})\mathrm{Y}_t = Z_t \quad (5)$$

Seasonal autoregressive integrated moving average (SARIMA) model is a modified form of ARIMA model [21]. It accommodates to study the seasonal and of the data as well. This model is represented as

$$\Phi_P(B^S)\phi(B)\nabla_S^D\nabla^d x_t = \alpha + \Theta_Q(B^S)\theta(B)w_t \quad (6)$$

$$\nabla_S^D = (1 - B^S)^D \quad (7)$$

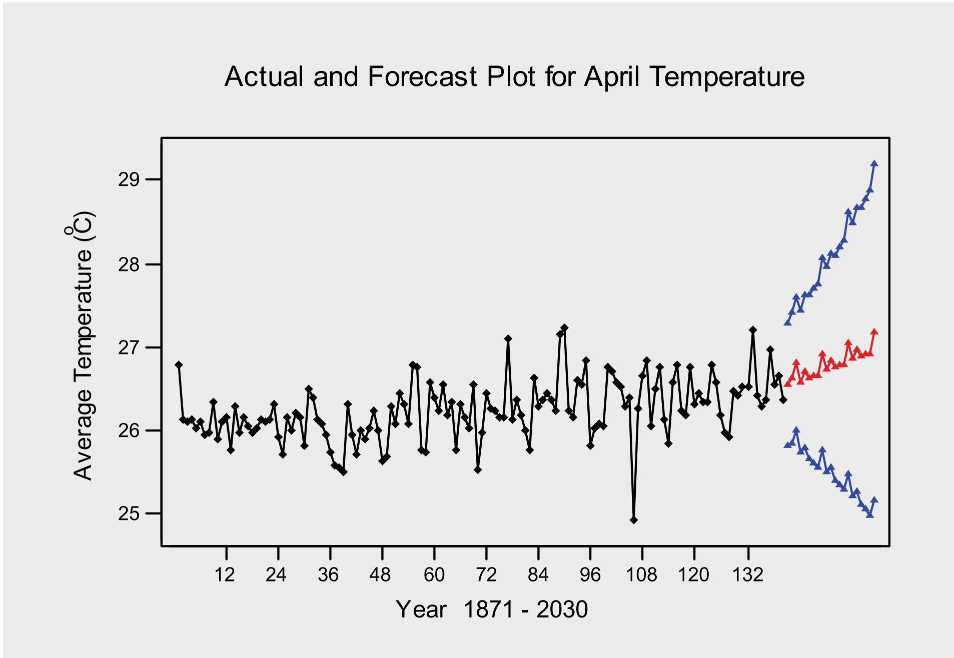

Fig. 3 Time series plot with twenty one years forecast trend for the month of April.

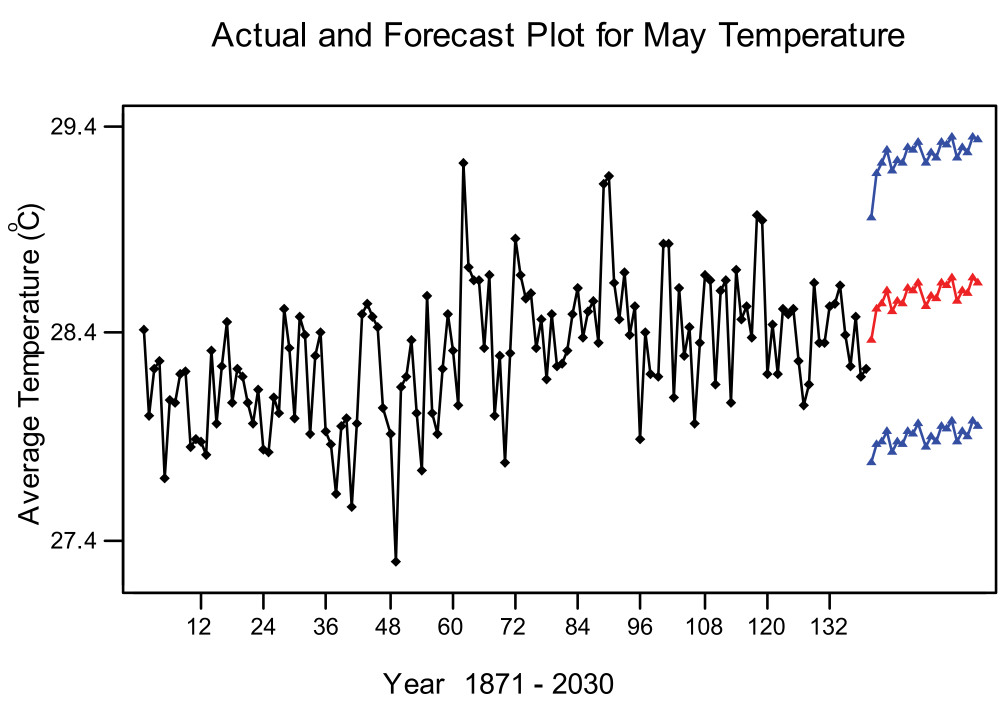

Fig. 4 Time series plot with twenty one years forecast trend for the month of May.

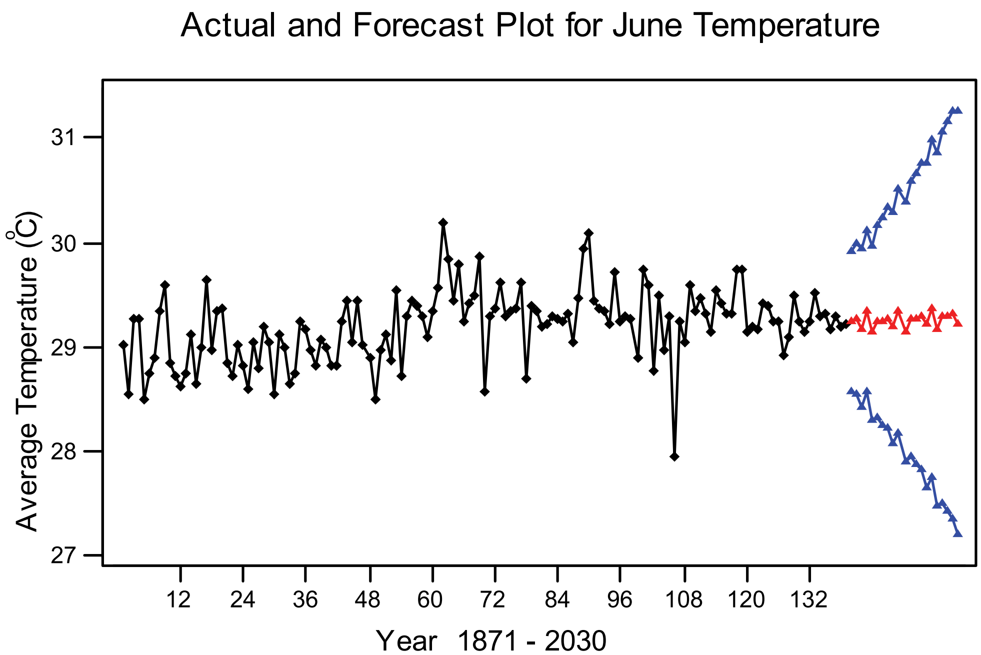

Fig. 5 Time series plot with twenty one years forecast trend for the month of June.

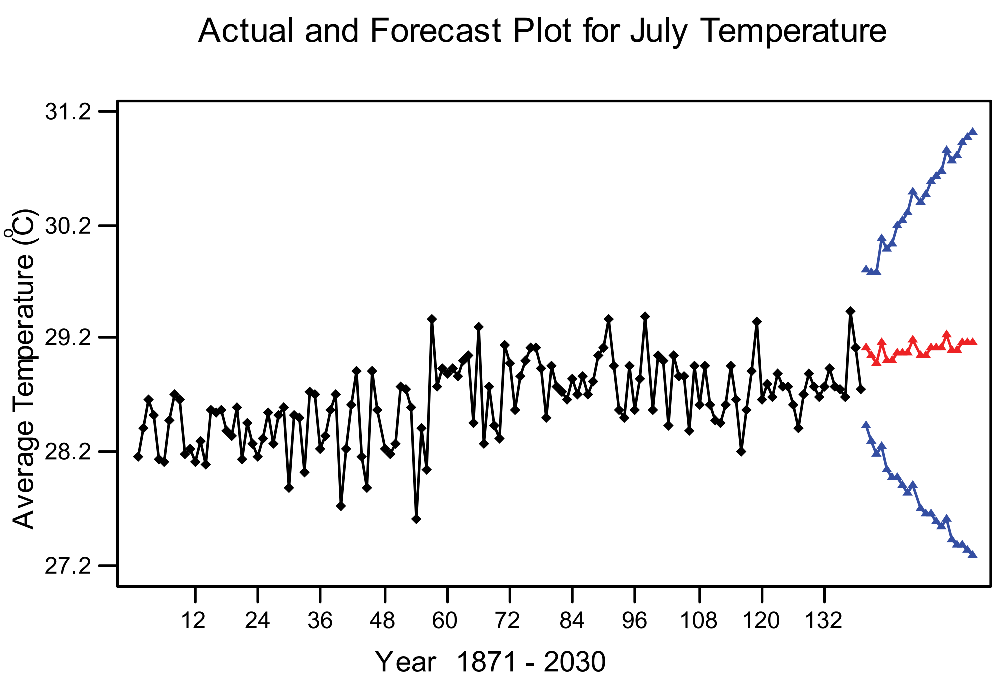

Fig 6. Time series plot with twenty one years forecast trend for the month of July.

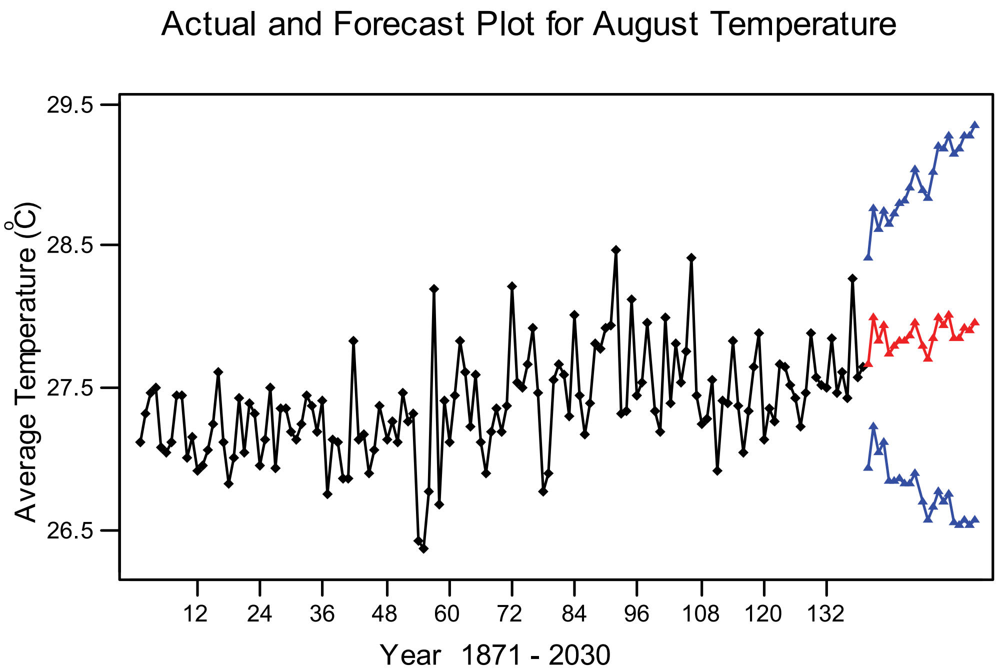

Fig. 7. Time series plot with twenty one years forecast trend for the month of August.

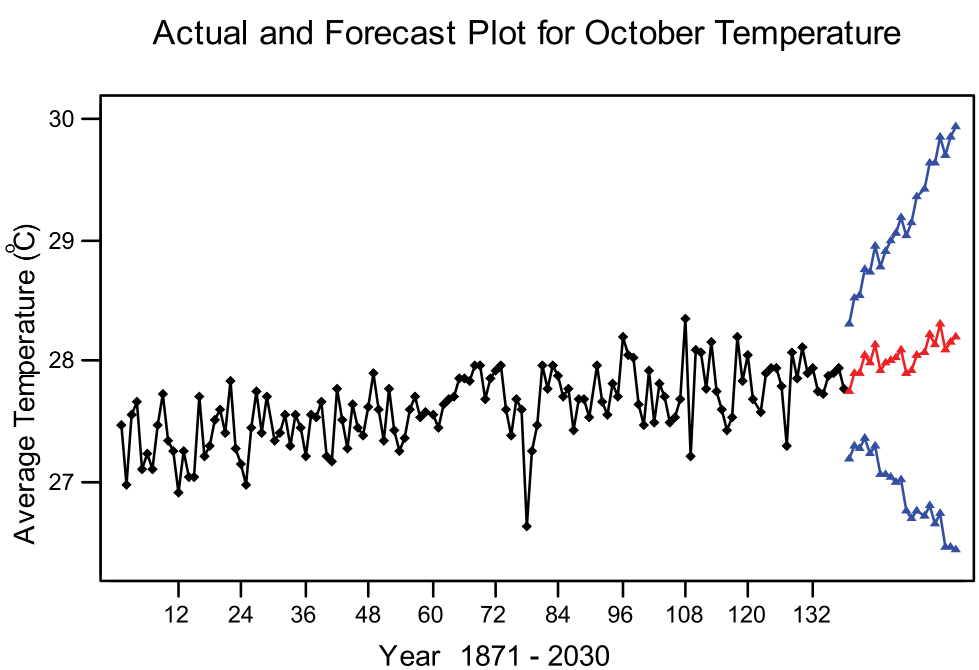

Fig. 8 Time series plot with twenty one years forecast trend for the month of October.

where w_t is the usual Gaussian white noise process. It is in fact ARIMA $(p, d, q) \times (P, D, Q)_s$ model. $\Phi_P(B^S)$ and $\Theta_Q(B^S)$ are polynomials of order P and Q representing the usual autoregressive and moving average components whereas the seasonal difference components.

3. RESULTS AND DISCUSSION

The models forecast Arabian seawater temperature near Karachi coast for the months of April, May, June, July and October re for. MINITAB version 14 was used for the estimation of statistically significant model parameters. Models for April, May, June, July, August, October (1871-2009) appears in Table 2. In Table 3 to 8 gives the temperature forecast values from 2010 to 2030 with their 95% confidence intervals. The breadth of CI increases as we go far into the future as can be seen from the table values as well as the forecast Fig. 2 to 1.7.For the short term forecasts Table 9 gives a comparison of actual and forecasted temperature values for the months of April, May, June, July, August and October 2010.

Table 1 Global average temperature anomaly.

Year	Temp Anomaly (as compared to 14.0 °C global average)
1998	+0.512 °C
2001	+0.198°C
2002	+0.311°C
2003	+0.275°C
2004	+0.193°C
2005	**+0.338°C**
2006	+0.260°C
2007	+0.282°C
2009	+0.259°C

Table 2 Models for April, May, June, July, August, October during 1871-2009.

Months	Model	Type	Coeff.	SE of Coeff.	T-Statistic	P-Value
April	SARIMA $(4, 2, 1)(0, 1, 1)_6$	AR 1	-0.6792	0.0905	-7.51	0.000
		AR 2	-0.6770	0.1013	-6.68	0.000
		AR 3	-0.3878	0.1016	-3.82	0.000
		AR 4	-0.1752	0.0910	-1.92	0.056
		MA 1	0.9586	0.0401	23.91	0.000
		SMA 6	0.9221	0.0586	15.72	0.000
May	ARIMA $(1, 1, 1)(0, 1, 1)_6$	AR 1	0.4798	0.0884	5.43	0.000
		MA 1	0.9865	0.0050	196.49	0.000
		SMA 6	0.9363	0.0547	17.11	0.000
June	ARIMA $(4, 2, 1)(1, 1, 1)_{12}$	AR 1	-0.6948	0.0916	-7.59	0.000
		AR 2	-0.4895	0.1057	-4.63	0.000
		AR 3	-0.4099	0.1067	-3.84	0.000
		AR 4	-0.2236	0.0912	-2.45	0.016
		SAR 12	-0.1725	0.1027	-1.68	0.096
		MA 1	1.0011	0.0004	2316.96	0.000
		SMA 12	0.8743	0.0788	11.10	0.000
		Constant	-0.00027	0.000096	-2.86	0.005
July	ARIMA $(3, 2, 1)(0, 1, 1)_6$	AR 1	-1.5567	0.0961	-16.20	0.000
		AR 2	-0.9115	0.1454	-6.27	0.000
		AR 3	-0.3061	0.0887	-3.45	0.001
		MA 1	-0.9545	0.0389	-24.52	0.000
		SMA 6	0.9335	0.0590	15.83	0.000
August	ARIMA $(3, 2, 1)(0, 1, 1)_{12}$	AR 1	-0.6918	0.0859	-8.06	0.000
		AR 2	-0.5285	0.0944	-5.60	0.000
		AR 3	-0.3691	0.0873	-4.23	0.000
		MA 1	1.0098	0.0002	6161.37	0.000
		SMA 12	0.8858	0.0732	12.10	0.000
October	ARIMA $(4, 2, 2)(0, 1, 1)_{12}$	AR 1	-1.1573	0.2810	-4.12	0.000
		AR 2	-0.7862	0.2064	-3.81	0.000
		AR 3	-0.4330	0.1581	-2.74	0.007
		AR 4	-0.2564	0.0917	-2.80	0.006
		MA 1	0.4326	0.2845	1.52	0.131
		MA 2	0.5093	0.2770	1.84	0.068
		SMA 12	0.8189	0.0765	10.71	0.000

Table 3 Seawater temperature forecast Values for the month of April during 2010-2030.

Year	Forecast Temp.(°C)	Lower 95% C.I.	Upper 95% C.I.
2010	0.2654	78.429	81.122
2011	0.2661	78.419	81.376
2012	0.2681	78.753	81.759
2013	0.2658	78.247	81.430
2014	0.2673	78.366	81.848
2015	0.2661	77.980	81.807
2016	0.2665	77.900	82.025
2017	0.2663	77.758	82.113
2018	0.2691	78.121	82.747
2019	0.2671	77.602	82.530
2020	0.2685	77.718	82.938
2021	0.2672	77.308	82.807
2022	0.2674	77.190	83.077
2023	0.2675	77.039	83.262
2024	0.2703	77.383	83.918
2025	0.2682	76.841	83.701
2026	0.2696	76.931	84.130
2027	0.2682	76.500	84.047
2028	0.2687	76.367	84.351
2029	0.2688	76.194	84.556
2030	0.2654	78.429	81.122

Table 4 Seawater temperature forecast values for the month of May during 2010-2030.

Year	Forecast Temp.(°C)	Lower 95% C.I.	Upper 95% C.I.
2010	0.2837	82.005	84.128
2011	0.2852	82.158	84.525
2012	0.2855	82.172	84.598
2013	0.2861	82.269	84.711
2014	0.2851	82.086	84.533
2015	0.2856	82.182	84.633
2016	0.2854	82.144	84.603
2017	0.2862	82.279	84.742
2018	0.2861	82.255	84.721
2019	0.2865	82.328	84.794
2020	0.2854	82.132	84.599
2021	0.2859	82.222	84.690
2022	0.2857	82.181	84.657
2023	0.2864	82.315	84.794
2024	0.2863	82.291	84.771
2025	0.2867	82.363	84.844
2026	0.2856	82.167	84.649
2027	0.2861	82.257	84.740
2028	0.2859	82.215	84.707
2029	0.2866	82.349	84.844
2030	0.2865	82.325	84.821

Table 5 Seawater temperature forecast values for the month of June during 2010-2030.

Year	Forecast Temp.(°C)	Lower 95% C.I.	Upper 95% C.I.
2011	0.2909	83.142	85.574
2012	0.2887	82.695	85.223
2013	0.2916	83.199	85.784
2014	0.2888	82.631	85.335
2015	0.2893	82.627	85.530
2016	0.2896	82.617	85.632
2017	0.2892	82.501	85.616
2018	0.290	82.602	85.806
2019	0.2902	82.585	85.894
2020	0.2873	82.009	85.427
2021	0.2887	82.202	85.716
2022	0.2883	82.101	85.682
2023	0.2883	82.061	85.724
2024	0.2856	81.542	85.288
2025	0.2877	81.864	85.692
2026	0.2856	81.454	85.360
2027	0.2864	81.558	85.537
2028	0.2862	81.487	85.538
2029	0.2857	81.368	85.493
2030	0.286	81.386	85.582
2030	0.2654	78.429	81.122

Table 6 Seawater temperature forecast values for the month of July 2010-2030.

Year	Forecast Temp.(°C)	Lower 95% C.I.	Upper 95% C.I.
2010	0.2911	83.160	85.655
2011	0.2904	82.931	85.617
2012	0.2899	82.743	85.629
2013	0.2917	82.857	86.138
2014	0.2902	82.485	85.971
2015	0.2901	82.355	86.075
2016	0.2908	82.343	86.344
2017	0.2907	82.208	86.435
2018	0.2907	82.108	86.542
2019	0.2919	82.220	86.877
2020	0.2905	81.875	86.722
2021	0.2906	81.785	86.830
2022	0.2912	81.775	87.047
2023	0.2911	81.667	87.137
2024	0.2911	81.575	87.229
2025	0.2924	81.703	87.552
2026	0.291	81.361	87.385
2027	0.291	81.286	87.489
2028	0.2916	81.281	87.691
2029	0.2916	81.185	87.778
2030	0.2915	81.094	87.860

Table 7 Seawater temperature forecast values for the month of August during 2010-2030.

Year	Forecast Temp.(°C)	Lower 95% C.I.	Upper 95% C.I.
2010	0.2767	80.481	83.137
2011	0.2801	81.016	83.788
2012	0.2783	80.665	83.513
2013	0.2793	80.811	83.750
2014	0.2775	80.313	83.573
2015	0.2779	80.334	83.723
2016	0.2783	80.352	83.845
2017	0.2782	80.282	83.884
2018	0.2786	80.287	84.039
2019	0.2796	80.410	84.273
2020	0.2779	80.043	84.005
2021	0.2770	79.837	83.897
2022	0.2784	80.000	84.242
2023	0.2798	80.203	84.556
2024	0.2794	80.072	84.525
2025	0.2801	80.159	84.710
2026	0.2785	79.804	84.470
2027	0.2785	79.759	84.520
2028	0.2792	79.842	84.692
2029	0.2791	79.772	84.710
2030	0.27961	79.816	84.842

Table 8 Seawater temperature forecast values for the month of October during 2010-2030.

Year	Forecast Temp.(°C)	Lower 95% C.I.	Upper 95% C.I.
2009	0.2774	80.922	83.326
2010	0.2790	81.130	83.387
2011	0.2790	81.070	83.765
2012	0.2805	81.230	83.706
2013	0.2797	81.021	84.112
2014	0.2812	81.133	83.810
2015	0.2791	80.683	84.017
2016	0.2797	80.692	84.172
2017	0.2800	80.647	84.302
2018	0.2802	80.596	84.536
2019	0.2809	80.618	84.245
2020	0.2788	80.148	84.458
2021	0.2791	80.034	84.828
2022	0.2805	80.169	84.962
2023	0.2806	80.076	85.367
2024	0.2822	80.234	85.336
2025	0.2814	79.972	85.751
2026	0.2830	80.128	85.482
2027	0.2808	79.625	85.727
2028	0.2815	79.625	85.910
2029	0.2818	79.560	86.074
2030	0.2821	79.481	83.326

Table 9 Seawater temperature comparison of Actual and Forecasted values (for the year 2010).

Year	Month	Actual Temp.(°C)	Forecast Temp.(°C)
2010	April	0.2667	0.2661
2010	May	0.2823	0.2852
2010	June	0.29.22	0.2909
2010	July	0.28.76	0.2904
2010	August	0.27.64	0.2801
2010	October	0.27.80	0.2790

4. CONCLUSIONS

This study presents short- and long-term forecasts models of Arabian seawater temperature fluctuations of coastal water in Karachi region during two summer seasons. The short-term temperature forecasts reveal that in case of first summer the months of May to August were the months of extreme temperature and in case of second summer the month of October was of extreme temperature. Actual values for the year 2010 verify the forecasts. As far as long-term forecasts are concerned, warm summers are expected during 2014, 2016, 2018 and 2019. The short-term forecasts are generally more accurate and accompany low degree of uncertainty, as compared to long-term forecasts. It is noted that the lack of information about future changes in extreme weather is a major constraint of contemporary Integrated Assessment Models (IAMs) of climate change. So in future the extreme value theory is expected to gain importance. Our findings were in agreement with the global scale findings of National Oceanic and Atmospheric Administration (NOAA). They declared that the land surface temperature of June 2010 exceeded the previous records by 0.11°C [12]. The analysis presented here would be useful for coastal urban planners in emphasizing the impact of seawater extreme temperatures on urban industrial activities etc. It would also be helpful in doing analysis on tropical cyclone forecast in the Arabian Sea in near future.

5. ACKNOWLEDGEMENTS

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

6. REFERENCES

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