JUEE

Journal of Urban and Environmental Engineering, v.4, n.1, p.9-22

ISSN 1982-3932
doi: 10.4090/juee.2010.v4n1.009022

Journal of Urban and Environmental Engineering

www.journal-uee.org

MODELING OF WEATHER DATA FOR THE EAST ANATOLIA REGION OF TURKEY

S. Akpinar[1] and Ebru K. Akpinar[2*]

[1]*Physics Department, Firat University, TR-23119, Elazig, Turkey*

[2]*Department of Mechanical Engineering, Firat University, TR-23119, Elazig, Turkey*

Received 08 March 2010; received in revised form 21 May 2010; accepted 24 May 2010

Abstract: Monthly average daily data of climatic conditions over the period 1994–2003 of cities in the east Anatolia region of Turkey is presented. Regression methods are used to fit polynomial and trigonometric functions to the monthly averages for nine parameters. The parameters namely temperature, maximum–minimum temperature, relative humidity, pressure, wind speed, rainfall, solar radiation and sunshine duration are useful for renewable energy applications. The functions presented for the parameters should enable determination of specific parameter values and prediction of missing values. They also provide some insight into the variation of these parameters. The models developed can be used in any study related to climatic and its effect on the environment and energy.

Keywords: Energy; environment; temperature, maximum–minimum temperature, relative humidity, wind speed, pressure, rainfall, solar radiation, sunshine duration; weather parameters

---

* Correspondence to: Dr. Ebru Kavak Akpinar, Mechanical Eng. Department, Firat University, TR-23119, Elazig, Turkey. E-mails: ebruakpinar@firat.edu.tr, kavakebru@hotmail.com; Tel: +90-424-2370000/5325; Fax: +90-424-2415526.

INTRODUCTION

Energy is one of the precious resources in the world. Energy conservation becomes a hot topic around people, not just for deferring the depletion date of fossil fuel but also concerning the environmental impact due to energy consumption (Apple *et al.*, 2006). Performance of environment-related systems, such as heating, cooling, ventilating and air-conditioning of buildings (HVAC systems), solar collectors, solar cells, greenhouses, power plants and cooling towers, are dependent on weather variables like solar radiation, dry-bulb temperature, wet-bulb temperature, humidity, wind speed, etc. In order to calculate the performance of an existing system or to predict the energy consumption of a system in design step, the researcher/designer needs appropriate weather data (Üner & İleri, 2000).

Accurate weather data are needed for design optimization and performance prediction of solar technologies and environmental control systems. However, these types of data are not often readily available in easily usable form. Analyzed weather data developed into an atlas provides useful information on renewable energy sources. The modeling of weather data results in mathematical and statistical models, which enable the determination of data and prediction of weather conditions (Dorvlo & Ampratwum, 1999).

A number of studies are found in the literature dealing with the climatic characteristics, solar and wind energy related issues for different region of the World. Global solar irradiation (GSI) had been estimated in a number of studies by the known climatic parameters of bright sunshine duration (Sen, 2007; Abdul-Aziz *et al.*, 1993), cloud fraction (Norris, 1968; Kasten and Czeplak, 1980), air temperature range (Bristow & Campbell, 1984), precipitation status (McCaskill, 1990), both temperature and rainfall (Hansen, 1999) and both sunshine duration and cloud (Tasdemiroglu and Sever, 1991; Ododo, 1996), trends to years of the weather parameters such as temperature, relative humidity, wind speed, dust and fog (Al-Garni *et al.*, 1999).

Climatic differences between urban and suburban have been studied by many other authors (Unger, 1997; Unkasevic, 2001; Roba, 2003; Bernatzky, 1982; Wilmers, 1988; Nowak *et al.*, 1998; Yılmaz *et al.*, 2007). Cañada *et al.* (1997) developed correlation models for global diffuse and tilted irradiation, ambient temperature, sunshine hours and specific humidity for Valencia in Italy. The coefficients of determination of their models were 0.75 or more. Coppolino (1994) developed a polynomial relationship between the clearness index and relative sunshine hours. Raja & Twidell (1994) have carried out statistical analysis of measured global insolation data for up to 15 years from six locations in Pakistan. They obtained cumulative frequency information for application when planning solar installations. Dorvlo & Ampratwum (1999) developed regression models for the weather data of Oman for the period 1987–1992. However, there is limited information and research dealing with the climatic characteristics, solar and wind energy related issues for different region of the Turkey in the literature (Tatli *et al.*, 2005; Sahin *et al.*, 2006; Sahin 2007; Türkes & Erlat, 2008; Tatli, 2007).

This paper models weather data for the determination of specific climatic parameter values that could be used for developing solar and wind technologies and environmental control systems, and for the calculation of missing data required for the development of a solar and wind atlas for the east Anatolia region of Turkey.

MATERIAL AND METHODS

Features of study area

There are thirteen cities at the east Anatolia region of Turkey. **Table 1** gives the names and locations of the major meteorological stations in the east Anatolia region of Turkey. The east Anatolia region of Turkey has a typical highland climate, in that it is generally cold in winter and hot in summer and there are considerable temperature differences between day and night. Location of cities at the east Anatolia region of Turkey can be shown from **Fig. 1**. The parameters observed daily at the stations are temperature, maximum–minimum temperature, relative humidity, wind speed, pressure, rainfall, solar radiation and sunshine duration. The measurements have been carried out by conventional meteorological instruments by the Turkish Meteorological State Department (TMSD). The Department produces monthly summaries of this data. The data for the present study is obtained from the summaries of 1994 to 2003.

Fig. 1 Location of cities in the east Anatolia region of Turkey.

Table 1. Geographic location of weather stations in the east Anatolia region of Turkey

Location	Longitude east	Latitude north
Agri	43º 03’	39º 44’
Bingöl	40º 29’	38º 53’
Bitlis	42º 06’	38º 22’
Elazig	39º 14’	38º 41’
Erzincan	39º 29’	39º 44’
Erzurum	41º 17’	39º 55’
Hakkari	43º 45’	37º 34’
Igdir	44º 02’	39º 55’
Kars	43º 05’	40º 36’
Malatya	38º 19’	38º 21’
Muş	41º 30’	38º 44’
Tunceli	39º 33’	39º 07’
Van	43º 20’	38º 28’

Modeling of climatic parameters

Statistical techniques of regression models are frequently used to study a set of experimental data. Adequacy and validity of the model is performed to determine if the model will function in a successful manner in its intended operating field.

Linear regression analysis is a statistical tool by which a line is fitted through a set of experimental data using the least-squares method. Regression is used in a wide variety of applications in order to analyze how a single dependent variable is affected by the values of one or more independent variables. In this study, temperature, maximum temperature, minimum temperature, relative humidity, wind speed, pressure, rainfall, solar radiation and sunshine duration collected for a period of 10 years (1994–2003) is modeled using linear regression analysis with 95% confidence level.

The correlation coefficient (*R*) was primary criterion for selecting the best equation to describe the curve equation. In addition to *R*, the reduced χ^2 as the mean square of the deviations between the observed and calculated values for the models and root mean square error analysis (RMSE) were used to determine the goodness of the fit. The higher the values of the *R*, and lowest values of the χ^2 and *RMSE*, the better the goodness of the fit (Akpinar and Akpinar, 2004; Akpinar *et al.*, 2006). These can be calculated as:

$$R^2 = \frac{\sum_{i=1}^{n}\left(Y_{\exp,i} - Y_{\text{expmean}}\right)^2 - \sum_{i=1}^{n}\left(Y_{pre,i} - Y_{\exp,i}\right)^2}{\sum_{i=1}^{n}\left(Y_{\exp,i} - Y_{\text{expmean}}\right)^2} \quad (1)$$

$$\chi^2 = \frac{\sum_{i=1}^{n}\left(Y_{\exp,i} - Y_{pre,i}\right)^2}{N-n} \quad (2)$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}\left(Y_{pre,i} - Y_{\exp,i}\right)^2\right]^{1/2} \quad (3)$$

where, $Y_{exp,i}$ is the *ith* experimentally observed value, $Y_{expmean,}$ is the mean of experimentally observed value, $Y_{pre,i}$ the *ith* predicted value, *N* the number of observations and *n* is the number constants.

Validation of the established model was made by comparing the computed climatic data with the observed climatic data in any particular run under certain conditions. The performance of the models for the climatic data was illustrated. The experimental data are generally banded around the straight line representing data found by computation, which indicates the suitability of the model in describing the computed climatic data.

RESULTS

The monthly daily summaries over the ten years 1994–2003 for the nine meteorological parameters were used in developing the models presented (**Table 2**). The summaries are calculated over all the meteorological stations where possible. Scatter diagrams of the monthly average daily measurements for each year are presented in **Figs 2, 4, 6, 8, 10, 12, 14, 16,** and **18**. Polynomial and trigonometric models were fitted to the data with the months (**m**: 1–12) as the predictor variable. The performance of these models was investigated by comparing the determination of coefficient (*R*), reduced chi-square (χ^2) and root mean square error (RMSE) between the observed and predicted values. Over fitting was avoided by listing only the functions with statistically non-zero coefficients.

The monthly average temperatures

From **Fig. 2**, it can be seen that there is an evident difference at monthly average temperatures between the investigated cities. The overall average temperature for 10 years was found to be about 13.19°C for Elazig, 11.50°C for Erzincan, 5.18°C for Erzurum, 5.58°C for Kars, 6.83°C for Agri, 12.74°C for Igdir, 13.28°C for Tunceli, 10.11°C for Van, 14.14°C for Malatya, 12.56°C for Bingöl, 10.69°C for Muş, 9.87°C for Bitlis, 10.70°C for Hakkari. While the Erzurum city is the coldest area for the whole period, Malatya city is the hottest area for the whole period. The monthly average temperatures showed changing between -9.4 and 19.4°C for Erzurum city, 1.6 and 27.9°C for Malatya city.

The simple function of the monthly average temperature (AT_1) fit the ambient temperature data very well. The results of statistical analyses undertaken on trigonometric model for the monthly average temperature are given in **Table 3**. The model was evaluated based on R, χ^2 and RMSE. Generally, R, χ^2 and RMSE values were varied between 0.99660–0.99920, 0.226–0.979 and 0.395–0.823, respectively. The function has coefficients of determination of better than 0.99 and the lowest values of χ^2 and RMSE for all cities. Hence, the trigonometric model (AT_1) satisfactorily described characteristics of the monthly average temperature. Considering trigonometric model (AT_1), the observed monthly average temperature values were compared with calculated ones. **Figure 3** shows the predicted and observed values of monthly average temperature. As seen from **Fig. 3**, there is a good agreement between predicted and observed values.

Table 2. Models for the weather data

Monthly average temperature	AT1 = $a+b\cdot\sin(m)+c\cdot\sin((m/2)+d)$
Monthly average maximum temperature	AT2 = $a+b\cdot\sin(m)+c\cdot\sin((m/2)+d)$
Monthly average minimum temperature	AT3 = $a+b\cdot\sin(m)+c\cdot\sin((m/2)+d)$
Monthly average relative humidity	RH = $a+b\cdot\sin(m)+c\cdot\sin((m/2)+d)$
Monthly average wind speed	WS = $a+b\cdot m+c\cdot(m^2)+d\cdot(m^3)+e\cdot(m^4)$
Monthly average pressure	P = $a+b\cdot m+c\cdot(m^2)+d\cdot(m^3)+e\cdot(m^4)$
Monthly average rainfall	RF = $a+b\cdot m+c\cdot(m^2)+d\cdot(m^3)+e\cdot(m^4)$
Monthly average solar radiation	SR = $a+b\cdot\sin(m)+c\cdot\sin((m/2)+d)$
Monthly average sunshine duration	SD = $a+b\cdot\sin(m)+c\cdot\sin(2\cdot m)+d\cdot\sin(m/2+e)+f\cdot m$

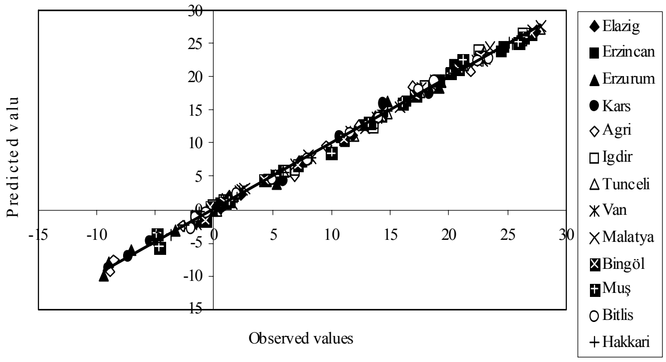

Fig. 3 Observed and predicted values of the monthly average temperatures.

The monthly average maximum temperatures

The overall average maximum temperature for 10 years was found to be about 19.35°C for Elazig, 18.05°C for Erzincan, 12.64°C for Erzurum, 12.72°C for Kars, 13.7°C for Agri, 19.59°C for Igdir, 19.7°C for Tunceli, 15.05°C for Van, 19.62°C for Malatya, 18.95°C for Bingöl, 16.52°C for Muş, 16.22°C for Bitlis, 15.18°C for Hakkari. While maximum temperatures are at highest values in August and July, at lowest values in January. While Erzurum is coldest city for the whole period, Tunceli is warmest city. Monthly average maximum temperatures changed between -3.2 and 28.1°C for Erzurum city, 4.8 and 35.3°C for Tunceli city at **Fig. 4**.

The simple function of the monthly average maximum temperature (AT_2) fit the maximum temperature data very well. The results of statistical analyses undertaken on trigonometric model for the monthly average maximum temperature are given in **Table 4**. Generally, R, χ^2 and *RMSE* values were varied between 0.99380–0.99911, 0.194–1.832 and 0.366–1.126, respectively. The function has coefficients of determination of better than 0.99 and the lowest values of χ^2 and RMSE for all cities. Hence, the trigonometric model (AT_2) satisfactorily described characteristics of the monthly average maximum temperature. Considering trigonometric model (AT_2), the observed monthly average maximum temperature values were

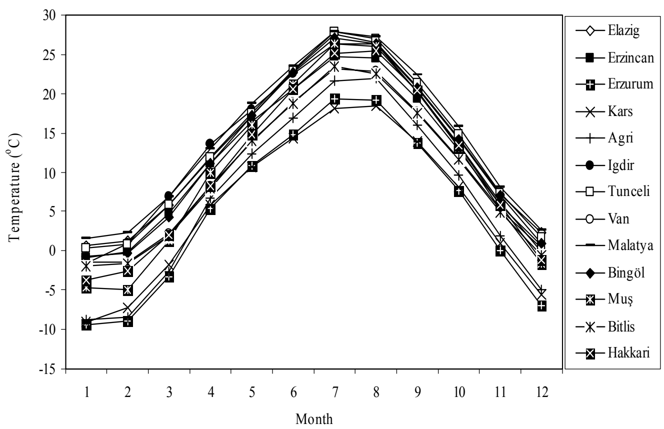

Fig. 2 Monthly average temperatures during the years 1994–2003 for the cities.

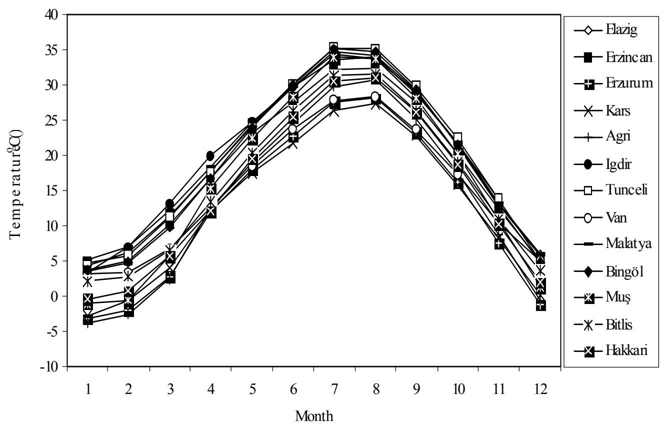

Fig. 4 Monthly average maximum temperatures during the years 1994–2003 for the cities.

Table 3. The results of statistical analyses according to the model (AT_1) for the monthly average temperature

Model		Monthly average temperature $= a + b \cdot \sin(m) + c \cdot \sin((m/2) + d)$			
City	Constant	Model constants	R	χ^2	RMSE
Elazığ	*a*	12.611	0.99 880	0.284	0.443
	b	1.1621			
	c	-13.494			
	d	7.387			
Erzincan	*a*	11.055	0.99 812	0.415	0.536
	b	0.7980			
	c	-13.090			
	d	1.1222			
Erzurum	*a*	4.5316	0.99 679	0.897	0.788
	b	0.1522			
	c	-14.733			
	d	1.0937			
Kars	*a*	4.9791	0.99 660	0.812	0.750
	b	-0.1157			
	c	-13.62			
	d	1.0898			
Agri	*a*	6.1518	0.99 686	0.979	0.823
	b	-0.0053			
	c	-15.555			
	d	1.0638			
Igdir	*a*	12.1077	0.99 667	0.843	0.764
	b	0.7469			
	c	-14.032			
	d	1.1860			
Tunceli	*a*	12.6769	0.99 864	0.340	0.485
	b	1.08504			
	c	-13.893			
	d	1.1011			
Van	*a*	9.5648	0.99 858	0.295	0.452
	b	0.9691			
	c	-12.663			
	d	1.0589			
Malatya	*a*	13.577	0.99 890	0.257	0.422
	b	1.0822			
	c	-13.473			
	d	1.1070			
Bingöl	*a*	11.947	0.99 881	0.311	0.464
	b	0.8917			
	c	-14.214			
	d	1.088			
Muş	*a*	9.9987	0.99 747	0.823	0.755
	b	0.3676			
	c	-15.886			
	d	1.0665			
Bitlis	*a*	9.3095	0.99 863	0.297	0.454
	b	0.9693			
	c	-12.917			
	d	1.0696			
Hakkari	*a*	10.0726	0.99 920	0.226	0.395
	b	0.9066			
	c	-14.744			
	d	1.0315			

compared with calculated ones. **Figure 5** shows the predicted and observed values of the monthly average maximum temperature. There is a good agreement between predicted and observed values.

The monthly average minimum temperatures

The overall average minimum temperature for 10 years was determined to be about 7.06°C for Elazig, 5.70°C

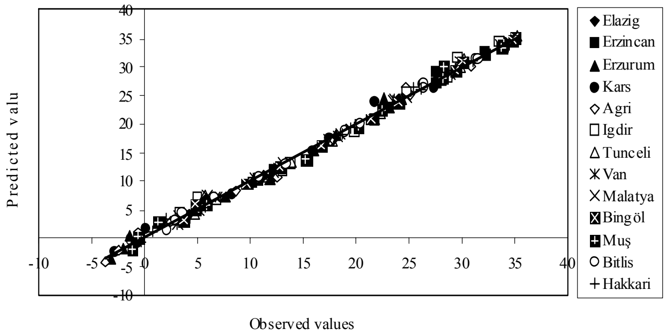

Fig. 5 Observed and predicted values of the monthly average maximum temperatures.

Table 4. The results of statistical analyses according to the model (AT_2) for the monthly average maximum temperature

Model		Monthly average maximum temperature $= a + b \cdot \sin(m) + c \cdot \sin((m/2) + d)$			
City	Constant	Model constants	R	χ^2	RMSE
Elazığ	*a*	18.688	0.99 873	0.390	0.519
	b	1.2062			
	c	-15.392			
	d	1.0942			
Erzincan	*a*	17.409	0.99 752	0.692	0.692
	b	0.9192			
	c	-14.693			
	d	7.372			
Erzurum	*a*	11.946	0.99 618	1.272	0.938
	b	0.4447			
	c	-16.044			
	d	1.0534			
Kars	*a*	12.082	0.99 576	1.212	0.916
	b	0.3482			
	c	-14.860			
	d	1.0479			
Agri	*a*	12.951	0.99 698	1.189	0.907
	b	0.4140			
	c	-17.455			
	d	1.0296			
Igdir	*a*	18.916	0.99 380	1.832	1.126
	b	0.6014			
	c	-15.117			
	d	1.1388			
Tunceli	*a*	19.021	0.99 805	0.625	0.658
	b	1.1777			
	c	-15.723			
	d	1.0700			
Van	*a*	14.512	0.99 911	0.194	0.366
	b	1.0207			
	c	-12.956			
	d	1.0194			
Malatya	*a*	18.970	0.99 814	0.534	0.608
	b	1.0786			
	c	-14.898			
	d	1.114			
Bingöl	*a*	18.249	0.99 884	0.396	0.523
	b	1.2421			
	c	-16.236			
	d	1.0714			
Muş	*a*	15.739	0.99 753	1.048	0.852
	b	0.5124			
	c	-18.122			
	d	1.0546			
Bitlis	*a*	15.580	0.99 906	0.284	0.443
	b	1.299			
	c	-15.252			
	d	7.312			
Hakkari	*a*	14.509	0.99 874	0.419	0.538
	b	1.0466			
	c	-15.983			
	d	1.0133			

Table 5. The results of statistical analyses according to the model (AT_3) for the monthly average minimum temperature

Model	Monthly average minimum temperature $= a + b\cdot\sin(m) + c\cdot\sin((m/2) + d)$				
City	Cons-tant	Model constants	R	χ^2	RMSE
Elazığ	*a*	6.6105	0.99 587	0.612	0.651
	b	0.9345			
	c	-10.65			
	d	1.0598			
Erzincan	*a*	5.2303	0.99 727	0.461	0.554
	b	0.4802			
	c	-10.804			
	d	1.1158			
Erzurum	*a*	-2.9692	0.99 206	1.593	1.050
	b	-0.54468			
	c	-12.450			
	d	1.1088			
Kars	*a*	-1.4663	0.99 437	1.119	0.880
	b	-0.4760			
	c	-12.415			
	d	1.1056			
Agri	*a*	-0.2878	0.99 326	1.519	1.025
	b	-0.6481			
	c	-13.192			
	d	1.0772			
Igdir	*a*	6.0989	0.99 720	0.558	0.622
	b	0.7160			
	c	-12.440			
	d	1.1732			
Tunceli	*a*	6.7410	0.99 630	0.616	0.653
	b	0.8648			
	c	-11.326			
	d	1.0893			
Van	*a*	4.8203	0.99 781	0.340	0.485
	b	0.7447			
	c	-10.920			
	d	1.0275			
Malatya	*a*	8.1937	0.99 804	0.318	0.469
	b	0.9545			
	c	-11.172			
	d	1.0725			
Bingöl	*a*	6.6144	0.99 725	0.508	0.593
	b	0.6555			
	c	-11.942			
	d	1.0754			
Muş	*a*	4.4451	0.99 544	1.006	0.834
	b	-0.06851			
	c	-13.0715			
	d	1.0561			
Bitlis	*a*	4.3441	0.99 688	0.454	0.561
	b	0.6756			
	c	-10.589			
	d	1.0588			
Hakkari	*a*	4.944	0.99 906	0.208	0.379
	b	0.6985			
	c	-13.086			
	d	1.0560			

for Erzincan, -2.40°C for Erzurum, -0.90°C for Kars, 0.3°C for Agri, 6.65°C for Igdir, 7.23°C for Tunceli, 5.28°C for Van, 8.67°C for Malatya, 7.13°C for Bingöl, 5.01°C for Muş, 4.8°C for Bitlis, 5.50°C for Hakkari (**Fig. 6**). While minimum temperatures are at highest values in July, at lowest values in January and February. Minimum temperatures reach the warmest values in the Malatya. The monthly average minimum temperatures demonstrated changing between -1.5 and 20.3°C for Malatya city.

The simple function of the monthly average minimum temperature (AT_3) fit the minimum temperature data very well. The results of statistical analyses undertaken on trigonometric model for the monthly average minimum temperature are given in **Table 5**. Generally, R, χ^2 and $RMSE$ values were varied between 0.99 206–0.99 906, 0.208–1.593 and 0.379–1.050, respectively. The function has coefficients of determination of better than 0.99 and the lowest values of χ^2 and RMSE for all cities. Hence, the trigonometric model (AT_3) satisfactorily described characteristics of the monthly average minimum temperature. Considering trigonometric model (AT_3), the observed mean minimum monthly temperature values were compared with calculated ones. **Figure 7** shows the predicted and observed values of the monthly average minimum temperature. There is a good agreement between predicted and observed values.

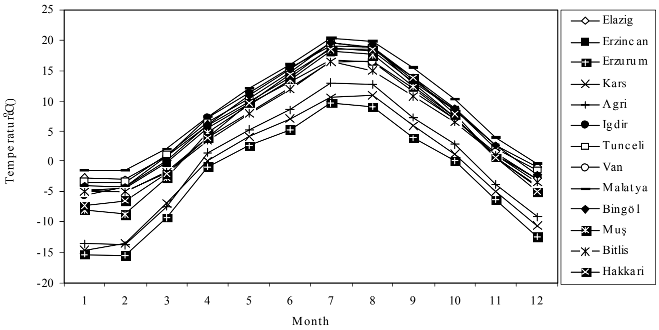

Fig. 6 Monthly average minimum temperatures during the years 1994–2003 for the cities.

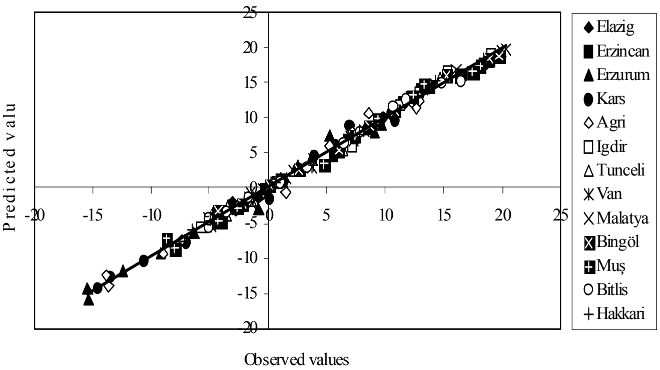

Fig. 7 Observed and predicted values of the monthly average minimum temperatures.

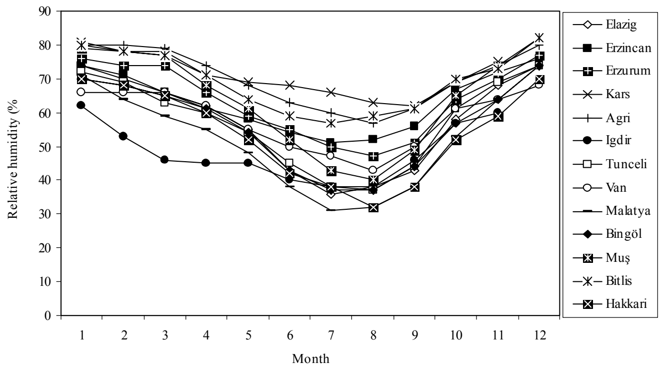

Fig. 8 Monthly average relative humidity values during the years 1994–2003 for the cities.

Table 6. The results of statistical analyses according to the model (RH) for the monthly average relative humidity

Model		Monthly average relative humidity $= a + b\cdot\sin(m) + c\cdot\sin((m/2) + d)$			
City	Cons-tant	Model constants	R	χ^2	RMSE
Elazığ	*a*	58.040	0.99 772	1.099	0.872
	b	-4.347			
	c	18.755			
	d	32.524			
Erzincan	*a*	63.721	0.99 382	1.211	0.915
	b	-1.975			
	c	-12.168			
	d	17.077			
Erzurum	*a*	64.193	0.98 907	3.167	1.481
	b	-2.596			
	c	14.599			
	d	51.322			
Kars	*a*	72.1167	0.95 044	5.308	1.917
	b	-0.5718			
	c	8.7419			
	d	88.968			
Agri	*a*	70.881	0.99 479	0.941	0.807
	b	-1.754			
	c	11.593			
	d	95.207			
Igdir	*a*	50.135	0.97 286	5.918	2.024
	b	-2.866			
	c	12.430			
	d	-17.219			
Tunceli	*a*	57.918	0.99 545	1.961	1.165
	b	-4.836			
	c	17.532			
	d	20.038			
Van	*a*	58.635	0.98 484	2.795	1.391
	b	-3.148			
	c	11.330			
	d	45.070			
Malatya	*a*	53.114	0.99 415	3.163	1.480
	b	-4.430			
	c	19.897			
	d	7.473			
Bingöl	*a*	56.892	0.99 622	1.572	1.043
	b	-4.236			
	c	17.329			
	d	32.515			
Muş	*a*	64.806	0.99 549	2.427	1.296
	b	-4.973			
	c	19.633			
	d	70.174			
Bitlis	*a*	69.792	0.98 791	2.373	1.282
	b	-1.024			
	c	12.222			
	d	95.400			
Hakkari	*a*	54.555	0.99 294	3.185	1.485
	b	-3.332			
	c	18.185			
	d	0.9574			

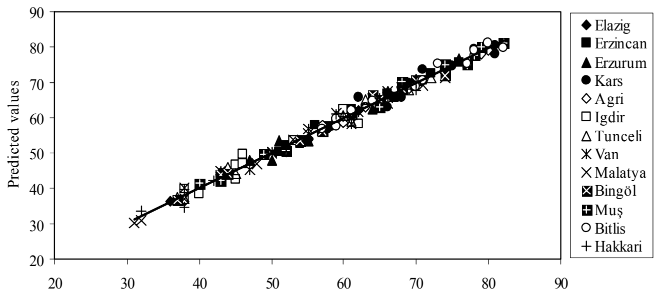

Fig. 9 Observed and predicted values of the monthly average relative humidity.

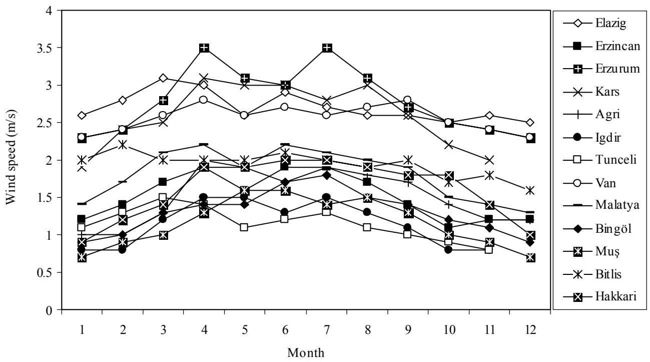

Fig. 10 Monthly average wind speed values during the years 1994–2003 for the cities.

The monthly average relative humidity

Kars city is the most humid area almost throughout the period while Igdir is the least humid area. The monthly average relative humidity showed changing between 63 and 81% for Kars city and 38 and 65% for Igdir city (**Fig. 8**). The overall average humidity ratio was about a57.69% for Elazig, 63.52% for Erzincan, 63.58% for Erzurum, 71.75% for Kars, 70.41% for Agri, 49.58% for Igdir, 57.40% for Tunceli, 58.16% for Van, 52.76% for Malatya, 56.59% for Bingol, 64% for Muş, 69.25% for Bitlis, 53.83% for Hakkari. While relative humidity is at highest values in December and January, at lowest values in July and August.

The simple function of the monthly average relative humidity (RH) fit the relative humidity data very well. The results of statistical analyses undertaken on trigonometric model for the monthly average relative humidity are given in **Table 6**. Generally, R, χ^2 and $RMSE$ values were varied between 0.95 044–0.99 772, 1.099–5.308 and 0.872–1.91, respectively. The function has coefficients of determination of better than 0.95 and the lowest values of χ^2 and $RMSE$ for all cities. Therefore, the trigonometric model (RH) satisfactorily described characteristics of the monthly average relative humidity. Considering trigonometric model (RH), the observed monthly average relative humidity values were compared with calculated ones. **Figure 9** shows the predicted and observed values of the monthly average relative humidity. There is a good agreement between predicted and observed values.

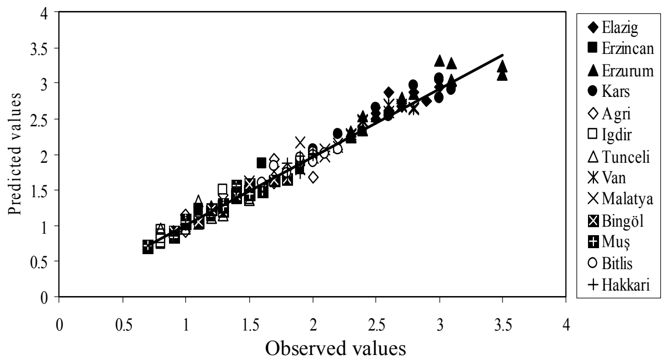

Fig. 11 Observed and predicted values of the monthly average wind speed.

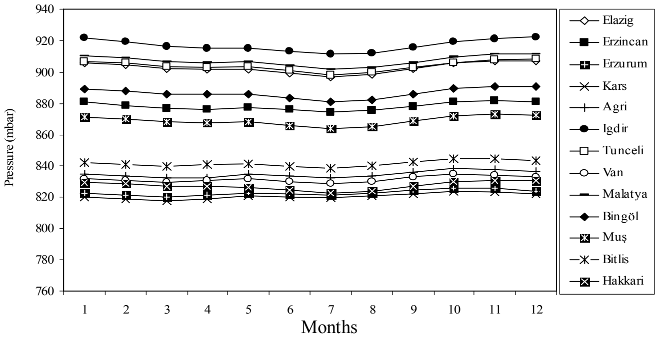

Fig. 12 Monthly average pressure values during the years 1994–2003 for the cities.

The monthly average wind speed

The overall average of wind speed for the same period was obtained to be approximately 2.69 m/s for Elazig, 1.47 m/s for Erzincan, 2.80 m/s for Erzurum, 2.54 m/s for Kars, 1.50 m/s for Agri, 1.11 m/s for Igdir, 1.21 m/s for Tunceli, 2.55 m/s for Van, 1.79 m/s for Malatya, 1.3 m/s for Bingol, 1.15 m/s for Mus, 1.94 m/s for Bitlis, 1.60 m/s for Hakkari. The windiest city is Erzurum. The monthly average wind speed showed changing between 2.3 and 3.5 m/s for Erzurum city.

The simple function of the monthly average wind speed (WS) fit the wind speed data very well. The results of statistical analyses undertaken on polynomial model for the monthly average wind speed are given in **Table 7**. Generally, *R*, χ^2 and RMSE values were varied between 0.82965–0.98047, 0.007–0.049 and 0.067–0.174, respectively. The function has coefficients of determination of better than 0.82 and the lowest values of χ^2 and RMSE for all cities. Therefore, the polynomial model (WS) satisfactorily described characteristics of the monthly average wind speed. Considering polynomial model (WS), the observed monthly average wind speed values were compared with calculated ones. **Figure 11** shows the predicted and observed values of the monthly average wind speed. There is a good agreement between predicted and observed values.

The monthly average pressure

The overall pressure was found to be about 902.74 mbar for Elazig, 878.03 mbar for Erzincan, 822.89 mbar for Erzurum, 820.79 mbar for Kars, 834.63 mbar for Agri, 916.84 mbar for Igdir, 903.79 mbar for Tunceli, 831.53 mbar for Van, 907.19 mbar for Malatya, 886.50 mbar for Bingol, 868.95 mbar for Mus, 841.53 mbar for Bitlis, 827.20 mbar for Hakkari. While pressure values are at highest values in November and December, at lowest values in July. Pressure reaches the highest values in the Igdir. Pressure values are at lowest values in Kars. The monthly average pressure changed between 818 and 823.8 mbar for Kars city and 832.1 and 838.2 mbar for Agri city.

Table 7. The results of statistical analyses according to the model (WS) for the monthly average wind speed.

Model	Monthly average wind speed $= a+b\cdot m+c(m^2)+d(m^3)+e(m^4)$				
City	Constant	Model constants	*R*	χ^2	RMSE
Elazığ	*a*	2.023	0.84 615	0.015	0.097
	b	0.737			
	c	-0.188			
	d	0.0178			
	e	-0.00 057			
Erzincan	*a*	1.086	0.92 905	0.017	0.103
	b	0.0634			
	c	0.0790			
	d	-0.0155			
	e	0.00 071			
Erzurum	*a*	2.031	0.90 236	0.049	0.174
	b	0.131			
	c	0.0969			
	d	-0.018			
	e	0.00 084			
Kars	*a*	1.517	0.96 062	0.021	0.113
	b	0.391			
	c	0.0244			
	d	-0.0111			
	e	0.00 055			
Agri	*a*	0.819	0.92 233	0.027	0.130
	b	0.0071			
	c	0.1132			
	d	-0.0185			
	e	0.000 772			
Igdir	*a*	0.655	0.94 967	0.012	0.088
	b	0.005 955			
	c	0.101 663			
	d	-0.01 795			
	e	0.000 794			
Tunceli	*a*	0.939	0.82 965	0.018	0.104
	b	0.2319			
	c	-0.0277			
	d	-0.00 146			
	e	0.000 189			
Van	*a*	1.970	0.88 004	0.010	0.078
	b	0.3716			
	c	-0.0725			
	d	0.00 665			
	e	-0.00 025			
Malatya	*a*	0.953	0.94 573	0.016	0.100
	b	0.5166			
	c	-0.063			
	d	0.00 166			
	e	0.000 018			
Bingöl	*a*	0.9186	0.96 260	0.009	0.073
	b	-0.112			
	c	0.112			
	d	-0.0158			
	e	0.000 605			
Muş	*a*	0.6712	0.97 545	0.007	0.067
	b	-0.0738			
	c	0.1176			
	d	-0.0175			
	e	0.000 692			
Bitlis	*a*	2.022	0.87 855	0.009	0.074
	b	0.0392			
	c	-0.0117			
	d	0.0012			
	e	-0.00 006			
Hakkari	*a*	0.392 929	0.98 047	0.009	0.072
	b	0.523 326			
	c	-0.05 629			
	d	0.002 995			
	e	-0.00 013			

The simple function of the monthly average (P) fit the pressure data very well. The results of statistical analyses undertaken on polynomial model for the monthly average pressure are given in **Table 7**. Generally, R, χ^2 and RMSE values were varied between 0.83 395–0.96 460, 0.728–2.286 and 0.669–1.186, respectively. The function has coefficients of determination of better than 0.83 and the lowest values of χ^2 and RMSE for all cities. The polynomial model (P) satisfactorily described characteristics of the monthly average pressure. Considering polynomial model (P), the observed monthly average pressure values were compared with calculated ones (**Fig. 13**). As seen from **Fig. 13**, there is a good agreement between predicted and observed values.

The mean rainfall

The overall average pressure is found to be about 32.65 mm for Elazig, 32.15 mm for Erzincan, 32.53 mm for Erzurum, 41.26 mm for Kars, 41.32 mm for Agri, 20.78 mm for Igdir, 71.61 mm for Tunceli, 31.32 mm for Van, 29.94 mm for Malatya, 79.89 mm for Bingol, 65.03 mm for Mus, 93.49 mm for Bitlis, 61.61 mm for Hakkari. While rainfall values are at highest values in April and May, at lowest values in August. Rainfall reaches the highest values in the Bitlis. Rainfall values are at lowest values in Igdir. The monthly average rainfall showed changing between 3.6 and 196.4 mm for Bitlis city and 6.5 and 46.1 mm for Igdir city.

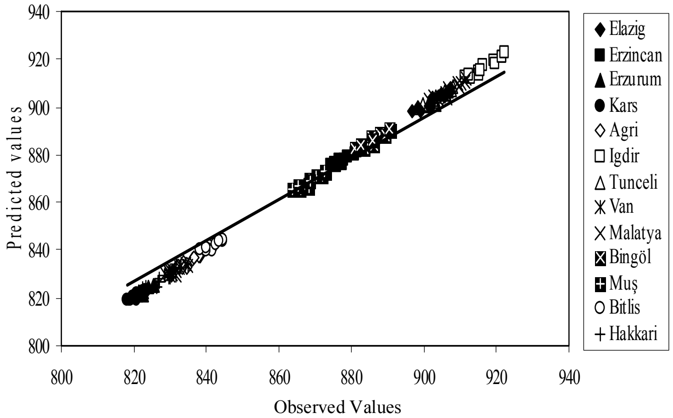

Fig. 13 Observed and predicted values of the monthly average pressure.

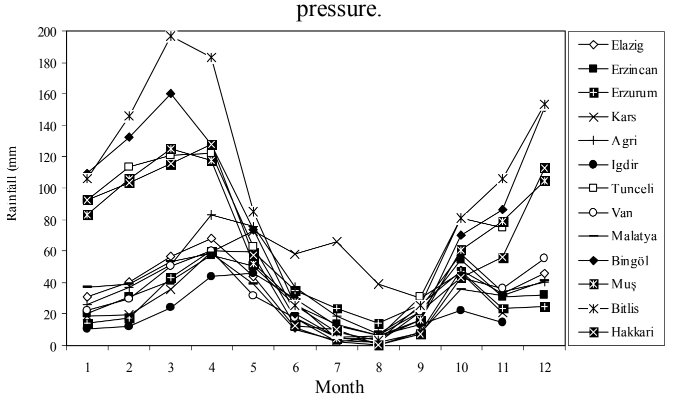

Fig. 14 Monthly average rainfall values during the years 1994–2003 for the cities.

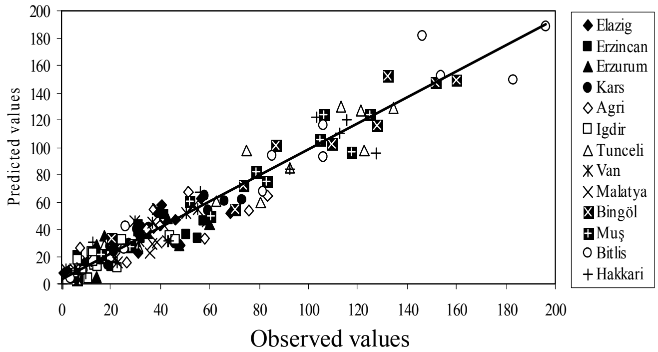

Fig. 15 Observed and predicted values of the monthly average rainfall.

The simple function of the monthly average rainfall (RF) fit the rainfall data very well. The results of statistical analyses undertaken on polynomial model for the monthly average rainfall are given in **Table 9**. Generally, R, χ^2 and RMSE values were varied between 0.70 915–0.98 088, 115.818–2075.940 and 8.220–34.799, respectively. The function has coefficients of determination of better than 0.70 and the lowest values of χ^2 and RMSE for all cities. Hence, the polynomial model (RF) satisfactorily described characteristics of the monthly average rainfall. Considering polynomial model (RF), the observed the monthly average rainfall values were compared with calculated ones (**Fig. 15**). There is a good agreement between predicted and observed values.

The monthly average direct solar radiation

The overall average of solar radiation for the same period is obtained to be approximately 363.06 cal/cm^2 for Elazig, 356.69 cal/cm^2 for Erzincan, 369.72 cal/cm^2 for Erzurum, 338.37 cal/cm^2 for Kars, 314.26 cal/cm^2 for Agri, 344.58 cal/cm^2 for Igdir, 387.25 cal/cm^2 for Tunceli, 449.39 cal/cm^2 for Van, 382.37 cal/cm^2 for Malatya, 373.01 cal/cm^2 for Bingol, 339.51 cal/cm^2 for Mus, 340.99 cal/cm^2 for Bitlis, 378.92 cal/cm^2 for Hakkari. While direct solar radiation values are at highest values in June and July, at lowest values in December. Direct solar radiation reaches the highest values in the Tunceli.

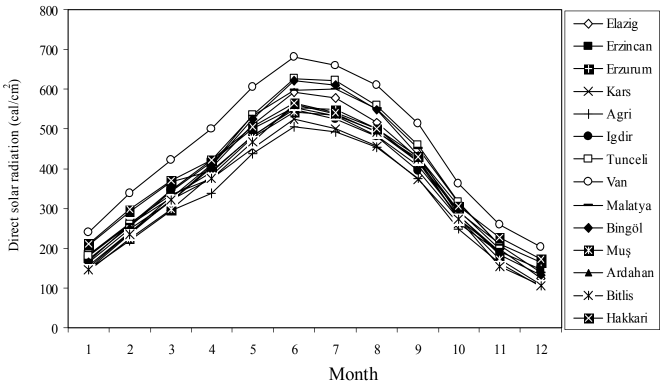

Fig. 16 Monthly average solar radiation values during the years 1994–2003 for the cities.

Table 8. The results of statistical analyses according to the model (P) for the monthly average pressure

Model	Monthly average pressure $= a+b\cdot m+c(m^2)+d(m^3)+e(m^4)$				
City	Cons-tant	Model constants	R	χ^2	RMSE
	a	902.284			
	b	5.0578			
Elazığ	*c*	-2.327	0.94 263	1.868	1.072
	d	0.2966			
	e	-0.0112			
	a	880.768			
	b	0.2636			
Erzincan	*c*	-0.7429	0.90 961	1.518	0.966
	d	0.1207			
	e	-0.00501			
	a	822.793			
	b	-0.1523			
Erzurum	*c*	-0.2463	0.87 859	0.931	0.757
	d	0.05768			
	e	-0.00292			
	a	821.693			
	b	-1.808			
Kars	*c*	0.3053	0.91 362	0.728	0.669
	d	-0.0054			
	e	-0.00058			
	a	833.869			
	b	0.7709			
Agri	*c*	-0.6021	0.88 911	1.324	0.902
	d	0.10181			
	e	-0.00459			
	a	920.707			
	b	1.5712			
Igdir	*c*	-1.4437	0.96 460	1.399	0.928
	d	0.2048			
	e	-0.00785			
	a	903.710			
	b	4.1956			
Tunceli	*c*	-1.9108	0.93 011	1.831	1.061
	d	0.2376			
	e	-0.0087			
	a	829.202			
	b	2.9758			
Van	*c*	-1.2465	0.83 395	1.567	0.982
	d	0.1686			
	e	-0.00691			
	a	907.553			
	b	4.0417			
Malatya	*c*	-1.9701	0.93 946	1.801	1.053
	d	0.2521			
	e	-0.00944			
	a	885.310			
	b	4.8864			
Bingöl	*c*	-2.1285	0.91 095	2.286	1.186
	d	0.2677			
	e	-0.01008			
	a	867.718			
	b	4.8704			
Muş	*c*	-2.1587	0.92 736	1.680	1.017
	d	0.2768			
	e	-0.01065			
	a	839.499			
	b	2.8874			
Bitlis	*c*	-1.2416	0.86 872	1.346	0.910
	d	0.16710			
	e	-0.00676			
	a	825.666			
	b	5.2156			
Hakkari	*c*	-2.1874	0.92 909	1.352	0.912
	d	0.27324			
	e	-0.01035			

Table 9. The results of statistical analyses according to the model (RF) for the monthly average rainfall

Model	Monthly average rainfall $= a+b\cdot m+c(m^2)+d(m^3)+e(m^4)$				
City	Constant	Model constants	R	χ^2	RMSE
	a	-56.982			
	b	107.576			
Elazığ	*c*	-31.259	0.86 088	199.420	10.786
	d	3.221			
	e	-0.1086			
	a	-52.909			
	b	87.434			
Erzincan	*c*	-24.342	0.70 915	2075.940	34.799
	d	2.5168			
	e	-0.0871			
	a	-51.482			
	b	71.919			
Erzurum	*c*	-17.286	0.72 121	205.650	10.953
	d	1.604			
	e	-0.0514			
	a	7.777			
	b	1.091			
Kars	*c*	6.258	0.88 245	125.651	8.561
	d	-1.110			
	e	0.0494			
	a	-61.609			
	b	100.500			
Agri	*c*	-25.801	0.71 498	388.614	15.056
	d	2.451			
	e	-0.0782			
	a	-28.595			
	b	40.091			
Igdir	*c*	-8.296	0.74 827	117.670	8.285
	d	0.6222			
	e	-0.01527			
	a	-32.314			
	b	163.579			
Tunceli	*c*	-51.424	0.95 607	306.989	13.382
	d	5.375			
	e	-0177			
	a	-51.714			
	b	89.996			
Van	*c*	-25.495	0.87 435	128.233	8.649
	d	2.5873			
	e	-00855			
	a	-29.828			
	b	80.942			
Malatya	*c*	-24.104	0.89 658	115.818	8.220
	d	2.479			
	e	-0.0825			
	a	-29.922			
	b	183.345			
Bingöl	*c*	-56.892	0.98 088	195.252.	10.672.
	d	5.789			
	e	-0.184			
	a	-49.587			
	b	172.713			
Muş	*c*	-53.263	0.97 455	153.141	9.452
	d	5.546			
	e	-0.1847			
	a	-120.213			
	b	291.074			
Bitlis	*c*	-86.801	0.96 716	460.725	16.394
	d	8.895			
	e	-0.293			
	a	-10.777			
	b	131.047			
Hakkari	*c*	-39.702	0.95 756	292.439	13.061
	d	3.869			
	e	-0.116			

Table 10. The results of statistical analyses according to the model (SR) for the monthly average solar radiation

Model	Monthly average solar radiation = $a+b\cdot\sin(m)+c\cdot\sin((m/2)+d)$				
City	Constant	Model constants	R	χ^2	RMSE
Elazığ	*a*	352.441	0.99 783	142.643	9.937
	b	15.083			
	c	227.146			
	d	-158.72			
Erzincan	*a*	347.345	0.99 862	71.532	7.037
	b	10.931			
	c	202.003			
	d	142.948			
Erzurum	*a*	361.205	0.99 617	173.440	10.958
	b	26.720			
	c	-186.07			
	d	45.543			
Kars	*a*	330.177	0.99 678	132.002	9.560
	b	18.630			
	c	178.119			
	d	180.663			
Agri	*a*	305.321	0.99 689	149.901	10.187
	b	21.509			
	c	193.157			
	d	-20.477			
Igdir	*a*	334.978	0.99 767	125.225	9.311
	b	11.145			
	c	205.287			
	d	-114.693			
Tunceli	*a*	376.126	0.99 719	207.375	11.982
	b	23.556			
	c	239.240			
	d	61.156			
Van	*a*	438.504	0.99 823	124.832	9.296
	b	20.299			
	c	-234.433			
	d	-11.019			
Malatya	*a*	371.562	0.99 893	73.750	7.145
	b	18.861			
	c	231.646			
	d	36.048			
Bingöl	*a*	361.769	0.99 705	222.535	12.412
	b	24.394			
	c	242.097			
	d	-246.684			
Muş	*a*	329.416	0.99 836	98.421	8.255
	b	17.294			
	c	-216.399			
	d	-42.496			
Bitlis	*a*	330.900	0.99 537	286.837	14.092
	b	26.0458			
	c	-218.294			
	d	-42.469			
Hakkari	*a*	370.263	0.99 658	153.909	10.322
	b	15.914			
	c	-186.987			
	d	51.843			

Direct solar radiation values are at lowest values in Agri. The monthly average direct solar radiation demonstrated changing between 139.78 and 628.3 cal/cm² for Tunceli city, 102.01 and 504.6 cal/cm² for Agri city.

The simple function of the monthly average solar radiation (SR) fit the solar radiation data very well. The results of statistical analyses undertaken on trigonometric model for the monthly average solar radiation are given in **Table 10**. Generally, R, χ^2 and RMSE values were varied between 0.99 537–0.99 893, 71.532–286.837 and 7.037–14.092, respectively. The function has coefficients of determination of better than 0.99 and the lowest values of χ^2 and RMSE for all cities.

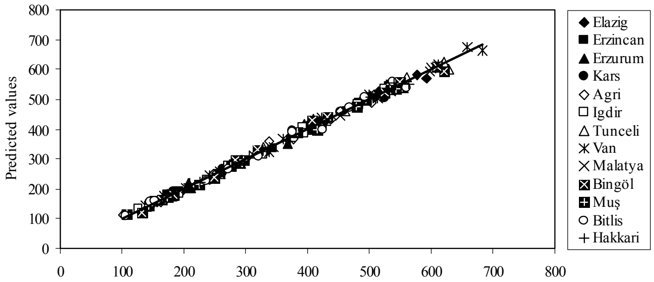

Fig. 17 Observed and predicted values of the monthly average solar radiation.

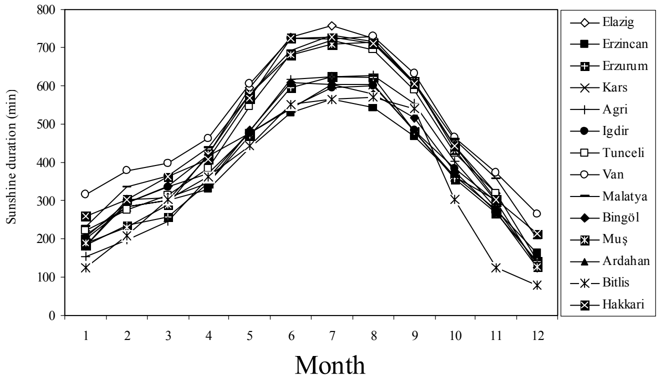

Fig. 18 Monthly average sunshine duration values during the years 1994–2003 for the cities.

Hence, the trigonometric model (SR) satisfactorily described characteristics of the monthly average solar radiation. Considering trigonometric model (SR), the observed monthly average solar radiation values were compared with calculated ones (**Fig. 17**). As seen from **Fig. 17**, there is a good agreement between predicted and observed values.

The mean sunshine duration

The overall average sunshine duration for 10 years is found to be about 464.76 min for Elazig, 369.48 min for Erzincan, 381.33 min for Erzurum, 396.75 min for Kars, 389.83 min for Agri, 393.25 min for Igdir, 441.33 min for Tunceli, 506.08 min for Van, 476 min for Malatya, 391.33 min for Bingol, 439.58 min for Mus, 347.58 min for Bitlis, 468.66 min for Hakkari. While sunshine duration values are at highest values in August and July, at lowest values in December. Sunshine duration reaches the highest values in the Van. Sunshine duration values are at lowest values in Bitlis. The monthly average sunshine duration displayed changing between 266 and 729 min for Van, 79 and 569 min for Bitlis. The simple function of the monthly average sunshine duration (SD) fit the sunshine duration data very well. The results of statistical analyses undertaken on

Table 11. The results of statistical analyses according to the model (SD) for the monthly average sunshine duration

Model	Monthly average sunshine duration = $a + b \cdot \sin(m) + c \cdot \sin(2m) + d \cdot \sin(m/2+e) + f \cdot m$				
City	Cons-tant	Model constants	R	χ^2	RMSE
Elazığ	a	550.849	0.99 606	560.581	17.374
	b	9.476			
	c	-17.66			
	d	309.566			
	e	29.334			
	f	-15.503			
Erzincan	a	421.032	0.99 224	449.272	15.554
	b	17.0438			
	c	-12.181			
	d	194.336			
	e	41.901			
	f	-8.9174			
Erzurum	a	414.286	0.99 382	578.584	17.651
	b	23.909			
	c	-5.732			
	d	242.411			
	e	431.515			
	f	-6.719			
Kars	a	395.491	0.99 126	577.074	17.628
	b	25.163			
	c	4.144			
	d	197.954			
	e	167.760			
	f	-1.168			
Agri	a	467.961	0.99 874	140.660	8.703
	b	-3.520			
	c	-13.659			
	d	280.737			
	e	481.627			
	f	-13.875			
Igdir	a	417.268	0.98 664	927.253	22.345
	b	21.314			
	c	-9.135			
	d	206.320			
	e	180.239			
	f	-5.136			
Tunceli	a	556.415	0.99 521	602.599	18.013
	b	6.835			
	c	-16.133			
	d	299.924			
	e	412.514			
	f	-19.677			
Van	a	580.767	0.99 757	216.658	10.801
	b	15.243			
	c	-25.283			
	d	244.779			
	e	242.953			
	f	-13.192			
Malatya	a	527.667	0.99 520	522.684	16.776
	b	16.933			
	c	-15.242			
	d	266.057			
	e	280.692			
	f	-9.786			
Bingöl	a	493.351	0.98 983	860.435	21.525
	b	3.722			
	c	-27.953			
	d	243.847			
	e	85.825			
	f	-17.382			
Muş	a	551.319	0.99 931	99.569	7.322
	b	-8.0482			
	c	-15.795			
	d	321.562			
	e	211.469			
	f	-19.343			

Table 11. Continuation

City	Cons-tant	Model constants	R	χ^2	RMSE
Bitlis	a	402.781	0.98 818	1278.975	26.243
	b	30.753			
	c	-23.861			
	d	257.439			
	e	16.897			
	f	-10.337			
Hakkari	a	522.847	0.99 625	426.125	15.148
	b	-10.204			
	c	25.971			
	d	-19.386			
	e	269.957			
	f	268.132			

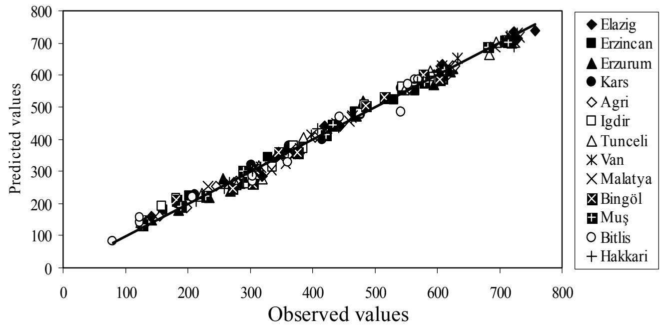

Fig. 19 Observed and predicted values of the monthly average sunshine duration.

trigonometric model for the monthly average sunshine duration are given in **Table 11**. The model was evaluated based on *R*, χ^2 and *RMSE*. Generally, *R*, χ^2 and *RMSE* values were varied between 0.98 664–0.99 931, 99.569–1278.975 and 7.322–26.243 respectively. The function has coefficients of determination of better than 0.98 and the lowest values of χ^2 and *RMSE* for all cities. Hence, the trigonometric model (SD) satisfactorily described characteristics of the monthly average sunshine duration. Considering trigonometric model (SD), the observed the monthly average sunshine duration values were compared with calculated ones. **Figure 19** shows the comparison of the predicted and observed values of the monthly average sunshine duration. There is a good agreement between predicted and observed values.

CONCLUSION

In the study, it was attempted to determine and model how much the climatic elements for the period 1994–2003 of thirteen cities in the east Anatolia region of Turkey. These data can be seen that:

(1) Malatya city is the hottest area whole period, while the Erzurum city is the coldest area. Maximum temperatures are at highest values in Tunceli. Minimum temperatures reach the warmest values in the Malatya. Minimum temperatures reach the

coldest values in the Erzurum. Kars city is the most humid area almost throughout the period while Igdir is the least humid area. Wind speed reaches the highest values in the Erzurum and the lowest values in the Igdir. Pressure reaches the highest values in the Igdir and the lowest values in the Kars. Bitlis city is the most rainfall almost throughout the period while Igdir is the least rainfall area. Direct solar radiation reaches the highest values in the Tunceli and the lowest values in the Agri. Sunshine duration reaches the highest values in the Van and the lowest values in the Bitlis.

(2) Regression models are presented for the weather data at the period 1994–2003 of thirteen cities in the east Anatolia region of Turkey. The best fits were for the monthly average temperature, maximum–minimum temperature, relative humidity, wind speed, solar radiation and sunshine duration. The model for the monthly average pressure and rainfall is also adequate. As seen from **Figs 3, 5, 7, 9, 11, 13, 15, 17, 19**, there are good agreements between predicted and observed values. In other words the new equations are able to predict effectively the monthly average variations of observed values. The three good indicators of solar and wind energy potential, temperature, maximum–minimum temperature, global radiation and sunshine hours have very high averages. These high values are maintained for a considerable part of the year. The functions presented for the parameters should enable the determination of specific parameter values and the prediction of missing values.

(3) The factors thought to be effective on the climatic differences mentioned above may result from the features of the investigated cities. The factors thought to be effective on the differences determined in the present study are briefly canopy and evapotranspiration effects, elevation difference between the areas and surface roughness, radiation and reflection factors, smoke and dust, the duration and color of snow cover on the ground, wind direction and other anthropogenic effects of the investigated city. Depending on the location of the city center, prevalent easterly and northerly winds in this area is effective on temperatures and humidity, which can decrease temperatures and increase humidity. As is known, there is a true relationship between the population and temperature in a city center. This effect may be smaller compared to those aforementioned, because of the relatively low population and the city lacks of any industrial facilities that may influence the temperature in the city.

This study is expected to be useful in analyzing and interpreting the environmental and energy related issues.

REFERENCES

Abdul-Aziz, J., Nagi, A. A. & Zumailan, A.A.R. (1993) Global solar radiation estimation from relative sunshine hours in Yemen. *Renewable Energy* **3**(7), 645–653. doi: 10.1016/0960-1481(93)90071-N.

Al-Garni, A.Z., Şahin, A.Z. & Al-Farayedhi, A. (1999) Modelling of weather characteristics and wind power in the Eastern Part of Saudi Arabia. *Int. J. Energy Res.* **23**(8), 805–812. doi: 10.1002/(SICI)1099-114X(199907).

Akpinar, E.K. & Akpinar, S. (2004) An analysis of the wind Energy Potential of Elazig. Turkey. *Int. J. Green Energy* **1**(2), 193–207. doi: 10.1081/GE-120038752.

Akpinar, E.K., Akpinar, S. & Öztop, H.F. (2006) Effects of meteorological parameters on air pollutant concentrations in Elazig, Turkey. *Int. J. Green Energy* **3**(4), 407–421. doi: 10.1080/01971520600873392.

Apple, L.S.C., Chow, T.T., Square, K.F.F. & Lin, J.Z. (2006) Generation of a typical meteorological year for Hong Kong. *Energy Convers. Manag.* **47**(1), 87–96. doi: 10.1016/j.enconman.2005.02.010.

Bernatzky, A. (1982) The contribution of trees and green spaces to a town climate. *Energy and Buildings* **5**(1), 1–10. doi: 10.1016/0378-7788(82)90022-6.

Bristow, K.L. & Campbell, G.S. (1984) On the relationship between incoming solar radiation and daily maximum and minimum temperature. *Agric. Forest Meteorol.* **31**(2), 159–166. doi: 10.1016/0168-1923(84)90017-0.

Cañada, J., Pinazo, J.M. & Bosca, J.V. (1997) Analysis of weather data measured in Valencia during the years. *Renewable Energy* **11**(2), 211–222. doi: 10.1016/S0960-1481(96)00124-3.

Coppolino, S. (1994) A new correlation between the clearness index and the relative sunshine hours. *Renewable Energy* **4**(4), 417–423. doi: 10.1016/0960-1481(94)90049-3.

Dorvlo, A.S.S. & Ampratwum, D.B. (1999) Technical note modelling of weather data for Oman. *Renewable Energy* **17**(3), 421–428. doi: 10.1016/S0960-1481(98)00121-9.

Hansen, J.W. (1999) Stochastic daily solar irradiance for biological modeling applications. *Agric. Forest Meteorol.* **94**(1), 53–63. doi: 10.1016/S0168-1923(99)00003-9.

Kasten, F. & Czeplak, G. (1980) Solar and terrestrial radiation dependent on the amount and type of cloud. *Solar Energy* **24**(2), 177–189. doi: 10.1016/0038-092X(80)90391-6.

McCaskill, M.R. (1990) Prediction of solar radiation from rainday information using regionally stable coefficients. *Agric. Forest Meteorol.* **51(2)**, 247–255. doi: 10.1016/0168-1923(90)90111-I.

Nowak, D.J., McHale, R.J., Ibarra, M., Crane, D., Stevens, J.C. & Luley, C. (1998) Modeling the effects of urban vegetation on air pollution. *Air pollution modeling and its application, XII.* New York: Plenum Pres, 399–407.

Norris, D.J. (1968) Correlation of solar radiation with clouds. *Solar Energy* **12**(1), 107–112. doi: 10.1016/0038-092X(68)90029-7.

Ododo, J.C., Agbakwuru, J.A. & Ogbu, F.A. (1996) Correlation of solar radiation with cloud cover and relative sunshine duration. *Energy Convers. Manag.* **37**(10), 1555–1559. doi: 10.1016/0196-8904(96)86837-3.

Raja I.A. & Twidell, J.W. (1994) Statistical Analysis of measured Global Insolation data for Pakistan. *Renewable Energy* **4**(3),199–216. doi: 10.1016/0960-1481(94)90005-1.

Roba, S.M. (2003) Urban–suburban/rural differences over Greater Cairo. *Egypt Atmosfera* **16**(3), 157–171.

Sahin, A.D., Dincer, I. & Rosen, M.A. (2006) New spatio-temporal wind exergy maps. *J. Energy Res. Techn.* **128(3),** 194–202. doi: 10.1115/1.2213271.

Sahin, A.D. (2007). A new formulation for solar irradiation and sunshine duration estimation. *Int. J. Energy Res.* **31**(2), 109–118. doi: 10.1002/er.1229.

Sen, Z. (2007) Simple nonlinear solar irradiation estimation model. *Renewable Energy* **32(3),** 342–350. doi: 10.1016/j.renene.2006.02.015.

Tasdemiroglu, E. & Sever, R. (1991) Estimation of total solar radiation from cloudiness in Turkey. *Renewable Energy* **1**(6), 775–778. doi: 10.1016/0960-1481(91)90026-L.

Tatli, H. (2007) Synchronization between the North Sea-Caspian pattern (NCP) and surface air temperatures in NCEP. *Int. J. Climatol.* **27**(9), 1171–1187. doi: 10.1002/joc.1465.

Tatli, H., Dalfes, H.N. & Menteş, S.S. (2005) Surface air temperature variability over turkey and its connection to large-scale upper air circulation via multivariate techniques. *Int. J. Climatol.* **25**(3), 331–350. doi: 10.1002/joc.1133.

Türkes, M. & Erlat, E. (2008) Influence of the Arctic Oscillation on variability of winter mean temperatures in Turkey. . *Theor. Appl. Climatol.* **92**(1), 75–85. doi: 10.1007/s00704-007-0310-8.

Üner, M. & İleri, A. (2000) Typical weather data of main Turkish cities for energy applications. *Int. J. Energy Res.* **24**(8) 727–748. doi: 10.1002/1099-114X(20000625).

Unger, J. (1997) Urban climatology of Szeged (in Hungarian). *Acta Climatologica Univ. Szegediensis, 30B* (*Urban climate special issue*). Szeged, Hungary.

Unkasevic, M., Jovanovic, O. & Popovic, T. (2001) Urban–suburban/rural vapor pressure and relative humidity differences at fixed hours over the area of Belgrade City. *Theor. Appl. Climatol.* **68**(1), 67–73. doi: 10.1007/s007040170054.

Wilmers, F. (1988) Green for melioration of urban climate. *Energy and Building* **11**(1–3), 289–299. doi: 10.1016/0378-7788(88)90045-X.

Yılmaz, S., Toy, S. Irmak, M.A. & Yilmaz, H. (2007) Determination of climatic differences in three different land uses in the city of Erzurum, Turkey. *Build. Environ.* **42**(4), 1604–1612. doi: 10.1016/j.buildenv.2006.01.017.