ELSEVIER

Applied Energy 70 (2001) 135–155

APPLIED ENERGY

www.elsevier.com/locate/apenergy

Bin weather data for Turkey

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Received 16 April 2001; received in revised form 7 May 2001; accepted 9 June 2001

Abstract

One of the well-known and simple steady-state methods used to predict heating and cooling energy consumption of buildings is the bin method that requires reliable and detailed bin data. In this study, the bin data for Turkey are determined by using long-term measured data. The bin data for dry-bulb temperature from −36 °C to 45 °C with 3 °C increments are calculated in six daily 4-h shifts for 78 provinces of Turkey.

Keywords: Energy analysis; Bin data; Turkey

1. Introduction

Total yearly energy consumption is needed to evaluate the operating cost, which is an essential step if one wants to come close to an optimal design, in the sense of minimizing the life cycle cost of a building [1]. There exist a large number of methods for evaluation of heating and cooling energy consumption of buildings. They range from simple steady-state models to comprehensive dynamic simulation procedures.

Today, there is a variety of dynamic simulation programs available (such as DOE-2, BLAST and TRNSYS) in which the influence of many parameters that are mainly function of time are taken into consideration. Although these models have gained widespread acceptance as reliable estimative tools, they have also become very complex and tedious to use [2].

The steady-state models, which are also called single-measure methods, are simple procedures developed for estimation of energy consumption in buildings. The degree-day methods are the most known and the simplest methods among the steady-state models. These type of methods can estimate energy consumption very accurately if the

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0306-2619/01/$ - see front matter
PII: S0306-2619(01)00029-0

Nomenclature

η	Efficiency of HVAC system
K_{tot}	Total heat loss coefficient (W/°C)
N_{bin}	Number of hours (h)
Q_{bin}	Energy consumption (Wh)
T_b	Base temperature (°C)
T_o	Outdoor temperature (°C)

Subscript and superscript

i	Temperature interval (bin)
m	Total number of temperature intervals (bin)
tot	Total

heat loss coefficient of the building, the efficiency of the heating, ventilating, and air-conditioning (HVAC) system, utilization of the building, which affect the internal heat gains, indoor temperature, and the ventilation rate, or the balance-point temperature are sufficiently constant. However, for many applications, at least one of the above parameters varies with time. For instance, the pattern of utilization of the building, especially of commercial buildings, may generally exhibit large variations during a day and during a week. The efficiency of a heat pump system and HVAC equipment may be affected directly or indirectly by outdoor temperature. Examples to the sources for non-steadiness can be increased.

In such cases the bin method can be used. This method is based on the calculation of the energy consumption for different values of the outdoor temperature ($T_{o,i}$) and multiplying it by the corresponding number of hours ($N_{bin,i}$) in the temperature interval (bin) centered on that temperature [1]:

$$Q_{bin,i} = N_{bin,i} \frac{K_{tot}}{\eta} \left(T_b - T_{o,i}\right)^{\pm} \tag{1}$$

where K_{tot} and η are, respectively, total heat loss coefficient of the building, and the efficiency of the HVAC system. The balance point temperature T_b is the value of outdoor temperature below or above which heating or cooling is needed [3,4]. The bin method can be used for predicting both heating and cooling energy requirements. The plus subscript on the parenthesis of Eq. (1) is for heating and indicates that only positive values are to be counted. For cooling, only negative values should be considered.

$Q_{bin,i}$ values are calculated separately using Eq. (1) for each temperature interval (bin) and summed to obtain total energy consumption:

$$Q_{tot} = \sum_{i=1}^{m} Q_{bin,i} \tag{2}$$

where m is the total number of the temperature intervals (bins).

Since the bin method is based on hourly weather data rather than daily averages, it is more accurate than the degree-day method [5]. The bin method can account for the part-load performance of HVAC equipment and has been specially used for analysis of heat pump systems. Additionally, by performing separate calculations for different time periods, variations of indoor loads with time, occupancy patterns and operating schedules of HVAC systems can be considered. The latent loads at each temperature bin can also be calculated, by the use of wet-bulb temperatures [6].

The bin method has several advantages over the degree-day method in that it provides information on concurrent weather conditions. Along with hours of occurrence of dry-bulb temperature, the mean coincident values of wet-bulb temperature, solar radiation, and wind speed can also be provided. This can lead to more precise evaluation of cooling tower performance, passive solar design, peak load conditions, and ventilative and/or evaporative cooling potential [2].

History of the analysis of weather data for design of HVAC systems and energy consumption predictions in Turkey is quite new. This subject has been considered seriously only in recent years and it is not complete yet. A comprehensive analysis of the degree-days data for 78 weather stations located in 78 different provinces of Turkey is presented by the present authors [7]. Although there are some studies on the degree-day and degree-hour data for Turkey [8–10], the bin data studies are very limited. İleri and Üner [11] presented yearly bin data for dry-bulb temperature for 12 weather stations of Turkey obtained from typical meteorological year data generated from 7 years data. They calculated bin data only in two separate time periods (08:00–16:00 and 16:00–08:00).

A complete and detailed bin weather data are not available for Turkey. The need to fill the gap in bin data for Turkey provided stimulus for this study. The bin weather data for 78 provinces of Turkey are presented in this study.

2. Meteorological data

Accuracy and reliability of calculations for building energy consumption depend directly on the weather data used. This necessitates use of a weather database that is based on a long term and recent values. In this study, bin weather data were calculated using hourly dry-bulb temperatures measured during at least 13 years between 1981 and 1998. The raw data were taken from The State Meteorological Affairs General Directorate (DMİ) in diskettes for 78 provinces. Information for the weather stations and the periods of the data considered are given in Table 1.

Based on the database shown in Table 1, bin data for dry-bulb temperature from $-36\,^{\circ}C$ to $45\,^{\circ}C$ with $3\,^{\circ}C$ increments were calculated in six daily 4-h shifts (1–4, 5–8, 9–12, 13–16, 17–20 and 21–24 h) for 78 provinces of Turkey.

The number of the hours (N_{bin}) within each temperature interval (bin) was calculated separately for every month of the year. The calculations were performed separately for every year of the period considered. Averaging over the years considered, the numbers of the hours are obtained for six separate time periods of the day for each month. Using these data, the monthly total and yearly total number of the hours were calculated.

Table 1
Information for the provinces considered in the study

Location	Longitude	Latitude	Elevation (m)	Period	Total years
Adana	35.18	36.59	20	1983–1998	16
Adapazarı	30.25	40.47	30	1982–1998	17
Adıyaman	38.17	37.45	678	1981–1998	18
Afyon	30.32	38.45	1034	1981–1998	18
Ağrı	43.08	39.31	1585	1981–1998	18
Aksaray	34.03	38.23	980	1981–1998	18
Amasya	35.51	40.39	412	1981–1998	18
Ankara	32.53	39.57	894	1983–1995	13
Antakya	36.07	36.15	100	1983–1998	16
Antalya	30.42	36.53	42	1983–1998	16
Ardahan	42.42	41.08	1829	1981–1998	17
Artvin	41.49	41.10	597	1981–1998	18
Aydın	27.50	37.51	57	1983–1998	16
Balıkesir	27.52	39.39	147	1983–1997	15
Bartın	32.21	41.38	30	1981–1998	18
Batman	41.10	37.52	540	1983–1998	15
Bayburt	40.15	40.16	1550	1981–1998	18
Bilecik	29.58	40.09	526	1981–1998	17
Bingöl	40.30	38.52	1177	1981–1998	18
Bitlis	42.06	38.22	1559	1981–1998	18
Bolu	31.36	40.44	742	1981–1998	18
Burdur	30.20	37.40	967	1981–1998	18
Bursa	29.04	40.11	100	1983–1998	16
Çanakkale	26.24	40.08	3	1981–1998	17
Çankırı	33.37	40.36	751	1981–1995	13
Çorum	34.58	40.33	798	1981–1998	18
Denizli	29.05	37.47	428	1983–1998	16
Diyarbakır	40.12	37.55	660	1983–1998	16
Edirne	26.34	41.40	48	1983–1998	16
Elazığ	39.13	38.40	1105	1981–1998	18
Erzincan	39.30	39.44	1215	1981–1998	18
Erzurum	41.16	39.55	1869	1983–1998	14
Eskişehir	30.31	39.46	800	1983–1998	15
Gaziantep	37.22	37.05	855	1983–1998	16
Giresun	38.24	40.55	38	1981–1998	18
Gümüşhane	39.27	40.27	1219	1981–1998	18
Hakkari	43.46	37.34	1720	1981–1998	18
Iğdır	44.02	39.56	858	1981–1998	16
İskenderun	36.07	36.37	3	1981–1998	18
Isparta	30.33	37.45	997	1981–1998	18
İstanbul	29.05	40.58	39	1983–1998	16
İzmir	27.10	38.24	25	1983–1998	16
K.Maraş	36.56	37.36	549	1984–1998	15
Karaman	33.14	37.11	1025	1981–1998	18
Kars	43.05	40.36	1775	1983–1998	15
Kastamonu	33.46	41.22	791	1981–1998	18
Kayseri	35.29	38.43	1068	1983–1998	16
Kilis	37.05	36.44	638	1981–1998	17

(*continued on next page*)

Table 1 (*continued*)

Location	Longitude	Latitude	Elevation (m)	Period	Total years
Kırıkkale	33.30	39.50	725	1981–1995	15
Kırklareli	27.13	41.44	232	1981–1998	18
Kırşehir	34.10	39.08	985	1981–1995	15
Kocaeli	29.54	40.46	76	1981–1998	18
Konya	32.30	37.52	1028	1983–1998	16
Kütahya	29.58	39.24	969	1981–1998	17
Malatya	38.18	38.21	998	1983–1998	16
Manisa	27.26	38.36	71	1983–1998	16
Mardin	40.44	37.18	1080	1983–1998	16
Mersin	34.36	36.49	5	1983–1998	16
Muğla	28.21	37.12	646	1983–1998	16
Muş	41.31	38.44	1283	1981–1998	18
Nevşehir	34.40	38.25	1260	1981–1998	18
Niğde	34.40	37.59	1208	1981–1998	18
Ordu	37.52	40.59	4	1981–1998	18
Rize	40.30	41.02	4	1983–1998	16
Samsun	36.20	41.17	44	1983–1998	16
Siirt	41.56	37.56	875	1981–1998	18
Sinop	35.10	42.02	32	1981–1998	18
Sivas	37.01	39.49	1285	1983–1998	16
Şanlıurfa	38.46	37.08	547	1983–1998	16
Tekirdağ	27.29	40.59	4	1983–1998	16
Tokat	36.54	40.18	608	1981–1998	17
Trabzon	39.43	41.00	30	1983–1998	16
Tunceli	39.32	39.06	979	1981–1998	18
Uşak	29.29	38.40	919	1981–1998	18
Van	43.41	38.28	1725	1983–1998	16
Yalova	29.16	40.39	2	1981–1998	18
Yozgat	34.49	39.50	1298	1983–1998	16
Zonguldak	31.48	41.27	136	1981–1998	18

3. Results and discussion

Although bin data are calculated in this study for each month of the year for 78 provinces, it is not practical to present all of them in this paper due to space limitations. Monthly bin data are given in Table 2 for Adana in 4-h periods, as an example. Also given in this table at the last row of the data group for each month is the monthly total number of hours (N_{bin}'s).

Fig. 1 shows distribution of monthly total N_{bin} values for Adana. The smallest temperature bin observed in Adana is −1.5 °C (−3 °C/0 °C) with a yearly total value of 12 h, whilst the maximum bin observed is 40.5 °C (39 °C/42 °C) with a yearly total value of 5 h. Heating and cooling seasons can be estimated from Fig. 1. Heating requirement is maximum in December and January, during which N_{bin} is maximum ($N_{bin}=227$ h in December and $N_{bin}=226$ h in January) for the temperature bin of 10.5 °C (9 °C/12 °C). Transitions from heating to cooling and cooling to

Table 2
Monthly total N_{bin} values (h/month) for Adana

	Temperature bin (°C)														
Time	−3/0	0/3	3/6	6/9	9/12	12/15	15/18	18/21	21/24	24/27	27/30	30/33	33/36	36/39	39/42
January															
1–4	1	8	29	49	31	6	0	0	0	0	0	0	0	0	0
5–8	2	13	35	44	26	4	0	0	0	0	0	0	0	0	0
9–12	0	1	8	27	46	31	10	1	0	0	0	0	0	0	0
13–16	0	0	1	4	25	41	41	12	0	0	0	0	0	0	0
17–20	0	1	5	24	52	33	9	0	0	0	0	0	0	0	0
21–24	0	4	19	45	46	9	1	0	0	0	0	0	0	0	0
Total	3	27	97	193	226	124	61	13	0	0	0	0	0	0	0
February															
1–4	2	8	22	36	35	8	1	0	0	0	0	0	0	0	0
5–8	4	11	23	39	29	6	0	0	0	0	0	0	0	0	0
9–12	0	2	7	17	34	29	19	4	0	0	0	0	0	0	0
13–16	0	0	2	8	15	24	38	21	4	0	0	0	0	0	0
17–20	0	1	6	15	34	35	17	3	1	0	0	0	0	0	0
21–24	1	5	16	27	45	16	2	0	0	0	0	0	0	0	0
Total	7	27	76	142	192	118	77	28	5	0	0	0	0	0	0
March															
1–4	0	2	10	31	48	26	6	1	0	0	0	0	0	0	0
5–8	1	3	12	31	47	23	5	2	0	0	0	0	0	0	0
9–12	0	0	1	6	20	34	33	22	7	1	0	0	0	0	0
13–16	0	0	0	2	9	18	32	37	18	7	1	0	0	0	0
17–20	0	0	1	6	23	37	35	15	6	1	0	0	0	0	0
21–24	0	1	5	19	43	40	13	3	0	0	0	0	0	0	0
Total	1	6	29	95	190	178	124	80	31	9	1	0	0	0	0
April															
1–4	0	0	1	4	25	45	31	12	2	0	0	0	0	0	0
5–8	0	0	1	3	25	43	33	12	3	0	0	0	0	0	0
9–12	0	0	0	0	2	7	29	38	25	12	5	2	0	0	0
13–16	0	0	0	0	1	5	11	28	33	22	12	6	2	0	0
17–20	0	0	0	0	3	13	34	34	20	10	4	2	0	0	0
21–24	0	0	0	2	11	35	45	20	6	1	0	0	0	0	0
Total	0	0	2	9	67	148	183	144	89	45	21	10	2	0	0
May															
1–4	0	0	0	0	1	19	43	44	15	2	0	0	0	0	0
5–8	0	0	0	0	2	15	34	46	22	4	1	0	0	0	0
9–12	0	0	0	0	0	1	6	17	34	35	18	8	4	1	0
13–16	0	0	0	0	0	1	3	9	18	34	29	16	10	3	1
17–20	0	0	0	0	0	2	9	25	36	28	15	6	2	1	0
21–24	0	0	0	0	0	7	29	46	31	10	1	0	0	0	0
Total	0	0	0	0	3	45	124	187	156	113	64	30	16	5	1

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Table 2 (*continued*)

Time	Temperature bin (°C)														
	−3/0	0/3	3/6	6/9	9/12	12/15	15/18	18/21	21/24	24/27	27/30	30/33	33/36	36/39	39/42
June															
1–4	0	0	0	0	0	0	5	34	67	14	0	0	0	0	0
5–8	0	0	0	0	0	0	3	26	61	28	2	0	0	0	0
9–12	0	0	0	0	0	0	0	0	6	36	52	21	4	1	0
13–16	0	0	0	0	0	0	0	1	2	10	41	49	14	3	0
17–20	0	0	0	0	0	0	0	2	14	45	42	14	2	1	0
21–24	0	0	0	0	0	0	1	13	58	46	2	0	0	0	0
Total	0	0	0	0	0	0	9	76	208	179	139	84	20	5	0
July															
1–4	0	0	0	0	0	0	0	2	28	86	7	1	0	0	0
5–8	0	0	0	0	0	0	0	2	24	78	19	1	0	0	0
9–12	0	0	0	0	0	0	0	0	0	4	48	58	12	2	0
13–16	0	0	0	0	0	0	0	0	0	1	6	65	44	7	1
17–20	0	0	0	0	0	0	0	0	1	11	61	43	7	1	0
21–24	0	0	0	0	0	0	0	1	5	80	36	1	1	0	0
Total	0	0	0	0	0	0	0	5	58	260	177	169	64	10	1
August															
1–4	0	0	0	0	0	0	0	1	21	86	16	0	0	0	0
5–8	0	0	0	0	0	0	0	2	24	76	21	1	0	0	0
9–12	0	0	0	0	0	0	0	0	0	2	40	62	18	2	0
13–16	0	0	0	0	0	0	0	0	0	0	3	47	63	9	2
17–20	0	0	0	0	0	0	0	0	0	11	58	44	9	2	0
21–24	0	0	0	0	0	0	0	0	4	63	56	1	0	0	0
Total	0	0	0	0	0	0	0	3	49	238	194	155	90	13	2
September															
1–4	0	0	0	0	0	0	4	21	60	34	1	0	0	0	0
5–8	0	0	0	0	0	1	5	23	58	30	3	0	0	0	0
9–12	0	0	0	0	0	0	0	0	4	20	48	39	8	1	0
13–16	0	0	0	0	0	0	0	1	1	2	15	59	32	9	1
17–20	0	0	0	0	0	0	0	2	5	43	46	19	4	1	0
21–24	0	0	0	0	0	0	2	8	37	65	8	0	0	0	0
Total	0	0	0	0	0	1	11	55	165	194	121	117	44	11	1
October															
1–4	0	0	0	0	2	16	43	41	21	1	0	0	0	0	0
5–8	0	0	0	0	4	20	43	40	15	2	0	0	0	0	0
9–12	0	0	0	0	0	1	6	20	28	31	23	10	4	1	0
13–16	0	0	0	0	0	0	2	7	14	25	33	26	12	5	0
17–20	0	0	0	0	0	2	11	24	37	32	13	4	1	0	0
21–24	0	0	0	0	1	8	31	42	34	8	0	0	0	0	0
Total	0	0	0	0	7	47	136	174	149	99	69	40	17	6	0

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Table 2 (*continued*)

Time	Temperature bin (°C)														
	−3/0	0/3	3/6	6/9	9/12	12/15	15/18	18/21	21/24	24/27	27/30	30/33	33/36	36/39	39/42
November															
1–4	0	1	4	9	31	46	24	4	1	0	0	0	0	0	0
5–8	0	1	5	12	35	42	22	3	0	0	0	0	0	0	0
9–12	0	0	0	3	10	22	35	27	16	5	2	0	0	0	0
13–16	0	0	0	0	3	12	20	29	29	20	5	2	0	0	0
17–20	0	0	1	3	11	27	41	26	9	2	0	0	0	0	0
21–24	0	0	2	7	22	46	35	7	1	0	0	0	0	0	0
Total	0	2	12	34	112	195	177	96	56	27	7	2	0	0	0
December															
1–4	0	3	18	42	42	17	2	0	0	0	0	0	0	0	0
5–8	1	5	24	43	35	14	2	0	0	0	0	0	0	0	0
9–12	0	0	3	19	37	39	19	6	1	0	0	0	0	0	0
13–16	0	0	0	4	20	32	41	22	5	0	0	0	0	0	0
17–20	0	0	3	19	44	40	16	2	0	0	0	0	0	0	0
21–24	0	1	10	35	49	25	4	0	0	0	0	0	0	0	0
Total	1	9	58	162	227	167	84	30	6	0	0	0	0	0	0

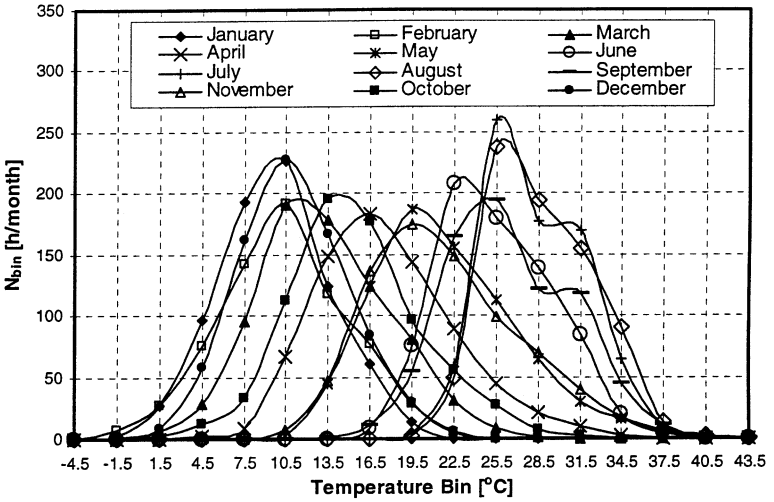

Fig. 1. Monthly total N_{bin} values for Adana.

heating occur in the months April–May and October–November, respectively. The most repeated temperature bin in cooling season is 25.5 °C (24 °C/27 °C) with $N_{bin} = 260$ h in July and $N_{bin} = 238$ h in August.

In Table 3, yearly total N_{bin} values for six separate time periods of the day are presented. Only 7 main provinces of Turkey that can be accepted the provinces representing the climatic conditions of their regions are considered in the table due to space limitations.

Table 3
Yearly total N_{bin} values (h/year) for six separate time periods of the day for representative provinces of Turkey

	Temperature bin (°C)																										
Time	−36/ −33	−33/ −30	−30/ −27	−27/ −24	−24/ −21	−21/ −18	−18/ −15	−15/ −12	−12/ −9	−9/ −6	−6/ −3	−3/ 0	0/ 3	3/ 6	6/ 9	9/ 12	12/ 15	15/ 18	18/ 21	21/ 24	24/ 27	27/ 30	30/ 33	33/ 36	36/ 39	39/ 42	42/ 45
Adana																											
1–4	0	0	0	0	0	0	0	0	0	0	0	3	22	84	171	215	183	159	160	215	223	24	1	0	0	0	0
5–8	0	0	0	0	0	0	0	0	0	0	0	8	33	100	172	203	168	147	156	207	218	46	2	0	0	0	0
9–12	0	0	0	0	0	0	0	0	0	0	0	0	3	19	72	149	164	157	135	121	146	236	200	50	8	0	0
13–16	0	0	0	0	0	0	0	0	0	0	0	0	0	3	18	73	133	188	167	124	121	145	270	177	36	5	0
17–20	0	0	0	0	0	0	0	0	0	0	0	0	2	16	67	167	189	172	133	129	183	239	132	25	6	0	0
21–24	0	0	0	0	0	0	0	0	0	0	0	1	11	52	135	217	186	163	140	176	273	103	2	1	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	12	71	274	635	1024	1023	986	891	972	1164	793	607	253	50	5	0
Ankara																											
1–4	0	0	0	0	0	0	0	4	15	37	73	118	164	172	171	173	191	189	120	30	3	0	0	0	0	0	0
5–8	0	0	0	0	0	0	2	8	21	40	77	124	170	176	158	165	177	177	120	40	5	0	0	0	0	0	0
9–12	0	0	0	0	0	0	0	1	5	19	45	87	124	138	127	117	113	124	159	168	139	70	20	4	0	0	0
13–16	0	0	0	0	0	0	0	0	1	3	23	65	95	117	128	120	104	117	123	138	156	153	87	27	3	0	0
17–20	0	0	0	0	0	0	0	0	2	13	44	77	124	127	133	126	123	127	135	141	136	100	42	10	0	0	0
21–24	0	0	0	0	0	0	0	1	8	28	56	104	146	148	159	150	158	165	166	117	48	6	0	0	0	0	0
Total	0	0	0	0	0	0	2	14	52	140	318	575	823	878	876	851	866	899	823	634	487	329	149	41	3	0	0
Diyarbakır																											
1–4	0	0	0	0	0	1	0	2	5	20	54	101	150	161	163	147	130	119	132	139	99	34	3	0	0	0	0
5–8	0	0	0	0	0	0	3	3	8	21	61	102	153	150	146	136	116	118	124	122	100	66	29	2	0	0	0
9–12	0	0	0	0	0	0	1	0	3	6	10	33	88	128	132	121	106	100	92	90	104	116	142	126	55	7	0
13–16	0	0	0	0	0	0	0	0	1	3	6	14	48	82	130	135	112	104	97	82	81	108	103	140	153	57	4
17–20	0	0	0	0	0	0	0	1	4	5	12	44	96	124	138	122	113	104	92	89	92	105	117	112	74	15	1
21–24	0	0	0	0	0	1	0	3	4	9	34	85	131	142	155	136	124	105	115	122	131	111	45	7	0	0	0
Total	0	0	0	0	0	2	4	9	25	64	177	379	666	787	864	797	701	650	652	644	607	540	439	387	282	79	5
Erzurum																											
1–4	2	4	9	14	26	28	36	50	56	88	117	146	175	171	185	162	114	61	14	2	0	0	0	0	0	0	0
5–8	1	5	9	19	26	28	38	50	64	89	115	139	163	162	155	152	122	83	36	4	0	0	0	0	0	0	0
9–12	0	1	2	6	11	17	28	39	55	71	82	99	120	101	112	105	115	129	147	130	68	20	2	0	0	0	0

(*continued on next page*)

Table 3 (*continued*)

	Temperature bin (°C)																										
Time	−36/ −33	−33/ −30	−30/ −27	−27/ −24	−24/ −21	−21/ −18	−18/ −15	−15/ −12	−12/ −9	−9/ −6	−6/ −3	−3/ 0	0/ 3	3/ 6	6/ 9	9/ 12	12/ 15	15/ 18	18/ 21	21/ 24	24/ 27	27/ 30	30/ 33	33/ 36	36/ 39	39/ 42	42/ 45
13–16	0	0	0	0	2	5	12	26	43	67	93	100	119	96	95	106	95	105	118	126	135	90	25	2	0	0	0
17–20	0	0	1	3	10	19	27	38	54	73	92	106	128	102	119	110	117	123	117	101	74	38	8	0	0	0	0
21–24	0	3	5	11	23	27	35	43	60	73	102	122	144	140	145	154	149	129	71	22	2	0	0	0	0	0	0
Total	3	13	26	53	98	124	176	246	332	461	601	712	849	772	811	789	712	630	503	385	279	148	35	2	0	0	0
İstanbul																											
1–4	0	0	0	0	0	0	0	0	0	0	3	22	88	186	205	203	192	200	223	127	11	0	0	0	0	0	0
5–8	0	0	0	0	0	0	0	0	0	0	3	22	95	179	198	198	180	171	205	162	45	2	0	0	0	0	0
9–12	0	0	0	0	0	0	0	0	0	0	2	11	48	120	189	165	154	147	155	175	195	87	12	0	0	0	0
13–16	0	0	0	0	0	0	0	0	0	0	1	10	38	102	170	162	150	144	149	157	185	153	36	3	0	0	0
17–20	0	0	0	0	0	0	0	0	0	0	3	13	52	149	188	171	164	149	160	198	156	49	7	1	0	0	0
21–24	0	0	0	0	0	0	0	0	0	0	3	17	68	177	194	191	185	172	213	201	37	2	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	15	95	389	913	1144	1090	1025	983	1105	1020	629	293	55	4	0	0	0
İzmir																											
1–4	0	0	0	0	0	0	0	0	0	0	0	8	46	113	157	204	197	177	181	211	142	22	2	0	0	0	0
5–8	0	0	0	0	0	0	0	0	0	0	0	11	55	121	159	192	191	168	170	212	146	32	3	0	0	0	0
9–12	0	0	0	0	0	0	0	0	0	0	0	1	14	49	113	160	180	153	136	132	176	199	115	29	3	0	0
13–16	0	0	0	0	0	0	0	0	0	0	0	0	5	24	63	138	180	165	137	128	142	182	188	88	17	3	0
17–20	0	0	0	0	0	0	0	0	0	0	0	1	13	49	111	171	191	162	142	140	172	176	104	25	3	0	0
21–24	0	0	0	0	0	0	0	0	0	0	0	4	29	84	146	191	203	165	148	178	194	102	14	2	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	25	162	440	749	1056	1142	990	914	1001	972	713	426	144	23	3	0
Samsun																											
1–4	0	0	0	0	0	0	0	0	0	0	4	18	83	174	209	189	205	230	227	108	12	1	0	0	0	0	0
5–8	0	0	0	0	0	0	0	0	0	0	3	18	82	172	198	176	194	195	212	156	51	3	0	0	0	0	0
9–12	0	0	0	0	0	0	0	0	0	0	0	6	37	106	179	174	161	171	176	199	199	50	2	0	0	0	0
13–16	0	0	0	0	0	0	0	0	0	0	0	2	28	92	173	189	157	173	175	190	216	63	2	0	0	0	0
17–20	0	0	0	0	0	0	0	0	0	0	1	9	51	129	208	188	176	167	177	199	142	13	0	0	0	0	0
21–24	0	0	0	0	0	0	0	0	0	0	1	15	69	163	210	188	194	198	220	169	32	1	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	9	68	350	836	1177	1104	1087	1134	1187	1021	652	131	4	0	0	0	0

Table 4
Yearly total N_{bin} values (h/year) for 78 provinces of Turkey

Province	Temperature bin °C																										
	−36/−33	−33/−30	−30/−27	−27/−24	−24/−21	−21/−18	−18/−15	−15/−12	−12/−9	−9/−6	−6/−3	−3/0	0/3	3/6	6/9	9/12	12/15	15/18	18/21	21/24	24/27	27/30	30/33	33/36	36/39	39/42	42/45
Adana	0	0	0	0	0	0	0	0	0	0	0	12	71	274	635	1024	1023	986	891	972	1164	793	607	253	50	5	0
Adapazarı	0	0	0	0	0	0	0	0	0	2	22	152	545	886	1053	977	1035	1090	1089	864	578	332	109	24	2	0	0
Adıyaman	0	0	0	0	0	0	0	0	0	6	40	151	464	811	971	887	737	687	689	708	726	641	521	391	256	69	5
Afyon	0	0	0	0	0	0	2	13	63	149	332	598	797	917	947	916	924	893	761	583	432	285	129	19	0	0	0
Ağrı	6	25	42	78	105	142	170	213	290	373	572	678	785	671	695	774	728	663	551	448	360	258	111	21	0	0	0
Aksaray	0	0	0	0	0	3	9	29	73	159	283	511	753	793	892	883	881	896	812	652	519	366	193	50	3	0	0
Amasya	0	0	0	0	0	0	2	4	8	36	147	428	751	874	887	888	903	987	899	727	560	382	196	64	15	2	0
Ankara	0	0	0	0	0	0	2	14	52	140	318	575	823	878	876	851	866	899	823	634	487	329	149	41	3	0	0
Antakya	0	0	0	0	0	0	0	0	0	0	2	35	160	362	736	1055	992	918	802	942	1412	869	374	71	25	5	0
Antalya	0	0	0	0	0	0	0	0	0	0	0	6	103	336	755	1080	1113	1138	970	955	884	733	406	188	73	18	2
Ardahan	0	3	22	50	85	170	234	333	435	530	623	724	757	793	902	923	760	590	402	257	129	35	3	0	0	0	0
Artvin	0	0	0	0	0	0	0	0	2	30	159	477	846	915	892	929	1037	1231	1165	656	287	94	32	7	1	0	0
Aydın	0	0	0	0	0	0	0	0	0	0	2	59	245	478	810	1066	1082	995	955	916	704	544	461	309	117	16	1
Balıkesir	0	0	0	0	0	0	0	0	1	12	68	251	572	825	1013	972	932	909	959	867	623	448	222	69	15	2	0
Bartın	0	0	0	0	0	0	0	0	3	15	74	336	725	969	1112	1034	1063	1050	902	669	509	229	59	11	0	0	0
Batman	0	0	0	0	0	0	0	5	20	34	96	273	540	755	871	847	756	705	687	697	645	542	450	368	306	149	14
Bayburt	0	0	0	1	18	45	102	186	300	433	577	728	843	805	887	978	881	694	523	362	240	122	32	3	0	0	0
Bilecik	0	0	0	0	0	0	0	0	3	26	174	491	811	904	923	936	975	1088	962	664	436	253	92	20	2	0	0
Bingöl	0	0	0	0	2	9	21	48	98	198	368	639	917	768	722	704	682	696	715	661	522	386	332	207	64	1	0
Bitlis	0	0	0	0	0	5	13	42	114	252	474	858	1085	788	734	795	770	689	645	531	422	335	172	35	1	0	0
Bolu	0	0	0	0	0	0	3	20	45	105	275	667	925	901	985	1061	1090	946	714	473	327	163	51	8	1	0	0
Burdur	0	0	0	0	0	0	0	0	4	52	176	406	689	949	1077	935	841	867	834	698	535	390	240	65	2	0	0
Bursa	0	0	0	0	0	0	0	0	2	5	36	237	568	810	1028	981	942	985	1011	829	618	428	224	49	7	0	0
Çanakkale	0	0	0	0	0	0	0	0	0	1	27	152	405	738	981	1048	1126	1017	991	977	689	416	168	22	2	0	0
Çankırı	0	0	0	0	0	0	8	22	60	167	358	659	943	874	826	831	869	867	749	581	435	284	165	53	9	0	0
Çorum	0	0	0	0	0	4	8	16	55	153	348	664	950	899	918	948	943	862	704	535	392	233	96	29	3	0	0
Denizli	0	0	0	0	0	0	0	0	0	3	31	171	418	684	930	1023	923	848	876	896	750	564	386	199	55	3	0
Diyarbakır	0	0	0	0	0	2	4	9	25	64	177	379	666	787	864	797	701	650	652	644	607	540	439	387	282	79	5
Edirne	0	0	0	0	0	0	0	2	13	55	166	414	749	880	871	864	886	961	915	694	537	406	253	83	9	2	0
Elazığ	0	0	0	0	0	0	3	16	53	136	305	573	836	837	787	750	692	705	730	703	601	447	351	191	43	1	0

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Table 4 (*continued*)

Province	Temperature bin (°C)																										
	−36/ −33	−33/ −30	−30/ −27	−27/ −24	−24/ −21	−21/ −18	−18/ −15	−15/ −12	−12/ −9	−9/ −6	−6/ −3	−3/ 0	0/ 3	3/ 6	6/ 9	9/ 12	12/ 15	15/ 18	18/ 21	21/ 24	24/ 27	27/ 30	30/ 33	33/ 36	36/ 39	39/ 42	42/ 45
Erzincan	0	0	0	0	2	12	29	61	131	253	425	639	781	787	812	820	795	812	733	600	471	330	202	59	6	0	0
Erzurum	3	13	26	53	98	124	176	246	332	461	601	712	849	772	811	789	712	630	503	385	279	148	35	2	0	0	0
Eskişehir	0	0	0	0	0	0	2	12	52	168	365	708	870	887	904	876	920	886	747	546	421	252	118	24	2	0	0
Gaziantep	0	0	0	0	0	0	0	0	2	20	84	294	638	920	958	857	738	705	739	794	689	504	425	293	95	5	0
Giresun	0	0	0	0	0	0	0	0	0	0	0	42	290	785	1252	1114	1085	1123	1219	1177	570	101	2	0	0	0	0
Gümüşhane	0	0	0	0	0	5	20	47	113	261	475	702	859	846	890	946	995	940	662	447	298	151	76	22	4	1	0
Hakkari	0	0	0	0	0	6	29	88	203	359	599	794	831	659	616	661	630	704	769	697	543	364	178	30	0	0	0
Iğdır	0	0	0	0	0	4	22	48	104	207	440	723	691	649	661	724	740	787	790	708	557	419	324	144	18	0	0
İskenderun	0	0	0	0	0	0	0	0	0	0	0	0	8	78	311	809	1232	1258	1023	1017	1477	1317	217	13	0	0	0
Isparta	0	0	0	0	0	0	0	2	20	86	240	528	802	939	1078	975	844	833	743	612	488	351	184	35	0	0	0
İstanbul	0	0	0	0	0	0	0	0	0	0	15	95	389	913	1144	1090	1025	983	1105	1020	629	293	55	4	0	0	0
İzmir	0	0	0	0	0	0	0	0	0	0	0	25	162	440	749	1056	1142	990	914	1001	972	713	426	144	23	3	0
K.Maraş	0	0	0	0	0	0	0	0	0	3	30	155	420	775	977	925	788	708	723	883	892	634	460	264	105	17	1
Karabük	0	0	0	0	0	0	0	0	0	10	109	381	750	948	965	934	1054	1085	930	651	463	302	149	23	6	0	0
Karaman	0	0	0	0	4	7	17	36	70	162	336	520	654	811	914	907	874	881	786	615	514	373	216	58	5	0	0
Kars	0	0	7	30	62	119	202	285	411	504	596	691	775	746	839	900	824	651	473	323	210	98	14	0	0	0	0
Kastamonu	0	0	0	0	0	0	2	17	55	133	378	802	1034	940	903	965	996	866	642	456	316	176	63	16	0	0	0
Kayseri	0	0	0	1	7	16	28	61	121	237	416	680	804	804	864	907	886	780	656	528	426	312	167	55	4	0	0
Kilis	0	0	0	0	0	0	0	0	0	0	12	80	298	713	1059	976	794	733	854	984	774	568	461	313	125	16	0
Kırıkkale	0	0	0	0	0	0	5	12	33	118	278	561	833	885	842	823	826	890	826	683	528	369	186	56	6	0	0
Kırklareli	0	0	0	0	0	0	0	1	9	55	140	359	770	883	905	964	938	963	957	670	516	374	199	47	9	1	0
Kırşehir	0	0	0	0	0	3	13	39	83	182	347	579	824	825	847	872	861	903	815	644	482	302	118	21	0	0	0
Kocaeli	0	0	0	0	0	0	0	0	0	1	14	115	502	852	1025	978	994	1097	1153	941	592	351	123	21	1	0	0
Konya	0	0	0	0	2	3	9	33	76	169	373	643	796	847	843	808	808	835	799	652	516	344	168	35	1	0	0
Kütahya	0	0	0	0	0	0	2	13	45	144	343	652	822	937	969	968	976	926	724	523	383	224	94	15	0	0	0
Malatya	0	0	0	0	0	0	0	4	32	103	253	540	795	833	792	728	693	715	761	763	651	492	364	188	50	3	0
Manisa	0	0	0	0	0	0	0	0	0	0	13	137	363	668	932	973	899	858	830	883	814	606	427	255	88	13	1
Mardin	0	0	0	0	0	0	0	0	1	19	99	297	613	881	870	798	664	620	631	715	832	763	566	305	83	3	0
Mersin	0	0	0	0	0	0	0	0	0	0	0	2	42	170	480	943	1108	1148	977	1034	1304	1301	243	8	0	0	0
Muğla	0	0	0	0	0	0	0	0	0	4	47	220	487	781	1153	1113	868	805	802	793	660	478	347	168	33	1	0
Muş	0	1	6	26	50	82	116	167	233	294	485	683	826	585	631	693	709	695	687	583	462	371	267	99	9	0	0

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Table 4 (*continued*)

Province	Temperature bin (°C)																										
	−36/−33	−33/−30	−30/−27	−27/−24	−24/−21	−21/−18	−18/−15	−15/−12	−12/−9	−9/−6	−6/−3	−3/0	0/3	3/6	6/9	9/12	12/15	15/18	18/21	21/24	24/27	27/30	30/33	33/36	36/39	39/42	42/45
Nevşehir	0	0	0	0	0	1	11	35	95	224	372	545	807	959	937	954	946	866	727	575	405	218	74	9	0	0	0
Niğde	0	0	0	0	1	8	20	42	97	198	341	586	776	814	879	912	919	907	765	605	478	291	109	12	0	0	0
Ordu	0	0	0	0	0	0	0	0	0	0	3	63	358	811	1221	1154	1089	1099	1174	982	592	207	7	0	0	0	0
Rize	0	0	0	0	0	0	0	0	0	0	3	52	392	820	1178	1155	1067	1114	1165	1081	615	113	5	0	0	0	0
Samsun	0	0	0	0	0	0	0	0	0	0	9	68	350	836	1177	1104	1087	1134	1187	1021	652	131	4	0	0	0	0
Siirt	0	0	0	0	0	0	0	1	10	30	79	281	670	869	890	782	685	644	645	705	740	638	502	374	190	25	0
Sinop	0	0	0	0	0	0	0	0	0	0	4	48	287	845	1357	1153	1074	1080	1229	1097	504	81	1	0	0	0	0
Sivas	0	0	0	1	9	22	54	98	178	292	460	658	865	844	859	934	947	808	614	466	353	195	81	21	1	0	0
Şanlıurfa	0	0	0	0	0	0	0	0	0	2	23	99	323	687	951	902	749	657	662	712	756	738	616	449	320	109	5
Tekirdağ	0	0	0	0	0	0	0	0	1	14	60	183	498	893	1074	1084	969	1002	1084	968	688	222	19	1	0	0	0
Tokat	0	0	0	0	0	2	3	7	21	71	209	476	767	807	885	1003	1019	1028	904	650	460	286	123	34	5	0	0
Trabzon	0	0	0	0	0	0	0	0	0	0	6	54	286	788	1205	1095	1044	1141	1233	1153	638	106	10	1	0	0	0
Tunceli	0	0	0	0	2	6	21	42	85	175	300	534	911	791	743	710	694	691	706	679	588	455	347	220	56	4	0
Uşak	0	0	0	0	0	0	0	0	7	50	186	423	748	981	1065	940	873	876	814	668	514	373	195	45	2	0	0
Van	0	0	0	0	0	4	22	70	149	287	470	748	941	827	781	803	785	802	717	588	495	228	39	4	0	0	0
Yalova	0	0	0	0	0	0	0	0	0	0	8	88	398	836	1088	1091	1042	1095	1125	972	652	312	49	4	0	0	0
Yozgat	0	0	0	0	0	3	17	52	122	272	467	680	940	930	894	928	984	838	658	484	308	138	43	2	0	0	0
Zonguldak	0	0	0	0	0	0	0	0	0	0	12	122	505	1018	1024	989	1120	1228	1339	1018	324	55	6	0	0	0	0

Summing up the N_{bin} values for six separate time periods of the day produces total number of hours within each temperature bin in a year. The results are given in Table 4 for 78 provinces of Turkey. Analysis of the table reveals that Turkey has a very non-uniform climate. The temperature bins observed vary between −34.5 °C (−36 °C/−33 °C) and 43.5 °C (42 °C/45 °C).

Fig. 2 shows average frequency distribution of temperature bins. The frequency values were obtained by averaging N_{bin} values for all the weather stations considered in this study for each temperature bin separately. As can be seen from the figure, frequency of very low and very high temperature bins are quite small in Turkey. The most repeated bins are between 4 °C and 22 °C (frequency is higher than 8%). Frequency exhibits a maximum at temperature bin of 10.5 °C (9 °C/12 °C). At the maximum point, frequency is 10.6%, corresponding an average total number of hours of 928. Increase of frequency with temperature bin at low temperature bins is slower than the decrease of frequency at high temperature bins.

The combined influence of latitude and longitude on bin data for Turkey is shown in the form of three-dimensional graphs in Fig. 3 for some selected temperature bins. N_{bin} is usually zero at low temperature bins (Fig. 3a). However, it has small values in eastern and especially in northeastern Turkey. This means that winter is quite severe in the cities located in these regions. At relatively higher temperature bins (Fig. 3b and c), N_{bin} starts to increase in inner and eastern Turkey. The most repeated bins are moderate ones (Fig. 3d–f) and for these temperature bins, N_{bin} is high and roughly uniform all over Turkey, although there are some non-uniformities. With the increase of temperature bin, N_{bin} starts to decrease (Fig. 3g), although N_{bin} is still high in southern and southeastern Turkey. At high temperature bins (Fig. 3h), N_{bin} is usually zero except a few provinces located in southeastern Turkey. Summer is quite severe in these cities and cooling is a necessity.

The landscape of Turkey, which contains large plains, high plateaus, high mountains and mountain chains, is quite non-uniform. Elevation of the cities varies between 0 and 1869 m. A correlation between N_{bin} and elevation is evident from

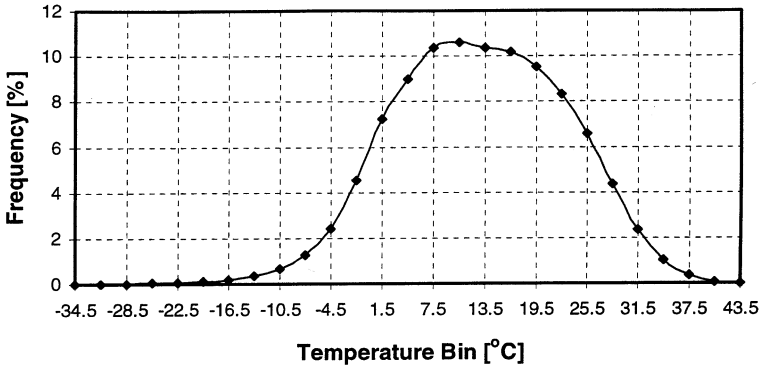

Fig. 2. Average frequency distribution of N_{bin} values for Turkey.

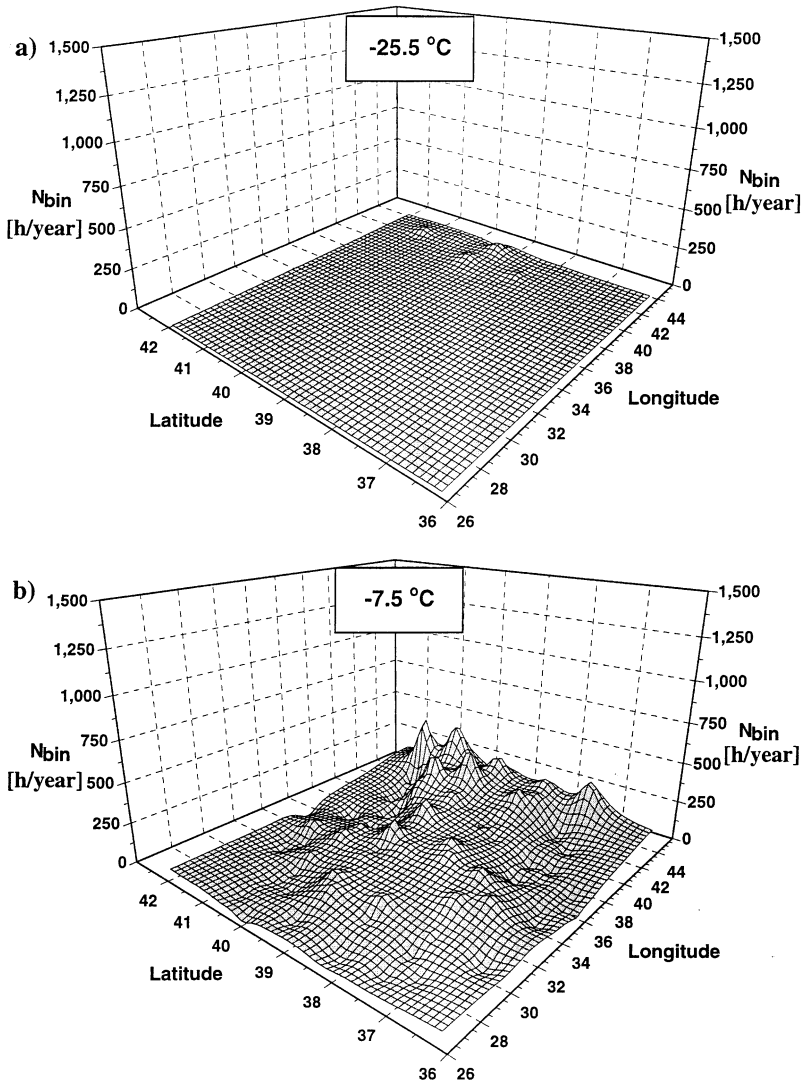

Fig. 3. Variation of yearly total N_{bin} with latitude and longitude for various temperature bins (temperature bins are (a) −25.5 °C; (b) −7.5 °C; (c) −1.5 °C; (d) 4.5 °C; (e) 13.5 °C, (f) 19.5 °C; (g) 28.5 °C; (h) 40.5 °C) (*continued on next page*).

Fig. 4a at low temperature bins (−31.5 °C/−1.5 °C). The value of N_{bin} increases with elevation, although the data points scatter. The picture is not so clear in the case of moderate (4.5 °C/19.5 °C) and high (25.5 °C/40.5 °C) temperature bins. However, it can be concluded roughly that elevation has a weak influence on N_{bin} at moderate temperature bins (Fig. 4b) and N_{bin} decreases with the increase of elevation at high temperature bins (Fig. 4c).

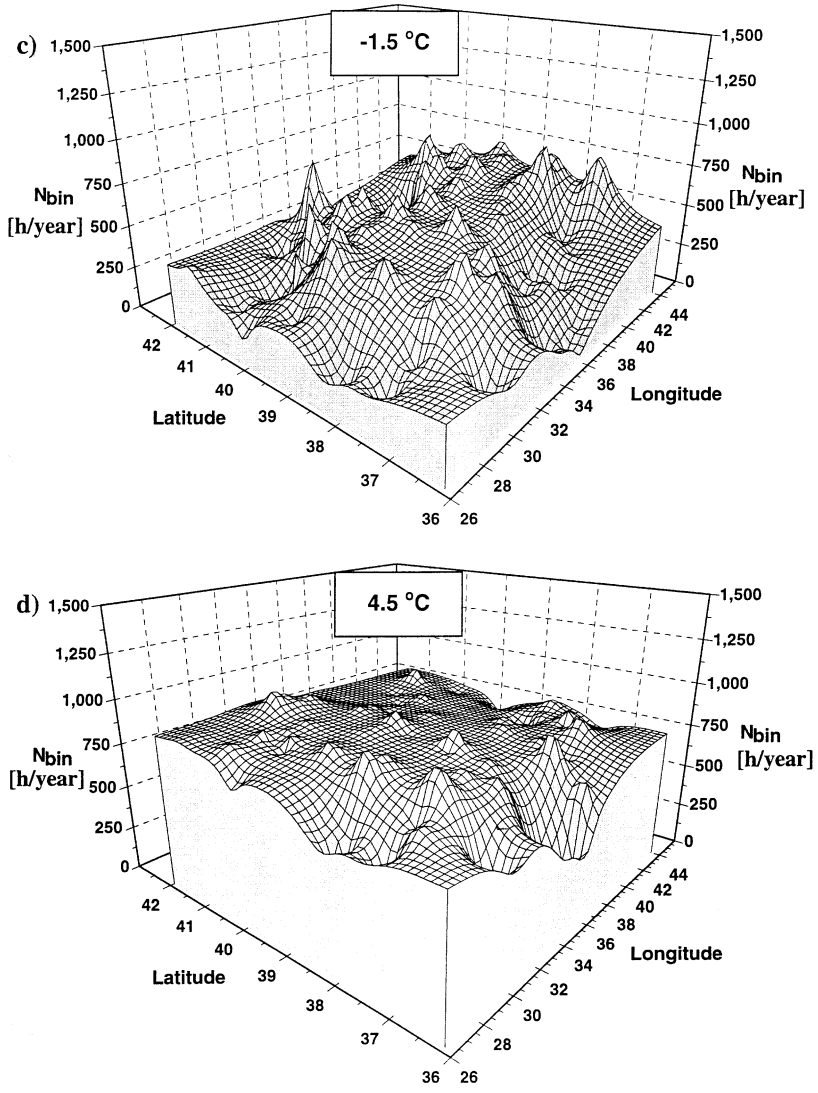

Fig. 3. (*continued*)

Yearly total bin data for some representative cities of Turkey are shown in Fig. 5. The difference in climatic conditions of extreme provinces (e.g. Adana and Erzurum) can be clearly seen from the figure. The most repeated bin is 1.5 °C in Erzurum and 25.5 °C in Adana. While, temperature can drop down to −36/−33 °C in Erzurum, only −3/0 °C is observed in Adana.

Cumulative distribution of yearly bin data for the same provinces is shown in Fig. 6. From the figure, one can get approximately the number of hours for heating

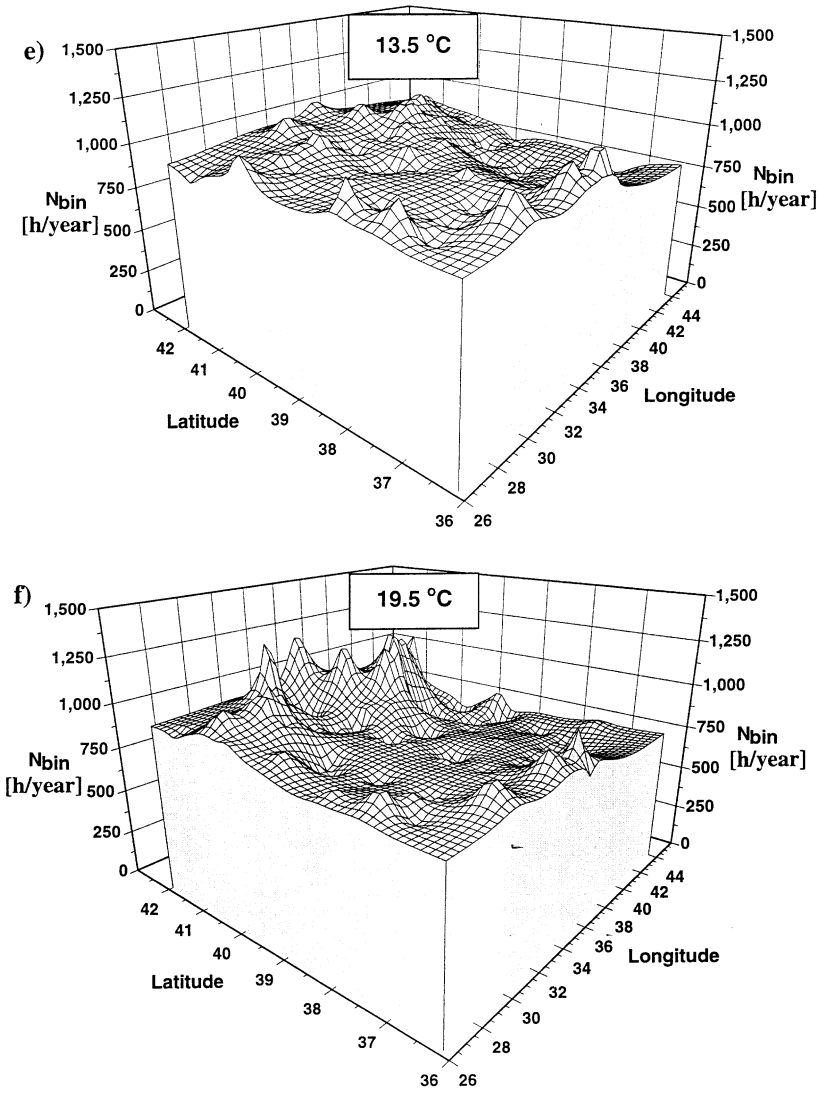

Fig. 3. (*continued*)

season or cooling season by choosing a base temperature (here selecting the outdoor dry-bulb temperature). For example, a building located in Adana without any significant internal and external heat gain needs heating for approximately 4000 h per year and cooling for about 2850 h per year. The heating period is taken as the period with temperatures less than 18 °C. The cooling period is taken as the time when outdoor temperature is higher than 22 °C. For Erzurum, while heating hours are 7500 h/year, cooling hours are only 450 h/year. These values show that, a building

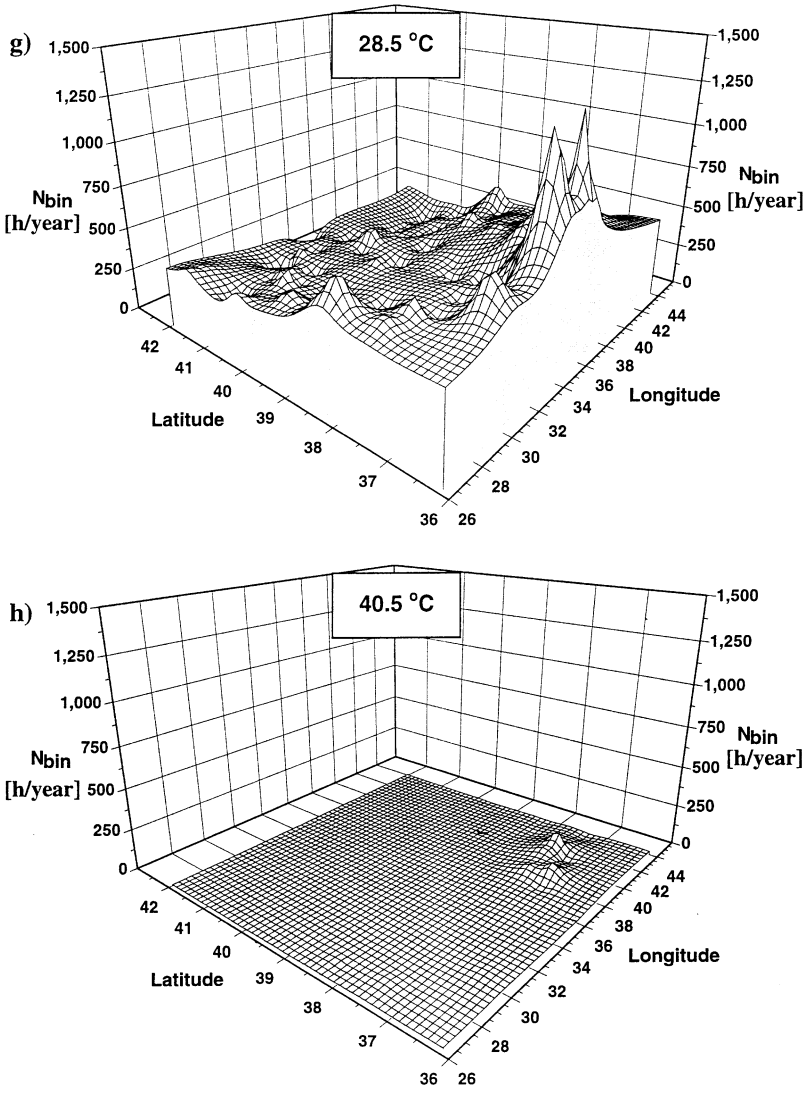

Fig. 3. (*continued*)

having moderate internal and external heat gains located in Erzurum needs no cooling, but the same building requires more cooling than heating in Adana.

4. Conclusions

The bin data for dry-bulb temperature from −36 °C to 45 °C with 3 °C increments are calculated in six daily 4-h shifts for 78 provinces of Turkey. The heating and

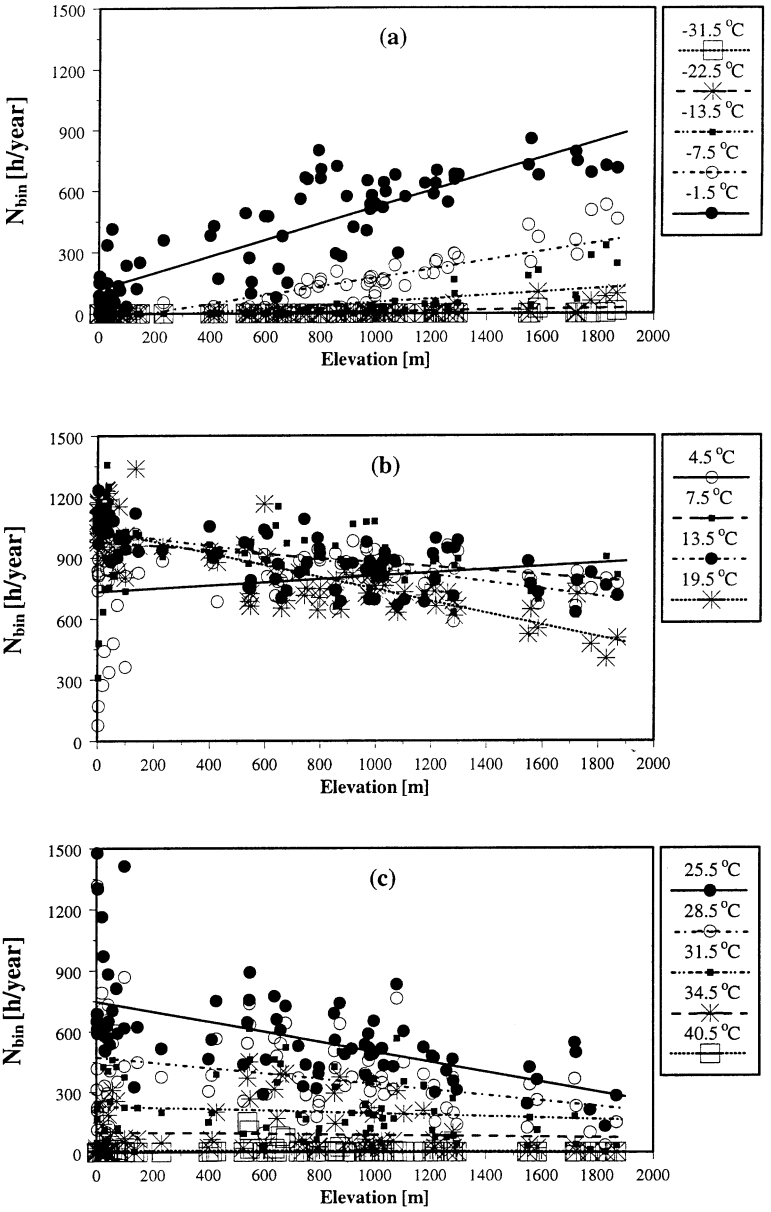

Fig. 4. Variation of yearly total N_{bin} with elevation: (a) low temperature bins; (b) medium temperature bins; (c) high temperature bins.

cooling energy requirements of buildings can be estimated according to the bin method using the data obtained. The monthly and yearly total bin data for six-time periods of the day are also calculated. Examples to the monthly total bin data for six-time periods of the day (for Adana) and to the yearly total bin data for six-time

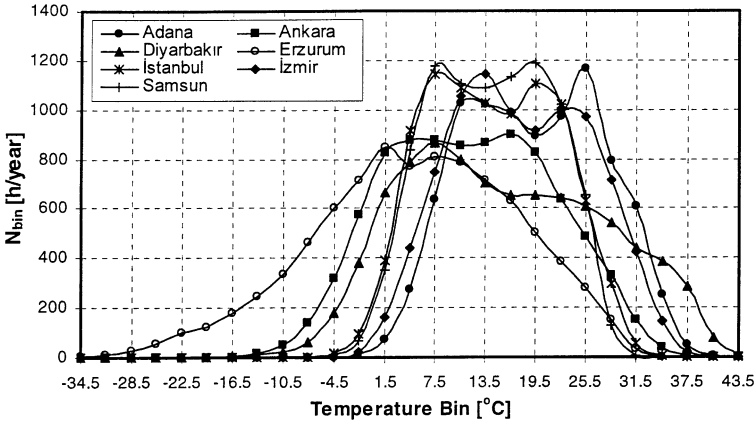

Fig. 5. Yearly total bin data for representative weather stations.

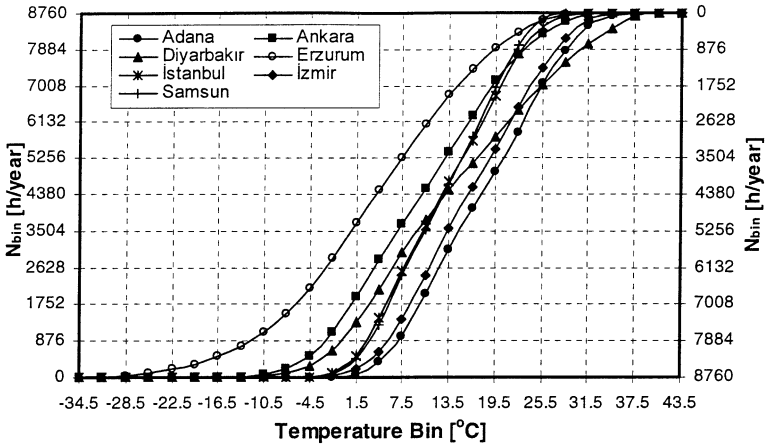

Fig. 6. Cumulative distribution of yearly total bin data for representative weather stations.

periods of the day (for Adana, Ankara, Diyarbakır, Erzurum, İstanbul, İzmir, and Samsun) are given. Yearly total number of hours within each temperature bin is presented for 78 provinces of Turkey in tables. The bin data for dry-bulb temperature for Turkey are analyzed in detail. The influences of elevation and of latitude and longitude on bin data are demonstrated. It is found that the low temperature bins appear in eastern and northeastern Turkey that have high elevations relatively. The high temperature bins were observed in southern and especially southeastern Turkey. Although the observed temperature bins are between −34.5 °C (−36 °C/−33 °C) and 43.5 °C (42 °C/45 °C) for Turkey, the most repeated temperature bins are in the range 4.5 °C to 22.5 °C.

Acknowledgements

The authors wish to express their gratitude to The State Meteorological Affairs General Directorate (DMİ) for providing meteorological data.

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