ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

PhD THESIS

Hüsamettin BULUT

DETERMINATION OF WEATHER DATA FOR TURKEY FOR HEATING AND COOLING SYSTEMS

DEPARTMENT OF MECHANICAL ENGINEERING

ADANA, 2001

ÇUKUROVA ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ

DETERMINATION OF WEATHER DATA FOR TURKEY FOR HEATING AND COOLING SYSTEMS

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MAKİNA MÜHENDİSLİĞİ ANABİLİM DALI

Bu Tez 05 / 07 / 2001 Tarihinde Aşağıdaki Jüri Üyeleri Tarafından Oybirliği İle Kabul Edilmiştir.

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Kod No: 622

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Bu çalışma Çukurova Üniversitesi Araştırma Fonu tarafından desteklenmiştir.
Proje No: FBE.99.D.17

ABSTRACT

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Year: 2001, Pages: 176

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Load calculations in HVAC applications and energy analysis in buildings primarily depend on weather data. This thesis presents detailed weather data for heating and cooling systems for Turkey. The heating degree-days at 14, 16, 18, 20, and 22 °C base temperatures and cooling degree-days at 18, 20 22, 24, 26 and 28 °C base temperature were determined for 78 weather stations of Turkey by using long-term, recently measured data. The bin data for dry-bulb temperature from -36 °C to 45 °C with 3 °C increments were calculated in six daily 4-h shifts for 78 provinces of Turkey. New outdoor design conditions were developed both for cooling and heating systems for all provinces of Turkey according to the format recommended by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). The current outdoor heating and cooling design conditions were analyzed according to their frequency level based on the database available. Daily maximum and minimum dry-bulb temperature, daily mean humidity ratio, and hourly dry-bulb temperature were modeled with trigonometric equations using the long-term meteorological data for 78 locations of Turkey. Monthly average dry-bulb temperature, wet-bulb temperature and humidity ratio for provinces of Turkey were presented and analyzed. Monthly average outdoor temperatures presented in TS825 for calculation of thermal insulation in buildings were examined.

Keywords: Degree-day, bin method, energy analysis, outdoor design conditions, weather data for Turkey.

ÖZ

DOKTORA TEZİ

TÜRKİYE İÇİN ISITMA VE SOĞUTMA SİSTEMLERİ İÇİN İKLİM VERİLERİNİN BELİRLENMESİ

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Danışman : Prof. Dr. Tuncay YILMAZ
Yıl: 2001, Sayfa: 176
Jüri : Prof. Dr. Salih KIRKGÖZ
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Isıtma, soğutma, iklimlendirme ve havalandırma sistemleri uygulamalarındaki ısıl yük hesaplamaları ve binalarda enerji analizi temelde iklim verilerine dayanır. Bu tezde Türkiye için ısıtma ve soğutma sistemlerinde kullanılmak üzere detaylı iklim verileri sunulmuştur. Türkiye'nin 78 ili için 14, 16, 18, 20 ve 22 °C denge noktası sıcaklıklarında ısıtma derece-gün ve 18, 20 22, 24, 26 ve 28 °C denge noktası sıcaklıklarında soğutma derece-gün değerleri belirlenmiştir. –36/+45 °C sıcaklık aralığında, 3 °C artışlarla, günlük 4 saatlik periyotlar için kuru termometre sıcaklığı bin değerleri hesaplanmıştır. ASHRAE'nin önerdiği formata uygun olarak hem ısıtma ve soğutma için yeni dış ortam tasarım şartları geliştirilmiştir. Türkiye'de mevcut kullanılan dış ortam tasarım şartları eldeki verilere dayanılarak frekans düzeylerine göre incelenmiştir. Günlük maksimum ve minimum kuru termometre sıcaklıkları, günlük ortalama mutlak nem ve saatlik kuru termometre sıcaklıkları trigonometrik fonksiyonlarla ifade edilmiştir. Türkiye'nin 78 ili için aylık ortalama kuru ve yaş termometre sıcaklıkları ve mutlak nem değerleri belirlenmiştir. Ayrıca TS825'te binalarda ısı yalıtımı hesaplamalarında kullanılan aylık ortalama kuru termometre sıcaklık değerleri irdelenmiştir.

Anahtar Kelimeler: Derece-gün, bin metodu, enerji analizi, dış ortam tasarım şartları, Türkiye için iklim verileri.

ACKNOWLEDGEMENTS

I am truly grateful to my research supervisor, Prof. Dr.-Ing. Tuncay YILMAZ, for his invaluable guidance and support throughout this thesis and during my undergraduate and graduate education.

I would like to express my sincere appreciation to Assoc. Prof. Dr. Orhan BÜYÜKALACA, for his technical support, guidance, and dedication throughout the preparation of this thesis.

I would like to extend my special thanks to Advisory Committee Member, Prof. Dr. Salih KIRKGÖZ.

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

I also would like to thank The Scientific and Technical Research Council of Turkey-Directorate of Human Resources Development (TÜBİTAK-BAYG) for providing scholarship during my thesis studies.

On a personal level many thanks go to Prof. Dr. Beşir ŞAHİN, Assist. Prof. Dr. Hüseyin AKILLI, Lecturer M. Murat BAYSAL, Research Assistant Ali KAHRAMAN, and Dr. Muammer ÖZGÖREN for their continuous moral support, motivation and friendship.

In addition, I would like to thank my entire Research Assistant friends and all staff of the Mechanical Engineering Department, Çukurova University and Harran University.

And thanks to my family for their patience and encouragement.

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NOMENCLATURE

T_b	Base Temperature (^oC)
T_i	Indoor Temperature (^oC)
T_o	Outdoor Temperature (^oC)
T_m	Daily Mean Outdoor Temperature (^oC)
K_{tot}	Total Heat Transfer Coefficient ($W/^oC$)
q_{gain}	Heat Gain (W)
Q	The Rate of Energy Consumption (W)
h	Heating
c	Cooling
η	Efficiency of HVAC System
t	time
N_{bin}	Number of Hours for Bin Temperature (h)
tot	Total
C	Constant
P_{ws}	Saturation Pressure of Water Vapor (Pa)
P_w	Water Vapor Partial Pressure (Pa)
φ	Relative Humidity
P_a	Atmospheric Pressure (Pa)
W	Humidity Ratio (gr/kg-dry air)
z	Elevation (m)
W_s	Saturated Humidity Ratio (gr/kg-dry air)
T_w	Wet-Bulb Temperature (^oC)
T_d	Dry-Bulb Temperature (^oC)
m	Number of Values (Equation 3.5.1)
m_p	Number of Parameters (Equation 3.5.1)
r	Coefficient of Correlation
Δ	Difference
T_{max}	Daily Maximum Dry-Bulb Temperature (^oC)

T_{min}	Daily Minimum Dry-Bulb Temperature (^{o}C)
n	The Number of Days from January 1
t_d	Daylength
t_{min}	The Occurrence Time of the Daily Minimum Temperature
t_{max}	The Occurrence Time of the Daily Maximum Temperature
ϕ	Local Latitude
δ	Solar Declination Angle
T_{wd}	Daily Average Wet-Bulb Temperature (^{o}C)
Q_{latent}	Latent Cooling Load (W)
$\dot{V}$	Monthly Mean Infiltration (m^3/s)
$W_{i,m}$	Monthly Average Indoor Humidity Ratio ($kg/kg_{dry\text{-}air}$)
$W_{o,m}$	Monthly Average Outdoor Humidity Ratio ($kg/kg_{dry\text{-}air}$)
A	Total Area of Building (m^2)
U	Heat Transmission Coefficient (W/m^2 ^{o}C)
$T_{i,m}$	Monthly Average Indoor Air Temperature (^{o}C)
$T_{o,m}$	Monthly Average Outdoor Air Temperature (^{o}C)
t_m	Total Time of Month
$T_{m,m}$	Long-Term Measured Monthly Average Outdoor Temperature (^{o}C)
T_{TS825}	Monthly Average Outdoor Temperature Given in TS825

LIST OF ABBREVIATIONS AND ACRONYMS

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
DMİ	The State Meteorological Affairs General Directorate
DB	Dry-Bulb
WB	Wet-Bulb
MWB	Mean Coincident Wet-Bulb
HVAC	Heating, Ventilating and Air-Conditioning
HDBT	Hourly Dry-Bulb Temperature
DMMT&RH	Daily Minimum and Maximum Temperature and Relative Humidity at 7,14, 21 o'clock
WBT	Wet Bulb Temperature at 7,14, 21 o'clock
HDD	Heating Degree-Day
CDD	Cooling Degree-Day
TRY	Test Reference Year
TMY	Typical Meteorological Year
WYEC	Weather Year for Energy Calculations
RMSE	Root Mean Square Error
CV	The Calculated Value
MV	The Measured Value
AE	Absolute Error
RE	Relative Error
MMV	The Mean of Measured Values
TS	Turkish Standard
StdD	Standard Deviation
Max	Maximum
Min	Minimum
TTMD	Turkish Society of HVAC & Sanitary Engineers
MMO	Chamber of Mechanical Engineers, Turkey

FL	Frequency Level (%)
NOO	Number of Occurrence (h)
MAE	Mean Absolute Error
MRE	Mean Relative Error
MTD	Monthly Temperature Differences

1. INTRODUCTION

Energy resources are fundamental components of all economic systems. Efficient use of energy is important since the reserve of our global energy resources is finite and limited in our world. These resources are depleting rapidly and energy costs are rising. In recent years, concern about energy consumption and its implications for the environment have been growing in the globe. The significant part of the energy is used in the commercial and residential buildings as cooling and heating energy requirements (Hui, 1996). Therefore, thorough analyses of energy use and conservation in heating, ventilating, and air-conditioning systems design and operation become necessity for designers and operators. This necessity come not only from an economic feasibility viewpoint but also from the viewpoint of energy standards which may be compulsory for all future buildings and HVAC systems.

Since the oil crises of 1970s, there has been a growing awareness of the influence of the building shell and the HVAC system on the energy bill. Significant savings can be realized by paying attention to energy consumption during the early design. Thus considerable feedback between architects and engineers is advisable. The tasks of the mechanical engineers are to calculate the demands for heating, cooling, and ventilation: to choose the necessary equipment and controls; and to ensure that the components are correctly integrated into the building. The HVAC equipment should cost no more than necessary, and thus its capacity should not be excessive. It follows that the first job of the HVAC engineer is the calculation of peak loads. A building must not only function correctly, it should also be economical. The annual energy is determined by annual performance. To minimize the true total cost of a building, it is therefore necessary to calculate its annual heating and cooling loads as well, or, what is equivalent, its average loads (Kreider and Rabl, 1994).

Climatic conditions have a major effect on building loads, HVAC equipment performance and energy consumption. The amount of energy use in a building is a direct result of the climate, the building's use and the building's form. One of the most important parameters for energy efficiency of buildings is the climate. Without knowing the temperature, solar radiation, wind velocity, etc., it is not possible to design a building that is energy efficient without being wasteful of resources. The efficiency of HVAC equipment changes with outdoor climatic conditions. The better design in building heating and cooling applications taken account of right climatic conditions, the more energy efficiently buildings and comfort.

The design of heating, ventilating and air-conditioning (HVAC) and solar energy systems, the energy analysis of buildings and the calculation of cooling and heating requirements depend on weather data. Different design situations will require different weather data for the energy studies. Weather data are used in the simulations, energy analyses, calculation of energy consumption and determination of capacities and suitability of energy related systems.

Weather data do not have constant values; they display great variations in yearly, monthly, daily and even hourly periods. It is very difficult to estimate these variations because of the stochastic behaviors of weather data. However, reasonable weather data can be determined by observing and assessing long-term measured data statistically. The type of weather data being used in the energy analysis determines the accuracy and characteristics of the results. Therefore, weather data must be accurate, reliable, and also easily handled. This can be developed through analysis of the weather data.

There is an increasing trend in energy demand in Turkey as a developing country. This trend will eventually lead to an energy deficit and energy crisis in future. In fact, energy deficit problems in Turkey are occurring today, because Turkey's present energy sources are insufficient and Turkey is an energy-importing country. Because of its demographic and economic growth, Turkey constitutes a major energy market. Domestic energy production has not exceeded half of energy demand (Demirbaş, 2001). Turkey must use their energy sources efficiently and not waste them. In Turkey, the amount of annual energy consumption in the buildings was calculated to be 35-45 % of the total energy consumption, and 85-90 % of this amount is consumed for heating and cooling (Dağsöz and Yüksel, 2000; Işıkel and Bayraktar, 1999; Lokman, 1999; Kılkış, 1991). Energy consumption in buildings is still at significant level and increasing. Because, standard of living in Turkey, as a developing country, is rising dramatically and the utilization of HVAC systems become widespread. Otherwise, there is an increasing awareness of the need conserve energy used for heating and cooling in buildings. The authorities take some measures for energy conservation.

Weather data for design of HVAC and solar energy systems for Turkey were determined approximately 35 years ago (Gülferi, 1966 and Üner, 1998). These climatic design conditions were determined according to the worse conditions. The minimum outdoor dry-bulb temperature for winter design condition and maximum outdoor dry-bulb temperature and wet-bulb temperature for summer design conditions were given. These data is still valid today and they were determined according to extreme weather conditions. Only one risk factor was considered in design stage (Arısoy, 1998). Therefore, peak loads of HVAC systems are calculated with current climatic design data. This may lead to an uneconomic design and oversizing may result in HVAC applications. In addition to all, weather data for energy calculations are either incomplete or non-existing for some locations. It is known that climatic conditions change and new calculation methods have been developed. Therefore, accurate, reliable and suitable weather data must be determined for the design and operation stage of HVAC, solar energy systems and energy analysis and the current valid weather data must be updated.

The main goal of this study is to determine and develop new weather data for energy calculations and to fulfill deficiency in climatic conditions for provinces of Turkey. For this purpose, the latest weather data format published by ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning) was used (ASHRAE, 1997). These weather data contain new climatic design information. 0.4%, 1%, and 2% of the summer frequencies and 99.6% and 99% of the winter frequencies for temperatures were determined for design conditions. This will enable engineers and designers to choose different risk levels desired for the project at hand. The current valid design conditions were also assessed and their risk level determined.

Weather data were modeled mathematically to use them in energy simulation studies and analysis of the systems. Meteorological values were expressed with functions. These functions can produce hourly values of temperature. The data obtained from the functions can be processed in psychrometric chart, so other weather data can be found easily.

It is necessary to estimate energy requirements of HVAC systems for short or long-term operation. The degree-day and bin methods are the best-known and well-established tools for determining energy requirements. The heating and cooling degree-days with variable base were calculated for each province taken into consideration. Therefore, the variation of degree-days with elevation, longitude and latitude for Turkey was determined. Bin data for outdoor dry-bulb temperature were calculated for all provinces of Turkey. The data obtained from degree-day and bin model can be used for energy analysis for each province of Turkey.

The typical climatic design conditions for HVAC applications were presented for each province. All the data given are based on recent long-term measured meteorological data. Information on monthly values of outdoor dry-bulb temperature, and humidity ratio were given in tabular form for all provinces.

The main purpose of this study is to present detailed weather data for energy analysis. It is hoped that the study can serve useful information on climatic and design conditions for HVAC engineers, designers and architects. It is the first step for analyzing weather data for the whole Turkey.

2. LITERATURE REVIEW

Requirements for design data in energy calculations of HVAC applications and energy concern have led to many studies on weather data and energy estimation methods. There are many studies on these topics for different countries around the world, but a few for Turkey. The literatures for this study were grouped according to weather data and energy estimation methods for global aspects and for Turkey.

2.1. Literature Review for Weather Data

Information on weather data is necessary in thermal analysis of buildings and heating and cooling load calculations to decide the correct sizing of a HVAC system for thermal comfort and in the performance evaluation and optimum design of many energy systems. Some selected studies on weather data are summarized below.

Hittle and Pedersen (1981) analyzed periodic and stochastic behavior of weather data. They showed that deterministic plus stochastic models could be used in lieu of weather data tapes as input to energy analysis programs.

Salcedo and Recio (1984) developed a method for obtaining a typical annual time function which allows the use and analysis of meteorological parameters such as daily global solar irradiation and the air temperature that show significant frequencies and that have sufficient climatological series, through the application of Fourier analysis. This method of calculation was applied to existing time series of solar and temperature parameters of Barcelona city, Spain.

Smart and Ballinger (1984) recommended Fourier-synthesized weather data for building energy use estimation. They proposed several tests of realism of synthetic weather. The study carried out for the two Australian locations, Williamtown and Laverton by using two years measured data.

Bahadori and Chamberlain (1986) showed that the hourly, daily and monthly energy needs of simple building can be estimated using only a limited available weather data for the location. The data needed are the mean daily maximum and the mean minimum temperatures and the average clearness index for each month. In their research, a residential building located in Ottawa, Ontario, Canada was considered for analysis using ten years of weather data.

Pissimanis *et al.* (1988) generated a typical meteorological year for the city of Athens. A representative data set for Athens includes solar radiation, temperature, dew point and wind velocity.

Ramesh *et al.* (1988) presented an analysis of the relation between weather variables and peak loads in Delhi, India and outlined a methodology for forecasting peak loads.

Kodah and El-Shaarawi (1990) presented the mean monthly temperatures for Jordan and showed that the traditional value of 18.3 °C is not suitable base temperature for evaluating the heating degree-days in Jordan. They recommended a base temperature of 15.5 °C for a typical Jordanian residence. They gave degree-days for 24 locations in Jordan.

Knight *et al.* (1991) presented models for generating hourly series of radiation and ambient temperature values. They described a methodology for the synthesis of hourly weather data. They compared statistics obtained from long-term (22 years), Typical Meteorological Year, and synthetically generated weather data at three locations (Albuquerque, NM; Madison, WI; and New York, NY).

Hokoi *et al.* (1992) proposed a statistical method to generate synthetic weather data as an alternative to the use of hourly historical data. They developed stochastic models for solar radiation and outdoor temperature time series, taking their correlations into consideration. They used weather data for Tokyo, Japan, for the year 1962 in the analysis.

Yoshida and Terai (1992) proposed a method for modeling weather data (temperature, global solar radiation, and absolute humidity) by time and Fourier series for air-conditioning load calculations. The modeling procedure is applied to Tokyo weather record. The statistical tests showed that the proposed model can substitute the reference year data that are used for similar load calculations.

Alaruri and Amer (1993) studied empirical regression models for weather data measured in Kuwait during the years 1985, 1986 and 1987. They developed empirical fits expressing the monthly average daily measurements as a function of month of the year by employing least-squares linear regression analysis. The weather data measured were global radiation, diffuse radiation, hemispherical global infrared radiation, global ultraviolet radiation, ambient temperature, relative humidity, atmospheric pressure, and wind speed.

Chapter 24 of ASHRAE Handbook-Fundamentals (1993) presents climatic conditions for a number of weather stations in the United State, Canada and other countries. The methods for calculations of heating, cooling and energy estimation were also outlined in Chapters 25, 26, and 28 of this Handbook.

Donn and Amor (1993) created standard weather data files covering the whole of New Zealand to fulfill the simulation needs of New Zealand.

Festa and Ratto (1993) presented a procedure which allows to create, from many years of available past weather data, a Reference Year, that is, a data set containing a squence of 8760 hourly values of some chosen meteorological quantities.

Said and Kadry (1994) generated typical years for some cities of Saudi Arabia, using the standard meteorological data obtained by measurements by the Meteorology and Environmental Protection Administration.

Sezai and Taşdemiroğlu (1995) proposed trigonometric relations incorporating daily and annual harmonics to predict the temperature, relative humidity and solar radiation at any time in a year using the long-term daily meteorological data obtained from the Meteorological Office of Northern Cyprus and short-term hourly data from the Eastern Mediterranean University.

Cannistraro *et al.* (1995) applied the method for setting up a reference year of reduced temperature data, proposed by Erbs and et al.(1983), to 29 European locations for which an official test-reference year is available. They tested the effectiveness of the method by calculating the annual energy demand in 29 European locations for three modules with different thermophysical characteristic.

Haberl *et al.* (1995) evaluated the impact of using measured weather data vs. TMY weather data for a DOE-2 simulation of large institutional building. They presented specific recommendations concerning the impact of the use of measured weather data and the use of TRY and TMY weather data on the calibration of the DOE-2 program.

Hong and Jiang (1995) presented a model which based on the vector auto-regresssive (VAR) time series method. They showed that the accuracy obtained is sufficient for the applications of the stochastic weather model in the simulation and stochastic analysis of building HVAC systems. The stochastic model was employed on Kew (U.K.) by using 12 years weather records.

Hui and Lam (1995) presented a research study on the determining of outdoor design conditions for HVAC applications in Hong Kong. They examined methods for determining outdoor design conditions and studied the existing data for Hong Kong. They found that the existing data of outdoor design conditions for Hong Kong are very limited and information on design weather data needs to be reviewed and expanded. They established new data for outdoor design conditions based on more recent meteorological data from the latest weather database developed for Hong Kong.

El-Shaarawi and Al-Masri (1996) presented monthly-average maximum, minimum and mean temperatures and medians of extreme temperatures for 24 weather stations in Saudia Arabia. They also reported heating degree-days for these locations.

Parrott *et al.* (1996) developed a mathematical model to generate daily average temperatures (DATs) on a yearly basis for any climate. The model contains a complete description of the patterns and variations in DATs for a given location using a set of 29 descriptor values, the magnitudes of which are determined using a Fourier frequency analysis of physical weather data. The model was tuned to imitate the climates at three Canadian sites.

Bouhaddou *et al.* (1997), presented the ARMA (AutoRegressive Moving Average) models of the weather parameters: ambient temperature, humidity and clearness index recorded at or near Marrakech, Morocco. The identification of the model parameters is based on Higher Order Statistics (cumulants). They performed comparison between the statistical characteristics of the measured data and the data generated using the models and showed that the weather parameters can be predicted with acceptable accuracy.

Canada *et al.* (1997) presented monthly average daily data over the period 1989-1992 for eight meteorological parameters (global and diffuse solar radiation, sunshine duration, minimum and maximum ambient temperature, atmospheric pressure, specific humidity and wind speed) in Valencia, Spain. They obtained equations to calculate the monthly average daily data for six parameters as a function of the month of the year using a multiple regression method.

Chapter 26 of ASHRAE Handbook-Fundamentals (1997) presents tables of new climatic conditions for 1459 locations in the United States, Canada, and around the world. The chapter includes values of dry-bulb, wet-bulb, dew-point temperature and wind speed with direction at various frequencies of occurrence. This information is commonly used for design, sizing, distribution, installation, and marketing of heating, ventilating, air-conditioning, and dehumidification equipment; as well as for other energy-related processes in residential, agricultural, commercial and industrial applications. Sources of other information such as degree-days and typical weather years for energy calculations are also described in that chapter.

Hui and Cheung (1997) investigated weather data of Hong Kong and Mainland China. They examined major climatic properties to develop a better understanding of the climate of China which is diverse and complex. They also studied quality of the climatic data and problems in developing data. They discussed important considerations for using climatic data in architectural design and building energy simulation to help improve building design and gain the maximum benefits from the local climatic conditions.

Hong and Jiang (1998) discussed the methods to select the outdoor design temperature for heating load calculation specified in current design codes in different countries. They presented a new method namely stochastic analysis to determine the outdoor synthetic temperature, which fully considers the randomness of weather and internal casual gains, and the thermal performance of buildings. They analyzed case studies of the influence of different building components on the outdoor synthetic temperature of a residential room in Beijing. They showed that the outdoor synthetic temperature depends upon building structures as well as weather conditions. Finally, they recommended that the outdoor synthetic temperature rather than the outdoor design temperature should be used in heating load calculation, hence sizing equipment for space heating systems.

Kissock *et al.* (1998) described a procedure for estimating weather-adjusted retrofit savings in commercial buildings using ambient-temperature regression models. They discussed the selection of ambient temperature as the sole independent regression variable. They also described the appropriate use of both linear and change-point least-square regression models for estimating savings.

Parishwad *et al.* (1998) presented a procedure to predict monthly-mean hourly values of relative humidity, ambient temperature and wind velocity for an Indian location. They prepared three maps, showing distribution of annual-average hourly values of humidity, temperature and wind velocities, from the analysis of available meteorological data of 205 Indian cities. They obtained an equation for annual-average temperature as a function of altitude of the location. They also developed sets of equations to predict the weather parameters by the least square regression analysis of the data of 14 cities, taken from different regions.

Petrakis *et al.* (1998) presented the generation of Typical Meteorological Year for Nicosia, Cyprus. They generated the Typical Meteorological Year from available hourly meteorological data recorded during the period 1986-1992, using Filkenstein-Schafer statistical method.

Zogou and Stamatelos (1998) made a comparative discussion of the effect of climatic conditions on applying ground source heat pump technologies. They reported specific examples for northern and southern parts of Europe and showed that the attainable building energy consumption reduction with ground source heat pump systems may be significantly higher in the warmer Mediterranean climatic conditions. They concluded that climatic conditions significantly affect the performance of heat hump systems, which should lead to markedly different strategies for domestic heating and cooling, if an optimization is sought on sustainability.

Argiriou *et al.* (1999) applied the major methodologies for Typical Meteorological Years (TMY) generation reported in literature to 20-year hourly measurements of weather data from Athens, covering the period 1977 to 1996. They produced seventeen different Test Reference Years (TRY). They developed a scoring system based on the results of each simulation exercise. They found that the best performing TRY is the one produced by a modified Festo-Ratto method.

Dhar *et al.* (1999) described development of a variant of Generalized Fourier Series approach which allows modeling both heating and cooling hourly energy use in commercial buildings with outdoor temperature as the only weather variable. They illustrated the model's application with monitored hourly data from several buildings in Texas. They found that the new temperature based Fourier Series approach (i) provides better approximation to heating energy use than the existing Generalized Fourier Series approach, (ii) can indirectly account for humidity and solar effects in the cooling energy use, (iii) offers physical insight into the operating pattern of a building HVAC system and (iv) can be used for diagnostic purposes.

Gelegenis (1999) presented an algorithm for extraction of hourly temperature distributions from their monthly average values. They used the climatic data of Greece as a case study.

Harriman *et al.* (1999) analyzed the new climatic design conditions which are given in Chapter 26 of the 1997 ASHRAE Handbook- Fundamentals. They reported detailed information on new weather data for energy calculations.

Lam (1999) used the computer package DOE-2.1E to simulate the thermal and energy performance of fully air-conditioned office buildings in Hong Kong. Seventeen weather data sets from 1979 to 1995 were used for the computer simulation. He investigated the likely diversity in computer predictions based on different weather years. He found that predictions of annual cooling loads, peak cooling loads and annual electricity consumption might differ by up to about 14%.

Njau (1999) established both theoretically and by means of actual records that major changes in mean minimum temperature variations at a given location are followed after time τ by (associated) major changes in mean maximum temperature variations at the same location. The value of parameter τ, which is apparently independent of the choice of the location involved, is found to be approximately eight years.

Adelard *et al.* (2000) presented new software, RUNEOLE, used to provide weather data in buildings applications with a method adapted to all kind of climates. RUNEOLE associates three modules of description, modeling and generation of weather data.

Dorvlo (2000) derived typical annual functions for global irradiation and mean, minimum, and maximum temperatures for Seeb, Sultanate of Oman, using Fourier analysis.

Richardson (2000) examined the stability of estimates of weather generation parameters relative to the length of record of actual data from which the parameters were estimated. He found that stable estimates of the parameters for generating daily temperature were obtained with relatively short records of actual data and precipitation parameters, however, required relatively long records to achieve stable estimates. He reported that the amount of data required to achieve a specific level of stability also depended on the geographic location and the season of the year. He also found that in general, at least 10 years of data are needed for estimation of temperature parameters and 20 or more years of data are needed for estimation of precipitation parameters.

2.2. Literature Review for Energy Estimating Methods

It is often necessary to estimate energy requirements and fuel consumption of HVAC systems for short or long term operation. Although sophisticated computer programs were developed for this aim, the simplified energy estimation methods such as degree-day method and bin method are best known and used in energy requirement analyses around the world. Some examples to the studies on degree-day method and bin method are given below.

Hitchin (1981) discussed the calculation of degree-day values and analyzed temperature records for a number of sites in Britain to compare regional variations.

Parken and Kelly (1981) presented a method (referred to as the modified building load and temperature bin method, MBLTBM) for calculating residential building cooling loads and seasonal cooling requirements for various geographical regions. The method requires little additional data to what are presently required for calculating design-cooling requirements. For the region of interest, temperature bin data, the summer daily average temperature, the average daily extreme temperature, solar heat gain factors for windows and incident solar radiation on vertical and horizontal opaque surfaces are required. The modified building load and temperature bin method was compared to the more comprehensive method obtained by the hour-by-hour cooling loads as determined by the BLAST computer program, and by results obtained by hand calculation presently in common use..

Erbs *et al.* (1983) presented a method, which only needs the monthly-average ambient temperature to obtain estimates of daily bin data and the monthly heating and cooling degree-days for any base temperature.

Degelman (1985) produced bin weather data (dry-bulb and wet-bulb temperature) and generated variable base degree-day information from ASHRAE's Weather Year for Energy Calculations tapes.

Letherman and Al-Azawi (1986) discussed briefly methods for the prediction of seasonal energy requirements for heating or cooling buildings and described a new method, the degree-hours method. They compared the predictions obtained using their method with the results from an alternative method for an example building.

Claridge *et al.* (1987a) compared the measured cooling energy consumption of 52 residential buildings in different parts of the United States of America with the consumption predicted by the variable-base degree-day (VBDD) method. They reported that the VBDD method correctly predicts cooling requirement.

Claridge et al. (1987b) compared the measured heating energy consumption of 124 houses in all regions of the United States of America with the consumption predicted by the variable-base degree-day (VBDD) method. They found that the VBDD method correctly predicts for the group of houses where the average heating season temperature is at least 10 F (5.6 ^{o}C) greater than the balance temperature.

Lin *et al.* (1987) developed a simplified method for predicting the cooling degree hours and heating degree hours. They applied a statistical technique to the calculation of cooling degree hours and heating degree hours. They verified that the inaccuracies of the simplified cooling degree hours and heating degree hours calculations are about 3% and 8%, respectively. They used weather data of Taiwan for their study.

Hitchin (1990) presented developments in degree-day methods for estimating energy use. He described how month-by-month degree-day calculations may be developed to capture effects of building thermal inertia and of day to day variations of incidental gains. He demonstrated a method to include the part-load efficiency of heating appliances and how the methodology may be applied to bivalent heating systems.

Schoenau and Kehrig (1990) presented a simple method for accurately computing the degree-days to any base temperature. The method is based on an assumed annual normal distribution of daily mean temperature around the monthly mean temperature. A maximum prediction error of only 0.28 degree-days per day was observed when compared to actual weather data at four representative locations.

Said (1992) presented monthly weather data summary and monthly average temperatures as a function of hour of the day for four cities (Dhahran, Riyadh, Jeddah, and Khamis Mushait) in Saudi Arabia.

Papakostas and Sotiropoulos (1997) discussed the necessary analysis of the ambient dry-bulb temperature and relative humidity for elaboration of bin weather data. They presented in tabular form annual total bin data and monthly bin data in four-hour periods using weather data from Thessaloniki, Greece.

Martinaitis (1998) described a method for the calculation of degree-day by means of a proposed cumulative air temperature duration function for heating season by additionally setting the temperature that determines the limits of the heating season in this function. He compared the results of his calculations received under climate conditions with factual data for Lithuanian.

Şen and Kadıoğlu (1998) reported degree-day calculations using only maximum temperature records in arid regions and explained risk assessments. They presented degree-days in the form of contour maps for Saudi Arabia.

Badescu and Zamfir (1999) reported the implementation of the degree-day (degree-hour) method for Romania. They presented the distribution of hourly average temperatures analytically and obtained the regression coefficients by fitting the distribution functions to the existing meteorological data. They produced various temperature cumulative distribution functions and calculated the degree-hour numbers from such functions. They also tested five models of computing degree-day numbers and used the most accurate method to evaluate the heating degree-days for 29 Romanian localities.

Papakostas (1999) calculated the annual total bin data and monthly bin data in four-hour periods using weather data from Athens, Greece. He presented these data in tabular form.

2.3. Literature Review for Weather Data in Turkey

A number of studies have been carried out on weather data and related topics for Turkey. However, these studies are not satisfactory and not at a desired level. Some selected studies are given below.

Arınç *et al.* (1983) reported a mathematical formulation for the hourly variation of ambient temperatures for use in solar system design for all locations in Turkey. They expressed the hourly variation of ambient temperatures with polynomials using average ambient temperatures at 7,14, and 21 o'clock. They presented results only for two cities and two different months.

Ünal *et al.* (1986) produced equations for daily average temperature and total solar radiation throughout the year for some cities of Turkey. The monthly average data obtained from 1984 bulletin of DMİ were used in the study.

Oğulata and Yılmaz (1989) developed equations analytically for determining the variation of ambient temperature during daytime. They verified the equations using data from some locations all over the world.

Kılkış and Arınç (1990) presented new outdoor dry-bulb temperatures used in the calculation of heat load of buildings for provinces of Turkey using DIN 4701-1983 German Standard.

Satman *et al.* (1990) explained the degree-day method for prediction of natural gas usage in heating of residential buildings and presented degree-day values for some locations in Turkey.

Yılmaz and et al. (1995) derived equations for daily and yearly variation of humidity ratio. They applied the equations to 3 years measured data for Adana.

Bulut and et al. (1996) presented the outdoor dry-bulb temperatures (minimum, maximum and mean), relative humidity, humidity ratio, solar radiation and wind data for Şanlıurfa using long term measured data.

Yılmaz and Bulut (1996) described the meteorological data of Şanlıurfa with mathematical equations using 14 years long-term measured data. Equations were given for daily absolute humidity, extreme temperature, solar radiation, and hourly temperature. The values obtained from the equations were compared with measured data.

Oğulata (1997) described solar radiation, ambient temperature, and sunshine duration with simple equations for 9 cities of Turkey for solar energy applications.

Arısoy (1998) discussed available weather data in Turkey. He explained the methods for determining weather data and presented design conditions for İstanbul, Ankara and İzmir.

İleri and Üner (1998) obtained typical weather years for the selected 23 provinces of Turkey using 7 years (1990-1996) hourly weather data. They presented heating and cooling degree-days, dry-bulb temperature bins and some frequency level of dry-bulb temperature as winter and summer design conditions by using these typical meteorological years. They also performed energy analysis on buildings located in Ankara.

Arısoy *et al.* (1999), produced temperature bins for İstanbul. They applied bin method to a building in İstanbul using these temperature bins for predicting yearly fuel consumption.

Biçer and et al. (1999) presented new outdoor dry-bulb temperatures as winter and summer design conditions for five provinces located at southeastern part of Turkey. They carried out a sample heating project with the new recommended design conditions for Diyarbakır based on energy requirement concern.

Dağsöz and Bayraktar (1999) calculated degree-day values at 15 ^{o}C base temperature for 69 cities of Turkey using 10 years weather data. They categorized the provinces of Turkey into five regions according to their degree-day values.

Kadıoğlu and Şen (1999) derived general formulations for various degree-day definitions by considering the dependence within the temperature time series. They presented the application of methodologies developed for five temperature measurement stations scattered throughout Turkey within different climate regions.

Satman and Yalçınkaya (1999) determined yearly heating degree hours with base temperature of 15, 17 and 18.3 °C and cooling degree-hours with base temperature of 24, 26, 27, and 30 °C for seventy-seven weather stations in Turkey. They used the hourly weather data collected since 1991.

Büyükalaca *et al.* (2000) calculated degree-day values of some provinces of Turkey with variable base temperature using long term measured weather data. In calculation of degree-days, they used both classical method and the method developed by Erbs *et al.* (1983). They also compared their results with previously published results by other authors.

Gümrah *et al.* (2000) developed a method which predicts natural gas demand in Ankara. Their method is based on degree-day method. They used 7 years (1991-1997) weather data for determining degree-days.

3. MATERIAL AND METHOD

3. 1. Weather Databases

Load and energy calculation carried out at outline and detail design stages will require weather data for calculation of cooling and heating requirements, design of heating, ventilating and air-conditioning (HVAC) systems, and energy estimation of buildings. Therefore, accurate, attainable, and reliable weather data information is crucial for energy simulation and analysis in HVAC systems. Because, the weather data being used in energy analysis determines the accuracy and characteristics of the results. The database used in energy analysis should cover long period and depend on recent values (ASHRAE, 1993). The number of years that weather data available will determine the breath of the weather database. In principle, as many years as possible should be considered for a proper analysis. The longer the period of records is, the better and more persuasive the results will be (since shorter periods will exhibit variations from the long-term average). For determining design conditions, weather data for at least 12 years is considered as long-term data (ASHRAE, 1997). Ten or more years of weather data are required to increase the statistical reliability of recommended models for weather data and so the estimated loads (Richardson, 2000). In practice, especially in developing countries, the availability of long-term weather data are often lacking and the measurements in early years may not be detailed enough.

Depending on the application, different weather data are used by designer, engineers and architects. The weather data generally include temperature data, solar radiation data, humidity data, and wind data.

The State Meteorological Affairs General Directorate (DMİ) takes required meteorological measurements in Turkey. 594 different type meteorological stations throughout Turkey records the meteorological parameters. In this study, 78 weather stations, which measure desired weather data and have long-term measurements were selected. The selected stations are located 78 different provinces of Turkey.

The raw weather data on which this study is based on were taken from The State Meteorological Affairs General Directorate (DMİ) in magnetic disks for 78 provinces of Turkey. Table 3.1.1 shows longitude, latitude, and elevation for the weather stations taken into consideration in this study. The meteorological parameters obtained from DMİ are hourly dry-bulb temperature, wet-bulb temperature and relative humidity (records at 07:00, 14:00 and 21:00 o'clock), and daily minimum and maximum dry-bulb temperatures.

Constructing climatic data for HVAC applications involves much more than acquiring the required raw information from the weather stations. There are many missing and wrong records in the obtained weather data because of the essence of raw data. Checks are required for missing data and erroneous data. In addition, corrections and interpolations are required to convert the data to the desired formats.

First of all, the raw data were analysed and missing and wrong data were determined for each province. Some corrections and interpolations were then carried out for these missing and wrong data. The raw meteorological data were rearranged in a suitable format to use them in computer programs that developed for this study. The data of each province selected have been saved separately in different files. The data files were re-constructed into following format: station number, year, month, day, and data (hourly or daily). Table 3.1.2 gives the period and total years of weather data (Hourly dry-bulb temperature: **HDBT**, daily minimum and maximum temperature and relative humidity at 7,14, 21 o'clock: **DMMT&RH**, and wet bulb temperature at 7,14, 21 o'clock: **WBT**) for each province. As seen from Table 3.1.2, all weather data are for long term and recently measured data.

Table 3.1.1. Information for the provinces considered in the present study

Location	Longitude [°E]	Latitude [°N]	Elevation [m]
Adana	35.18	36.59	20
Adapazarı	30.25	40.47	30
Adıyaman	38.17	37.45	678
Afyon	30.32	38.45	1034
Ağrı	43.08	39.31	1585
Aksaray	34.03	38.23	980
Amasya	35.51	40.39	412
Ankara	32.53	39.57	894
Antakya	36.07	36.15	100
Antalya	30.42	36.53	42
Ardahan	42.42	41.08	1829
Artvin	41.49	41.10	597
Aydın	27.50	37.51	57
Balıkesir	27.52	39.39	147
Bartın	32.21	41.38	30
Batman	41.10	37.52	540
Bayburt	40.15	40.16	1550
Bilecik	29.58	40.09	526
Bingöl	40.30	38.52	1177
Bitlis	42.06	38.22	1559
Bolu	31.36	40.44	742
Burdur	30.20	37.40	967
Bursa	29.04	40.11	100
Çanakkale	26.24	40.08	3
Çankırı	33.37	40.36	751
Çorum	34.58	40.33	798
Denizli	29.05	37.47	428
Diyarbakır	40.12	37.55	660
Edirne	26.34	41.40	48
Elazığ	39.13	38.40	1105
Erzincan	39.30	39.44	1215
Erzurum	41.16	39.55	1869
Eskişehir	30.31	39.46	800
Gaziantep	37.22	37.05	855
Giresun	38.24	40.55	38
Gümüşhane	39.27	40.27	1219
Hakkari	43.46	37.34	1720
Iğdır	44.02	39.56	858
İskenderun	36.07	36.37	3
Isparta	30.33	37.45	997
İstanbul	29.05	40.58	39
İzmir	27.10	38.24	25
K.Maraş	36.56	37.36	549
Karaman	33.14	37.11	1025
Kars	43.05	40.36	1775
Kastamonu	33.46	41.22	791
Kayseri	35.29	38.43	1068
Kilis	37.05	36.44	638
Kırıkkale	33.30	39.50	725
Kırklareli	27.13	41.44	232
Kırşehir	34.10	39.08	985
Kocaeli	29.54	40.46	76
Konya	32.30	37.52	1028
Kütahya	29.58	39.24	969
Malatya	38.18	38.21	998
Manisa	27.26	38.36	71
Mardin	40.44	37.18	1080
Mersin	34.36	36.49	5
Muğla	28.21	37.12	646
Muş	41.31	38.44	1283
Nevşehir	34.40	38.25	1260
Niğde	34.40	37.59	1208
Ordu	37.52	40.59	4
Rize	40.30	41.02	4
Samsun	36.20	41.17	44
Siirt	41.56	37.56	875
Sinop	35.10	42.02	32
Sivas	37.01	39.49	1285
Şanlıurfa	38.46	37.08	547
Tekirdağ	27.29	40.59	4
Tokat	36.54	40.18	608
Trabzon	39.43	41.00	30
Tunceli	39.32	39.06	979
Uşak	29.29	38.40	919
Van	43.41	38.28	1725
Yalova	29.16	40.39	2
Yozgat	34.49	39.50	1298
Zonguldak	31.48	41.27	136

Table 3.1.2. The recorded period and total years of weather data for provinces

Province	HDBT		DMMT&RH		WBT	
	Period	Total Years	Period	Total Years	Period	Total Years
Adana	1983-1998	16	1981-1996	16	1990-1996	7
Adapazarı	1982-1998	17	1982-1998	17	1982-1998	17
Adıyaman	1981-1998	18	1981-1998	18	1981-1998	18
Afyon	1981-1998	18	1981-1998	18	1981-1998	18
Ağrı	1981-1998	18	1981-1998	18	1981-1998	18
Aksaray	1981-1998	18	1981-1998	18	1981-1998	18
Amasya	1981-1998	18	1981-1998	18	1981-1998	18
Ankara	1983-1995	13	1981-1995	15	1983-1995	13
Antakya	1983-1998	16	1981-1996	16	1990-1996	7
Antalya	1983-1998	16	1981-1995	15	1990-1996	7
Ardahan	1981-1998	17	1981-1998	18	1981-1998	17
Artvin	1981-1998	18	1981-1998	18	1981-1998	18
Aydın	1983-1998	16	1983-1998	16	1983-1998	16
Balıkesir	1983-1997	15	1983-1997	15	1983-1997	15
Bartın	1981-1998	18	1981-1998	18	1981-1998	18
Batman	1983-1998	15	1983-1998	16	1983-1998	15
Bayburt	1981-1998	18	1981-1998	18	1981-1998	18
Bilecik	1981-1998	17	1981-1998	18	1981-1998	17
Bingöl	1981-1998	18	1981-1998	17	1987-1998	12
Bitlis	1981-1998	18	1981-1998	18	1981-1998	18
Bolu	1981-1998	18	1981-1998	18	1981-1998	18
Burdur	1981-1998	18	1981-1998	18	1981-1998	18
Bursa	1983-1998	16	1983-1998	16	1983-1998	16
Çanakkale	1981-1998	17	1981-1998	17	1981-1998	17
Çankırı	1981-1995	13	1981-1995	15	1981-1995	13
Çorum	1981-1998	18	1981-1998	18	1981-1998	18
Denizli	1983-1998	16	1983-1998	16	1983-1998	16
Diyarbakır	1983-1998	16	1981-1996	16	1990-1996	7
Edirne	1983-1998	16	1983-1998	16	1983-1998	16
Elazığ	1981-1998	18	1981-1998	18	1981-1998	18
Erzincan	1981-1998	18	1981-1998	18	1981-1998	18
Erzurum	1983-1998	14	1983-1998	16	1983-1998	14
Eskişehir	1983-1998	15	1991-1998	8	1991-1998	8
Gaziantep	1983-1998	16	1981-1996	16	1990-1996	7
Giresun	1981-1998	18	1981-1998	18	1981-1998	18
Gümüşhane	1981-1998	18	1981-1998	18	1981-1998	18
Hakkari	1981-1998	18	1981-1998	18	1981-1998	18
Iğdır	1981-1998	16	1981-1998	16	1981-1998	16

Table 3.1.2. (Continued) The recorded period and total years of weather data for provinces

Province	HDBT		DMMT&RH		WBT	
	Period	Total Years	Period	Total Years	Period	Total Years
İskenderun	1981-1998	18	1981-1998	18	1981-1998	18
Isparta	1981-1998	18	1981-1998	18	1981-1998	18
İstanbul	1983-1998	16	1981-1996	16	1990-1996	7
İzmir	1983-1998	16	1981-1996	16	1990-1996	7.
Kahramanmaraş	1984-1998	15	1983-1998	16	1984-1998	15
Karaman	1981-1998	18	1981-1998	18	1981-1998	18
Kars	1983-1998	15	1983-1998	16	1983-1998	15
Kastamonu	1981-1998	18	1981-1998	18	1981-1998	18
Kayseri	1983-1998	16	1981-1996	16	1990-1996	7
Kilis	1981-1998	17	1981-1998	18	1981-1998	17
Kırıkkale	1981-1995	15	1981-1995	15	1981-1995	15
Kırklareli	1981-1998	18	1981-1998	18	1981-1998	18
Kırşehir	1981-1995	15	1981-1995	15	1981-1995	15
Kocaeli	1981-1998	18	1981-1998	18	1981-1998	18
Konya	1983-1998	16	1981-1996	16	1990-1996	7
Kütahya	1981-1998	17	1981-1998	18	1981-1998	17
Malatya	1983-1998	16	1983-1998	16	1983-1998	16
Manisa	1983-1998	16	1983-1998	16	1983-1998	16
Mardin	1983-1998	16	1983-1998	16	1983-1998	16
Mersin	1983-1998	16	1983-1998	16	1983-1998	16
Muğla	1983-1998	16	1981-1996	16	1990-1996	7
Muş	1981-1998	18	1981-1998	18	1981-1998	18
Nevşehir	1981-1998	18	1981-1998	18	1981-1998	18
Niğde	1981-1998	18	1981-1998	18	1981-1998	18
0rdu	1981-1998	18	1981-1998	18	1981-1998	18
Rize	1983-1998	16	1981-1996	16	1990-1996	7
Samsun	1983-1998	16	1981-1996	16	1990-1996	7
Siirt	1981-1998	18	1981-1998	18	1981-1998	18
Sinop	1981-1998	18	1981-1998	18	1981-1998	18
Sivas	1983-1998	16	1983-1998	16	1983-1998	16
Şanlıurfa	1983-1998	16	1980-1993	14	-	-
Tekirdağ	1983-1998	16	1983-1998	16	1983-1998	16
Tokat	1981-1998	17	1981-1998	18	1981-1998	17
Trabzon	1983-1998	16	1981-1996	16	1990-1996	7
Tunceli	1981-1998	18	1981-1998	18	1981-1998	18
Uşak	1981-1998	18	1981-1998	18	1981-1998	18
Van	1983-1998	16	1981-1995	15	1990-1996	7
Yalova	1981-1998	18	1981-1998	18	1981-1998	18
Yozgat	1983-1998	16	1983-1998	16	1983-1998	16
Zonguldak	1981-1998	18	1981-1998	18	1981-1998	18

3. 2. Energy Estimating Methods

Energy requirement and fuel consumption of HVAC systems have a direct impact on the cost of operating a building and an indirect impact on the environment. All building energy calculations start with the space and building peak heating and cooling loads. The practicing HVAC system designer is more concerned with these peak loads and required equipment sizes than with the prediction of the building energy requirements. However, it is often necessary to estimate energy requirements and fuel consumption of HVAC systems for short or long-term operation. Procedures of energy estimation can be much more difficult than calculating design loads or required system capacity. Several methods are available to estimate energy requirements, depending on the complexity of the case, the time step used and the amount of parameters taken into account. In general, the methods can be divided into two categories (ASHRAE, 1993; Kreider and Rabl, 1994):

- Steady-state methods: They include degree-day methods and bin methods. Based on steady-state assumptions and correlation, these methods only require simple inputs, but their accuracy and capability are also limited.
- Dynamic methods: They estimate and analyze the building energy consumption by modeling the dynamic behavior of buildings. They base on transfer functions. The most popular one is generally known as building energy simulation which models building energy performance over the time domain.

In this study, based on the availability of weather data, the need filling the gap in this area, and their simplicities, the steady-state methods were studied and the results obtained analyzed for Turkey.

3.2.1. Degree-Day Methods

The degree-day methods are the simplest methods and well-established tools for energy analysis if the buildings use, the efficiency of HVAC equipment, indoor temperature and internal gains are relatively constant. The value of degree-days is a measure used to indicate the demand for energy to heat or cool buildings. The monthly and/or annual cooling and heating requirements of specific buildings in different locations can be estimated by means of degree-days concept. The method assumes that the energy needs for a building are proportional to the difference between the mean daily temperature and a base temperature. The base temperature is the outdoor temperature below or above which heating or cooling is needed (ASHRAE,1993; Said, 1992).

The base temperature T_b for heating can be obtained as

$$T_b = T_i - \frac{q_{gain}}{K_{tot}} \qquad (3.2.1)$$

where q_{gain} [W] is the heat gain from sun, occupants, lights, and so forth. K_{tot} is the total heat loss coefficient of the building in W/°C. T_i is the indoor temperature.

The rate of energy consumption of the heating systems is

$$Q = \frac{K_{tot}}{\eta}[T_b - T_o(t)]^+ \qquad (3.2.2)$$

where η is the efficiency of HVAC system, T_o is outdoor temperature at time t. If T_b, K_{tot}, and η are constant, the annual heating consumption can be written as an integral

$$Q = \frac{K_{tot}}{\eta}\int[T_b - T_o(t)]^+ dt \qquad (3.2.3)$$

where the plus sign above the parentheses indicates that only positive values are to be counted. This integral of the temperature difference conveniently summarizes the effect of outdoor temperatures on a building. In practice, it is approximated by summing averages over short time intervals (daily or hourly); the result is termed degree-days or degree-hours.

If daily average values of outdoor temperature are used for evaluating the integral, the annual energy consumption in the terms of degree-days, Q_{year} [W.day] can be generally calculated as;

$$Q_{year} = \frac{K_{tot}}{\eta} DD \tag{3.2.4}$$

DD is the value of degree-days for heating or cooling. For heating, heating degree-days (*HDD*) can be determined using following expression;

$$\text{HDD} = (1\ \text{day}) \sum_{days} (T_b - T_m)^+ \tag{3.2.5}$$

in which, T_b is the base temperature and T_m is the daily mean outdoor temperature. Cooling degree-days (*CDD*) can be calculated analogous to heating degree-days;

$$\text{CDD} = (1\ \text{day}) \sum_{days} (T_m - T_b)^+ \tag{3.2.6}$$

The plus signs above the brackets of Eqs. 3.2.5 and 3.2.6 indicate that only positive values are to be counted. Using *HDD* and *CDD*, the annual heating consumption, Q_h, and the annual cooling requirements, Q_c, in terms of kWh can be calculated, respectively as;

$$Q_h = \frac{K_{tot}}{\eta} HDD \frac{24}{1000} \tag{3.2.7}$$

$$Q_c = \frac{K_{tot}}{\eta} CDD \frac{24}{1000} \tag{3.2.8}$$

Traditionally, heating degree-days are calculated at a base temperature of 18 °C (or 65 °F) and cooling degree-days are determined at a base temperature of 22 °C (71.6 °F) for a typical uninsulated building. However, the average value of T_b varies widely from one building to another, because of widely differing personal preferences for the settings of thermostat and of the thermostat setback and because of different building characteristics such as thermal insulation, air leakage and solar gains. Hence degree-days with a base temperature of 18 °C in heating or 22 °C in cooling must be employed with caution (Kreider and Rabl, 1994).

The traditionally used base temperatures have been questioned by a number of authors. Said (1992), found that a heating base temperature in the range of 18 °C to 21 °C is suitable in Saudi Arabia depending upon the insulation level. The recommended cooling base temperature is between 23 °C and 25.5 °C for buildings without insulation and between 25.5 °C and 27.8 °C for well-insulated buildings. Kodah and El-Shaawari (1990) recommended that heating base temperature of 15.5 °C (60 °F) in Jordan is appropriate. Badescu and Zamfir (1999) reported that 18 °C base temperature for heating degree-day calculations is appropriate for living and bedrooms in Romania.

Degree-days or degree-hours for a base temperature of 18 °C in Europe or 65 °F in the United States have been widely tabulated, based on the observation that this has represented average conditions in typical buildings. Listings of heating and cooling degree-days as monthly are indeed more quite common than yearly (Kreider and Rabl, 1994).

Several authors have proposed formulas for estimating the degree-days relative to an arbitrary base, when detailed data are not available for evaluating the integral in Equ. 3.2.3. Erbs *et al.* (1983) have developed a model that needs only the monthly mean temperatures of the year as input. Büyükalaca *et al.* (2000) applied the method of Erbs et al. (1983) to some provinces in Turkey. They found that there are no significiant differences between the values of the method and traditional values of degree-day method. They also recommended that when detailed data are available, the method of Erbs *et al.* (1983) should not be used.

3.2.2. Bin Method

There are many applications where the degree-day method should not be used, even with the variable base method, because the heat loss coefficient, the efficiency of the HVAC system, or the base temperature may not be sufficiently constant. The efficiency of a heat pump, for example, varies strongly with outdoor temperature; or the efficiency of the HVAC equipment may be affected indirectly by outdoor temperature when the efficiency varies with load, a common situation for boilers and chillers. Furthermore, in most commercial buildings, the occupancy has a very pronounced pattern, which affects the heat gains, the indoor temperature, and the ventilation rate.

In such cases, a steady-state calculation can yield good results for the annual energy consumption, if different temperature intervals and time periods are evaluated separately. This approach is called the bin method, because the consumption is calculated for several values of the outdoor temperature $T_{o,i}$ and multiplied by number of hours $N_{bin,i}$ in the temperature interval (bin) centered around that temperature (ASHRAE,1993):

$$Q_{bin,i} = N_{bin,i} \frac{K_{tot}}{\eta} \left(T_b - T_{o,i}\right)^{\pm} \tag{3.2.9}$$

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 (ASHRAE,1993; Said, 1992). The bin method can be used for predicting both heating and cooling energy requirements. The plus subscript on the parenthesis of Eq. 3.2.9 is for heating and indicates that only positive values are to be counted. For cooling, only negative values should be considered.

Q_{bin} values are calculated separately using Eq. 3.2.9 for each temperature interval (bin) and summed to obtain total energy consumption :

$$Q_{tot} = \sum_{i=1}^{m} Q_{bin,i} \tag{3.2.10}$$

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

In the United States, the necessary data, called bin data, are widely available. The bins are usually in 2.8 °C increments and are often collected in three daily 8-h shifts. For enhanced flexibility, the data may be given for each month and for several periods of the day. Mean coincident wet-bulb temperature data (for each dry-bulb bin) are used to calculate latent cooling loads from ventilation and infiltration. The bin method considers both occupied and unoccupied building conditions and gives credit for internal loads by adjusting the base temperature. For example, a calculation would be performed for 4.5 °C outdoors (representing all occurrences from 3 to 6 °C) and with building operation during the midnight to 08:00 shift. Since there are twenty 3 °C bins between –24 and 39 °C and 3 shifts, 60 separate operating points are calculated. For many applications, the number of calculations can be reduced. A residential heat pump (heating mode), for example, could be calculated for just the bins below 18 °C without the three-shift breakdown (ASHRAE, 1993).

Various refinements, such as the seasonal variation of solar gains, can be included in a bin calculation. If a separate calculation is performed for each month, Q_{bin} could be based on the average solar heat gain of the month. The diurnal variation of solar gains can be accounted for by calculating the average solar gain for each of the hourly time periods of the bin method. If such a detailed calculation of solar gains is considered too tedious or if great accuracy in the treatment of solar gains is not required, one can take a shortcut and assume a linear correlation of monthly average solar heat gains with monthly average outdoor temperature. This approach called modified bin method (Hui, 1996; ASHRAE, 1993).

Since the bin method is based on hourly weather data rather than daily averages, it is more accurate than the degree-day method (Al-Homoud, 2001). 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 (Papakostas, 1999).

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 (Degelmen, 1985).

Although degree-days data are often available in Turkey, the bin weather data are rarely known, since they have never been calculated in a form which is appropriate for the bin method. The bin weather data for provinces of Turkey elaborated and presented in this study.

3.3. Outdoor Design Conditions

HVAC systems must counteract weather forces when outdoor temperature or humidity moves away from an acceptable range for safety and comfort. Consequently, a clear understanding of weather behaviour is helpful for system designers and operators. Shortcomings in that understanding are often at the root of problems involving poor indoor air quality and premature deterioration of buildings and HVAC equipment (Harriman *et al.*, 1999).

Outdoor design conditions are weather data information for design purposes showing the characteristic features of the climate at a particular location. They are usually determined by statistical analyses of long-term weather data and may include information on air temperature, humidity, wind, rainfalls and solar data. The climatic design information is commonly used for design, sizing, distribution, installation, and marketing of heating, ventilating, air-conditioning, and dehumidification equipment; as well as for other energy-related processes in residential, agricultural, commercial and industrial applications.

Outdoor design conditions affect building loads and economical design. The effect of incorrect selection of outdoor conditions can be dramatic. If some very conservative, extreme conditions are taken, uneconomic design and oversizing may result. If design loads are underestimated, equipment and system operation will be affected.

Outdoor design temperatures which indicate the extreme conditions for thermal load calculations are the most important parameters. The choice of these design temperatures depends on the assignment of design requirements and contingency involved. Current methods for determining outdoor design temperatures are similar in basic principle. Design temperatures for summer and winter periods are specified respectively by the highest and lowest temperatures likely to be encountered at a specific frequency of occurrence.

ASHRAE (ASHRAE, 1993) recommends climatic conditions in the United States, Canada, and other countries. The design temperatures are based on the assumption that the frequency level of a specific temperature over a suitable time period will repeat in the future. The selected frequencies enable the engineer to match the risk level desired to the problem at hand. As winter design conditions, two frequency levels are offered for each station representing temperatures that have been equaled or exceeded by 99% or 97.5% of total hours in the months of December, January, and February (a total of 2160 h). In a normal winter, there would be approximately 22 h at or below the 99% value and 54 h at or below the 97.5% value. As summer design conditions, the dry-bulb temperatures with their coincident wet-bulb temperatures are recommended with three frequency levels. The dry-bulb temperatures represent values that have been equaled or exceeded by 1%, 2.5%, and 5% of total hours during the months of June through September (a total of 2928 h). In a normal summer, it could be expected that there would be approximately 29 h at or above %1 value, 73 h at or above 2.5% value, and 146 h at or above %5 value. The coincident wet-bulb temperature listed with each design dry-bulb temperature is the mean of all wet-bulb temperatures occurring at the specific dry-bulb temperature.

The selection of frequency as risk level in design conditions depends on applications. For ordinary buildings, it is customary to base the design on level of 2.5 in summer and 97.5 in winter. For critical applications such as hospitals or sensitive industrial processes or for lightweight buildings, one may prefer more stringent level of 1% in summer (99% in winter). A 5% level may suffice for applications where comfort conditions are not critical (Kredider and Rabl, 1994).

In Chapter 26 of the 1997 ASHRAE Handbook-Fundamentals, new peak design conditions for sizing equipment were redefined. Design values of temperature and humidity have been updated from the 1993 ASHRAE-Handbook. The temperature and humidity conditions previously provided for at 1, 2.5, and 5 percentile frequency of occurrence during summer months have been replaced by conditions corresponding to annual percentile values of 0.4, 1, 2. Winter month conditions for 99 and 97.5 percentiles have been replaced by conditions based on annual percentiles of 99.6 and 99. This change was made in order to provide design conditions representing the same probability of occurrence anywhere, regardless of the seasonal distribution of extreme temperature and humidity. Previously, the summer and winter months used for the calculation of design conditions varied on location. For instance, summer design conditions for the United States were calculates over the four month period from June through September, whereas Canadian summer design conditions were based on only the month of July. So, the 1997 ASHRAE-Handbook data is based on annual extremes rather than seasonal or single-month peaks.

New recommended design temperatures for worldwide stations by ASHARE-Handbook 1997 were presented by using the frequency levels. For heating, two frequency levels were offered for each station representing temperatures that have been exceeded by 99% or 99.6% of the total hours in entire year (8760 h). In a normal heating season, there would be approximately 35 h below the 99.6% value and 88 h below the 99% value. The percentiles of 0.4%, 1% and 2 % for cooling were recommended. The dry-bulb temperatures represent values that have been exceeded by 0.4%, 1%, and 2% of the entire year's observations (8760 h). For cooling season, there would be approximately 35 h above the 0.4% value, 88 h above the 1% value, and 175 h above the 2% value.

The annual extreme temperatures data were also presented in ASHRAE-Handbook 1997. These data are the mean and standard deviation of the annual extreme maximum and minimum dry-bulb temperatures. The probability of occurrence of very extreme conditions can be required for the operational design of equipment to ensure continuous operation and serviceability (regardless of whether the heating or cooling loads are being met).

The mean daily range is the mean difference between the daily maximum and minimum temperatures during the hottest month. These values are calculated from the extremes of hourly temperature observations. The true maximum and minimum temperatures for any day generally occurs between hourly readings. Thus, the true daily temperature range is generally greater than the mean daily range calculated from hourly observations. This information was also discussed in ASHRAE-Handbook 1997.

In this study, winter and summer design conditions were calculated according to ASHRAE-Handbook 1997. In Turkey, wet-bulb temperature was recorded only at 07:00, 14:00, and 21:00 o'clock. For determining coincident wet-bulb temperatures for dry-bulb temperatures the following procedure was used: The variation of humidity ratio (absolute humidity) during day is insignificant, especially in summer season. Humidity ratio does not fluctuate and it can be accepted to be constant for the whole day (Yılmaz *et al.*, 1995; Yılmaz and Bulut, 1996; Al-Rabghi and Hittle, 2001). Therefore, firstly humidity ratio was calculated at 07:00, 14:00, and 21:00 o'clock using the measured wet and dry-bulb temperatures at these hours. From the humidity ratio obtained and measured dry-bulb temperature, the wet-bulb temperatures were calculated for each hour of the day using psychrometric equations (ASHRAE, 1993).

3.4. Psychrometric Equations

The atmosphere is a mixture of air (oxygen and nitrogen) and water vapor. Psychrometrics is the study of the physical and thermodynamic properties of the atmospheric air. The state of the atmospheric air at a specified pressure is completely specified by two intensive properties. The rest of the properties can be calculated easily from the thermodynamics relationships. Although the psychrometric chart graphically represents the interrelation of air temperature and moisture content and is a basic design tool for building engineers and designers, the properties of the atmospheric air can be calculated easily using the psychrometric equations.

The psychrometric equations used for determining weather data (humidity ratio and wet bulb temperature) in this study are presented below (ASHRAE, 1993; Papakostas, 1999):

The saturation pressure of water vapor P_{ws} is determined as a function of the dry-bulb temperature. Over ice for the temperature range of –100/0 °C, it is given by:

$$P_{ws} = \exp\left(\frac{C_1}{T} + C_2 + C_3 T + C_4 T^2 + C_5 T^3 + C_6 T^4 + C_7 \ln(T)\right) \quad (3.4.1)$$

Over liquid water for the temperature range of 0-200 °C is given by:

$$P_{ws} = \exp\left(\frac{C_8}{T} + C_9 + C_{10} T + C_{11} T^2 + C_{12} T^3 + C_{13} \ln(T)\right) \quad (3.4.2)$$

where C_1-C_{13} are constants and their values are given below:

$C_1 = -5.6745359.10^{3}$	$C_8 = -5.8002206.10^{3}$
$C_2 = -5.1523058.10^{-1}$	$C_9 = -5.5162560$
$C_3 = -9.6778430.10^{-3}$	$C_{10} = -4.8640239.10^{-2}$
$C_4 = 6.2215701.10^{-7}$	$C_{11} = 4.1764768.10^{-5}$
$C_5 = 2.074782.10^{-9}$	$C_{12} = -1.4452093.10^{-8}$
$C_6 = -9.4840240.10^{-13}$	$C_{13} = 6.545973$
$C_7 = 4.1635019$	

The water vapor partial pressure P_w is calculated as a function of the saturation pressure and relative humidity φ:

$$P_w = \varphi P_{ws} \quad (3.4.3)$$

The humidity ratio W is determined as a function of the atmospheric pressure P_a and partial water vapor pressure in term of gr/kg-dry air:

$$W = 0.62198 \frac{P_w}{100.P_a - P_{ws}} 1000 \quad (3.4.4)$$

The average atmospheric pressure on earth is approximated as a function of altitude by relation:

$$P_a = 101325(1 - 0.02256z)^{5.256} \quad (3.4.5)$$

where P_a is the atmospheric pressure in Pa and z is elevation in m with z=0 m at sea level (Çengel and Michael, 1998).

The saturated humidity ratio W_s is determined as a function of the saturation pressure:

$$W_s = 0.62198 \frac{P_{ws}}{100.P_a - P_{ws}} 1000 \quad (3.4.6)$$

The wet bulb temperature T_w is calculated iteratively as follows:

$$W = \frac{(2501 - 2.381T_w)W_s - (T_d - T_w)}{2501 + 1.805T_d - 4.186T_w} \quad (3.4.7)$$

where T_d is dry-bulb temperature.

3. 5. Models for Generation of Weather Data

Computer programs for energy simulation, energy estimation methods or even manual detailed energy calculation have a common input of weather data, usually preferred as hourly. The predicted performance or energy requirements of an HVAC system depend on these weather inputs. Simulations and energy estimation calculations can be performed with a specific year's data which is already available. However, there is no evidence that the weather data selected randomly is representative for the average situations for the simulation period. The weather data used can be a year's data which has passed colder than the other years and the result will be a higher energy demand for the heating energy estimations or less cooling energy requirements for cooling purposes. In addition, a system, which performs well for one set of inputs, may perform poorly for another set. Therefore, development of procedures for determining hourly weather data for a building location for an entire year received a great deal of attention.

It is not appropriate to average the hourly components of weather data over many years because this will wipe out peaks of high and low temperatures that affect the cost of operation of an HVAC system. Furthermore, hourly data is not available at all locations. Methods for developing annual weather data evolved over time separating the studies basically into two philosophy, one of which is the generation of each weather variable and the other is the selection of weather data among the real recorded data.

Many studies have been performed to develop models for generation of typical weather variables, both daily and hourly. However, since weather variables are neither completely random nor deterministic, it is very difficult to present all variance mathematically. They can be described as irregular functions of time. Although, a quite number of models for solar radiation have been developed, there are some models for dry-bulb temperature.

Time series and Fourier series analysis techniques were mostly used for synthetic generation of weather variables. The advantage of the synthetically generation of weather variable is the use mathematical expressions in the computer programs and thus, not requiring an input for variables and database files for simulation. However, the researchers have all concluded that the error of the generated data from the measured data could be due to the fact that generating the weather variables synthetically may not include or represent the real cross-correlation and auto-correlation of weather variables.

The real recorded hourly data from past weather data are selected for generation of representative weather data. A representative database for the one-year duration (8760 h) is known as Test Reference Year (TRY) or Typical Meteorological

Year (TMY). TMY or TRY consists of months selected from individual years and concatenated to form a complete year. Crow (1981) has developed representative weather data, so called the weather year for energy calculations (WYEC), for the American Society of Heating, Refrigeration and Air-Conditioning (ASHRAE).

The properties of a weather model can be as follows (Yoshida and Terai, 1992):

- More reliable statistical properties: Weather varies with time, not only deterministically due to diurnal and annual periodicity, but also randomly due to unpredictable atmospheric conditions. Therefore, several years of weather data, such as 10 years or more, are required to the statistical reliability of estimated loads. Providing a weather model, which contains long-term statistical properties and by which any length of data can be generated, is more desirable than providing many years of data as in the TRY.
- Treating climatic change and differences between locations: A weather data model, with which one can analyze how much change took place and in what component, can incorporate the change by putting adequate modifications in parameters.
- Handling of incomplete weather record: A complete hourly weather record is not always obtainable. This makes it difficult to create Reference Year weather data. If a systematic procedure can be developed to treat incomplete data, it will help scientists provide weather data for many sites.
- Accomplishing data compaction: The Reference Year contains 8760 h data values. The number is easier to handle now, because computer performance has increased significantly, but reducing the amount of data is preferable. The data can be compacted to a small number of parameters by modeling.
- A new load calculation method: Strictly speaking, all mechanisms related to air-conditioning load calculations, such as heat transfer through walls and radiative exchange between walls, are formulated as a nonlinear system. However, they can be simplified as linear system without creating much error, and this simplification is adopted in many load calculation methods. Therefore, load calculations can be approximately regarded to find the output

of a linear system with weather data as input. In addition, if a weather model can be constructed as a linear system and the statistical properties of loads can be determined directly based on system theory without hour-by-hour load simulations. Therefore, providing weather data as a linear model is one of the objectives.

In the present study, four weather elements-daily maximum dry-bulb temperature, daily minimum dry-bulb temperature, daily mean humidity ratio, and hourly dry-bulb temperature- are modeled with trigonometric functions, the parameters considered are the most important elements in load calculations.

The parameters of the recommended equations for weather elements were determined by means of statistical analysis. The following statistical indicators were used (Johnson and Bhattacharyya, 1996; Daniel and et al. 1971):

- Root Mean Square Error (RMSE):

$$RMSE = \left(\frac{\sum_{i=1}^{m} \left(CV_i - MV_i \right)^2}{m - m_p} \right)^{1/2} \quad (3.5.1)$$

where CV denotes the value calculated from the equation, MV denotes the measured value, m is the number of values, and m_p is the number of parameters in the particular model (m_p=2 for model used in this study).

- Absulate Error (AE):

$$AE = |CV - MV| \quad (3.5.2)$$

- Relative Error (RE)

$$RE = \frac{|CV - MV|}{MV} \quad (3.5.3)$$

- Correlation Coefficient (r):

$$r \equiv \sqrt{\frac{S_t - S_r}{S_t}} \tag{3.5.4}$$

where S_t and S_r are defined as follow:

$$S_t = \sum_{i=1}^{m} (MMV - MV_i)^2 \tag{3.5.5}$$

where MMV is the average of measured values is simply given by

$$MMV = \frac{\sum_{i=1}^{m} MV_i}{m} \tag{3.5.6}$$

$$S_r = \sum_{i=1}^{m} (MV_i - CV_i)^2 \tag{3.5.7}$$

For better data modeling, the RMSE, AE and RE must be minimal and the correlation coefficient r must approach unity as close as possible. In this study, the coefficients of the equations obtained were determined by considering the mean of RMSE, AE and RE by using long-term measured data.

4. RESULTS AND DISCUSSION

4. 1. Degree-Days

Degree-day values are main input data to many manual and computer-based procedures for estimating the energy use of buildings. The degree-day values are proportional to the difference between the mean daily temperature and a base temperature. The base temperature value varies widely from one building to another because of widely differing personal preferences for thermostat settings and setbacks and because of different building characteristics. Hence, degree-day with the traditional base 18 °C is not always acceptable. The degree-days with variable base temperature must be calculated.

Although some independent studies on degree-days for Turkey mentioned in literature reviews have been performed, well-established and reliable databases that can be used directly by designers and energy managers still do not exist. Not all of the cities of Turkey were considered in some of the studies, and in some studies, the results were based on the data obtained during a short-period of time (only a few years) or the data measured in recent years were not used. In some studies, the results were presented only for one base temperature.

In the present study, both heating and cooling degree-days with different base temperatures were calculated by using long-term recent measured data for 78 provinces of Turkey. In calculation of degree-days, daily mean temperatures were obtained by averaging the maximum and minimum temperatures. The information about the database for daily extreme temperatures used in the calculations are given in Table 3.1.2.

4.1.1. Heating Degree-Days

Heating degree-days with 14, 16, 18, 20, and 22 °C base temperatures were calculated for all provinces taken into consideration. The heating degree-day values can be presented monthly and yearly. Table 4.1.1. shows monthly heating degree-days for main cities which represent the all meteorological regions of Turkey. It can be concluded from the monthly degree-days data provided in the table that Turkey has different climatic regions. The monthly degree-days show that the climate of Turkey is very different. For example, Although Adana does not have degree-days in the months between May and September, Erzurum has significant degree-day values in all months. This shows that Erzurum needs more heating energy than Adana. As it can be expected from definition of the degree-day, when the base temperature is increased, the degree-days values increases. This is shown in the Table 4.1.1 throughout the year.

Figure 4.1.1. shows the variation of degree-day values at 18 °C for main provinces of Turkey. The monthly degree-days shown in this Figure exhibit a similar profile for all provinces. As can be seen from the Figure, whilst Ankara, Diyarbakır, İstanbul and Samsun need more heating than İzmir and Adana, it is clear that Erzurum needs more heating than the others.

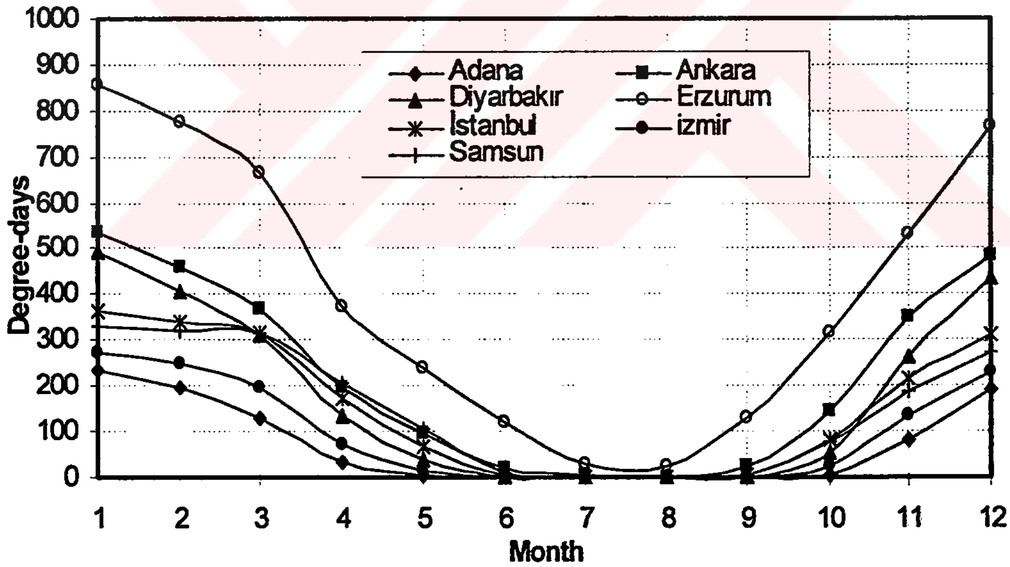


Figure 4.1.1. Variation of monthly heating degree-days at 18 °C base temperature for main provinces of Turkey

Table 4.1.1. Monthly heating degree-days for main provinces of Turkey

Province	Month	Base Temperature [°C]				
		14	16	18	20	22
Adana	1	112	173	235	297	359
	2	90	142	197	253	309
	3	39	78	131	190	252
	4	3	11	33	70	120
	5	0	1	4	16	39
	6	0	0	0	0	1
	7	0	0	0	0	0
	8	0	0	0	0	0
	9	0	0	0	0	0
	10	0	1	4	12	30
	11	20	42	79	129	185
	12	77	131	191	253	315
	Total	341	579	874	1220	1610
Ankara	1	414	476	538	600	662
	2	346	402	458	514	570
	3	246	307	369	431	493
	4	92	140	195	254	313
	5	30	58	98	147	204
	6	1	5	18	45	86
	7	0	1	3	11	32
	8	0	0	2	9	25
	9	2	9	23	50	91
	10	55	93	143	201	261
	11	228	287	347	407	467
	12	359	421	483	545	607
	Total	1773	2199	2677	3214	3811
Diyarbakır	1	371	433	495	557	619
	2	296	352	408	464	520
	3	187	248	310	372	434
	4	46	86	136	193	253
	5	5	16	38	72	117
	6	0	0	0	2	9
	7	0	0	0	0	0
	8	0	0	0	0	0
	9	0	0	1	3	9
	10	10	25	53	97	151
	11	147	204	264	324	384
	12	313	375	437	499	561
	Total	1375	1739	2142	2583	3057
Erzurum	1	734	796	858	920	982
	2	663	719	775	831	887
	3	542	604	666	728	790
	4	253	313	373	433	493
	5	117	175	237	299	361
	6	30	67	118	176	236
	7	3	9	27	62	113
	8	2	8	25	61	113
	9	44	81	131	188	247
	10	193	255	317	379	441
	11	413	473	533	593	653
	12	643	705	767	829	891
	Total	3637	4205	4827	5499	6207

Table 4.1.1. (Continued) Monthly heating degree-days for main provinces of Turkey

Province	Month	Base Temperature [°C]				
		14	16	18	20	22
İstanbul	1	239	301	363	425	487
	2	230	285	341	397	453
	3	195	254	315	377	439
	4	72	118	171	229	288
	5	11	31	65	112	167
	6	0	1	3	13	41
	7	0	0	0	2	9
	8	0	0	0	1	7
	9	0	1	6	21	54
	10	17	41	79	130	187
	11	104	154	213	272	332
	12	186	247	309	371	433
	Total	1054	1433	1865	2350	2897
İzmir	1	154	213	275	337	399
	2	140	193	248	304	360
	3	88	136	195	256	318
	4	14	36	72	120	175
	5	1	3	12	32	66
	6	0	0	0	1	3
	7	0	0	0	0	0
	8	0	0	0	0	0
	9	0	0	0	1	7
	10	3	9	23	51	93
	11	50	87	135	191	250
	12	112	168	228	290	352
	Total	562	845	1188	1583	2023
Samsun	1	208	268	330	392	454
	2	212	265	320	376	432
	3	197	256	316	378	439
	4	98	150	206	264	323
	5	24	56	105	162	222
	6	0	1	8	33	80
	7	0	0	0	2	15
	8	0	0	0	1	10
	9	0	1	7	26	66
	10	12	35	75	127	185
	11	87	131	185	242	302
	12	158	214	274	336	398
	Total	996	1377	1826	2339	2926

Table 4.1.2 shows the annual heating degree-days for 14, 16, 18, 20, and 22 °C base temperatures. As can be seen from the table, significant differences between the values of heating degree-days for different locations are evident at the same base temperature. For example, the annual heating degree-days for İskenderun (located in the east Mediterranean) is 690, while it is 5137 for Ardahan (located in the northeast), at a base temperature of 18 °C. This shows that a building in Ardahan needs 7.44 times more heating energy than a building located in İskenderun, both having the same characteristics.

Figure 4.1.2 shows variation of the annual heating degree-days with base temperature for main provinces of Turkey. The heating degree-days increase almost linearly with increasing base temperature. Increasing base temperature from traditionally accepted value of 18 °C to 20 °C results in approximately 14 % higher heating degree-days in Erzurum, whilst the increase is about 40 % in Adana. Therefore, thermal characteristics of the building and preferences of the occupants should be changed to lower the base temperature if possible. To lower the base temperature, thermostat settings should be reduced to the lower end of the comfort region, thermal insulation should be applied to buildings and air leakage should be minimised. Another factor that affect the value of the base temperature is the solar gains. Buildings should be constructed in such a way that they can receive the maximum possible solar radiation during the heating season and the minimum during the cooling season. A reduction in base temperature from 18 °C to 16 °C lowers heating-degree days approximately 13 % in Erzurum and 34 % in Adana.

A counter map of the annual heating degree-days at 18 °C base temperature is depicted in Figure 4.1.3. The figure shows clearly non-uniformity of the climate of Turkey. For locations near to the sea costs, the heating degree-days have lower values compared with the eastern and the inner regions. The higher degree-days appear in the Eastern and in the Northeastern Turkey. The counters are close to each other in the lower part of the inner region (around Niğde), in the east and in the northeast. This shows a rapid climate change in short distances due to mountainous nature of the landscape in these regions.

Table 4.1.2. The annual heating degree-days for Turkey.

Province	Base Temperature [°C]				
	14	16	18	20	22
Adana	341	579	874	1220	1610
Adapazarı	1049	1413	1833	2309	2862
Adıyaman	995	1328	1695	2094	2527
Afyon	1878	2325	2828	3395	4025
Ağrı	3353	3867	4423	5031	5692
Aksaray	1743	2157	2626	3153	3738
Amasya	1393	1778	2210	2700	3256
Ankara	1773	2199	2677	3214	3811
Antalya	439	731	1083	1481	1926
Ardahan	3861	4469	5137	5845	6571
Artvin	1535	1951	2429	2983	3619
Aydın	580	867	1213	1603	2037
Balıkesir	1128	1498	1914	2381	2907
Bartın	1330	1747	2226	2777	3403
Batman	1117	1450	1823	2235	2683
Bayburt	3006	3545	4149	4807	5510
Bilecik	1521	1933	2397	2922	3517
Bingöl	1994	2399	2838	3319	3848
Bitlis	2340	2800	3311	3863	4473
Bolu	1832	2291	2821	3423	4091
Burdur	1496	1902	2351	2848	3406
Bursa	1117	1491	1920	2401	2948
Çanakkale	1003	.1371	1789	2258	2782
Çankırı	1928	2370	2864	3418	4035
Çorum	1965	2428	2958	3563	4234
Denizli	907	1245	1627	2052	2520
Diyarbakır	1375	1739	2142	2583	3057
Edirne	1403	1791	2224	2708	3250
Elazığ	1805	2211	2653	3135	3662
Erzincan	2129	2564	3047	3577	4164
Erzurum	3637	4205	4827	5499	6207
Eskişehir	2043	2516	3049	3649	4310
Gaziantep	1242	1605	2009	2450	2926
Giresun	957	1328	1765	2263	2830
Gümüşhane	2228	2702	3234	3832	4492
Hakkari	2543	2986	3470	3997	4564
Hatay	528	797	1119	1489	1906
Iğdır	1914	2319	2764	3256	3792
İskenderun	218	420	690	1022	1406

Table 4.1.2. (Continued) The annual heating degree-days for Turkey

Province	Base Temperature [°C]				
	14	16	18	20	22
Isparta	1684	2120	2607	3156	3763
İstanbul	1054	1433	1865	2350	2897
İzmir	562	845	1188	1583	2023
K. Maraş	954	1284	1653	2059	2500
Karaman	1809	2229	2698	3222	3809
Kars	3573	4145	4772	5451	6168
Kastamonu	2088	2567	3112	3726	4402
Kayseri	2120	2587	3113	3704	4359
Kilis	877	1196	1554	1948	2372
Kırıkkale	1731	2145	2609	3129	3711
Kırklareli	1429	1828	2274	2770	3326
Kırşehir	1923	2365	2857	3404	4018
Kocaeli	1015	1375	1786	2257	2790
Konya	1916	2350	2836	3371	3968
Kütahya	1899	2360	2880	3469	4120
Malatya	1648	2037	2461	2923	3431
Manisa	843	1166	1535	1947	2400
Mardin	1270	1621	2004	2421	2869
Mersin	311	552	852	1211	1622
Muğla	1081	1458	1879	2339	2847
Muş	2656	3088	3563	4082	4647
Nevşehir	2044	2508	3033	3626	4281
Niğde	1922	2362	2856	3414	4038
Ordu	984	1361	1804	2303	2869
Rize	991	1375	1820	2331	2912
Samsun	996	1377	1826	2339	2926
Siirt	1230	1577	1958	2374	2826
Sinop	1038	1430	1879	2390	2969
Sivas	2412	2896	3444	4061	4732
Şanlıurfa	852	1157	1503	1885	2303
Tekirdağ	1193	1586	2032	2531	3098
Tokat	1534	1938	2399	2922	3516
Trabzon	923	1291	1724	2223	2800
Tunceli	1880	2280	2716	3198	3727
Uşak	1525	1945	2414	2939	3526
Van	2454	2938	3476	4069	4721
Yalova	1033	1409	1843	2340	2903
Yozgat	2350	2853	3422	4057	4743
Zonguldak	1162	1557	2020	2557	3181

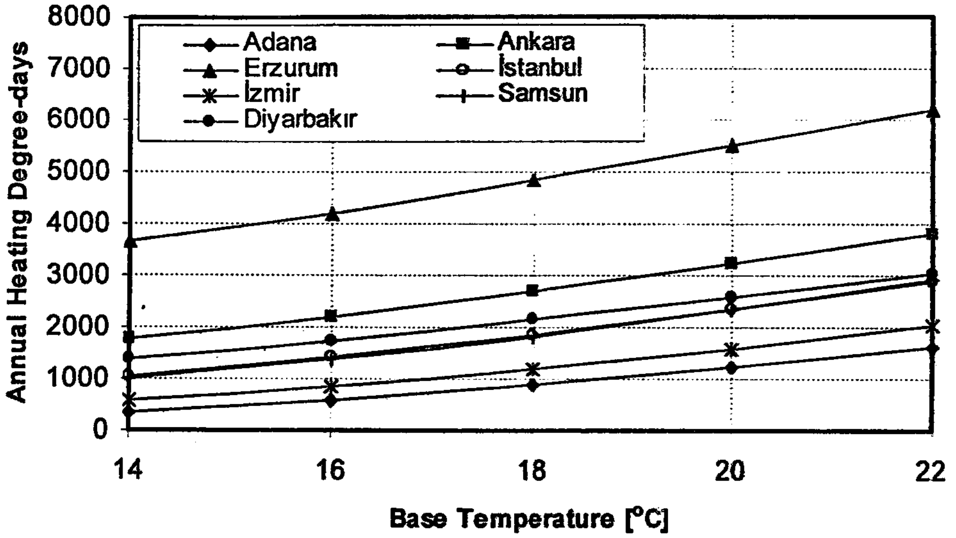


Figure 4.1.2. Variation of yearly heating degree-days with base temperature for main provinces of Turkey

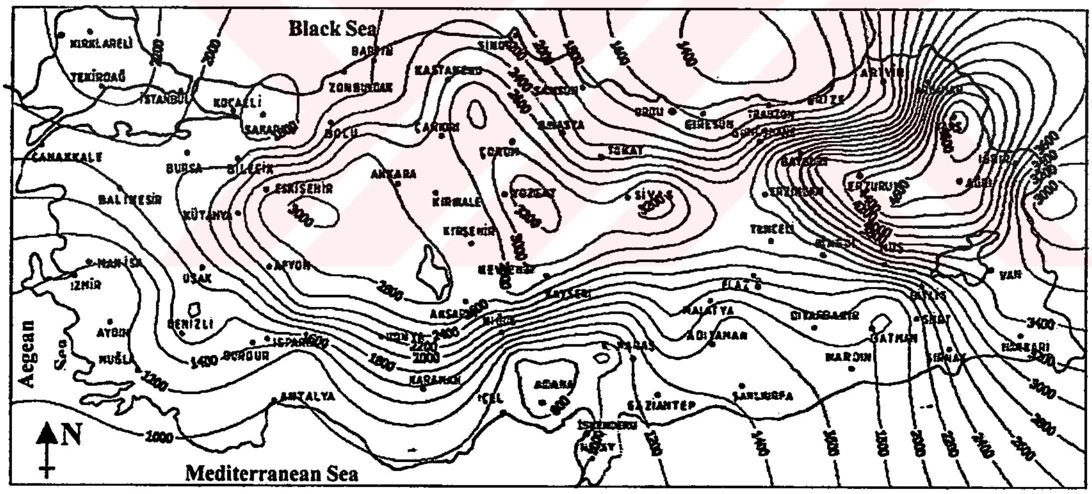


Figure 4.1.3. The counter map of yearly heating degree-days at 18 °C base temperature for Turkey

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 m and 1869 m. A correlation between the heating degree-days and elevation is evident from Figure 4.1.4. The value of the heating degree-days increases with elevation, although the data points scatter. The scatter is mainly due to effects of latitude and longitude. The combined influences on heating degree-days of elevation and latitude and of elevation and longitude are shown in the form of three-dimensional graphs in Figures 4.1.5. and 4.1.6, respectively. It is clear from Figure 4.1.5. that, heating degree-days are generally higher when both elevation and latitude are high, although there are some non-uniformities. They are quite small at the opposite corner (both elevation and latitude are low). Figure 4.1.6 shows the combined influences of elevation and longitude. The value of heating degree-days is generally higher for the regions having high elevation and high longitude.

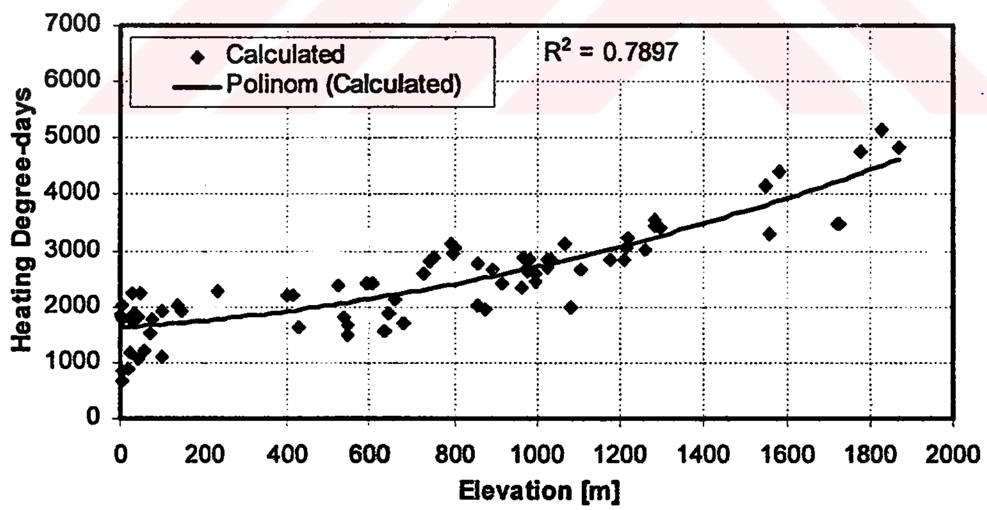


Figure 4.1.4. Variation of yearly heating degree-days with elevation for Turkey

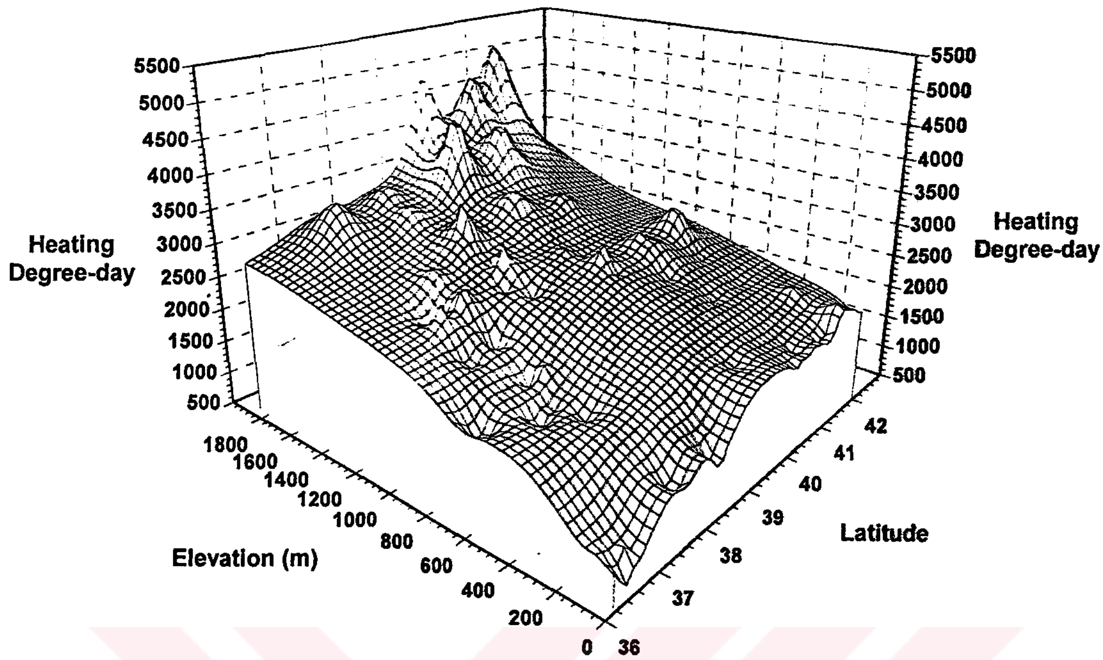


Figure 4.1.5. Variation of yearly heating degree-days with elevation and latitude for Turkey

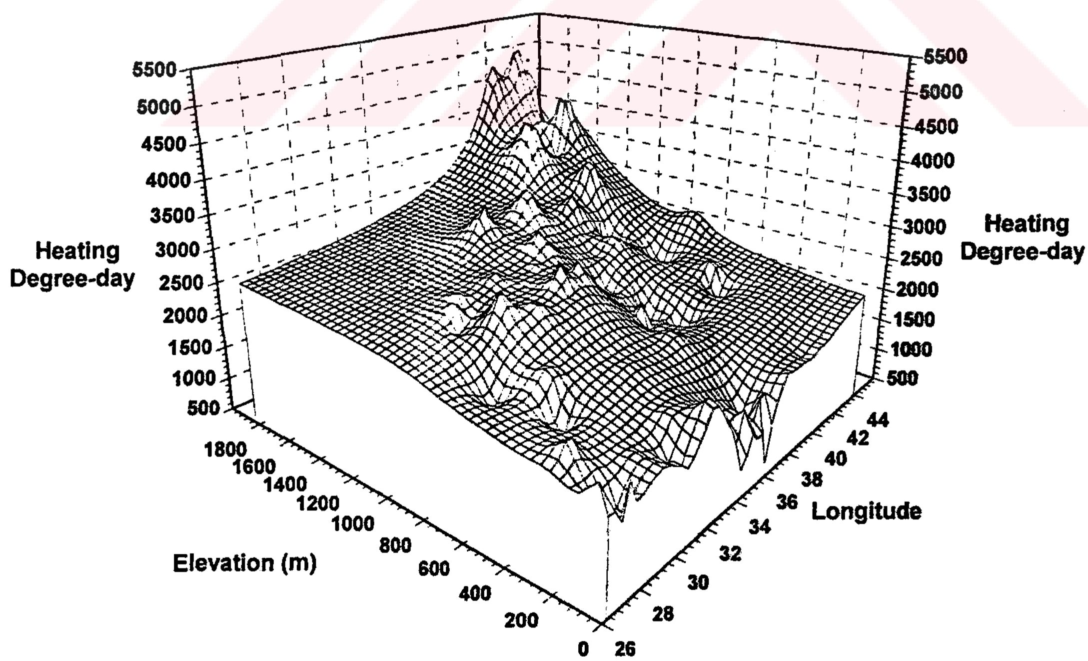


Figure 4.1.6. Variation of yearly heating degree-days with elevation and longitude for Turkey

A geographical area can be divided into climate regions according to degree-day values. These regions generally called degree-day regions instead of climate regions. Degree-day regions are used in calculation of thermal insulation of buildings for different locations (TS825,1999; Dağsöz and Bayraktar, 1999).

Based on the degree-days obtained in this study, Turkey can be divided into 5 different heating degree-day regions. Since the raw data used in this study were obtained from the weather stations located in the city centers, the classification is based on the center of the provinces. In determination of regions, first of all the degree-days are put in ascending order (Figure 4.1.7) and they were grouped considering the following criteria : In the same region, ratio of the maximum heating-days to the minimum heating degree-days at 18 °C base temperature should not exceed 1.5. Table 4.1.3 gives proposed heating degree-day regions for Turkey. There are 6 provinces in 1st region, 27 provinces in 2nd region, 28 provinces in 3rd region, 12 provinces in 4th region, and 5 provinces in 5th region. The classification is also shown on the map of Turkey in Figure 4.1.8.

Table 4.1.3. Heating degree-day regions for Turkey

Region	Province					
I	Adana	Antakya	Antalya	Aydın	İzmir	Mersin
II	Adapazarı	Adıyaman	Balıkesir	Batman	Bursa	Çanakkale
	Denizli	Diyarbakır	Gaziantep	Giresun	İstanbul	K. Maraş
	Kilis	Kocaeli	Manisa	Mardin	Muğla	Ordu
	Rize	Samsun	Siirt	Sinop	Şanlıurfa	Tekirdağ
	Trabzon	Yalova	Zonguldak			
III	Afyon	Aksaray	Amasya	Ankara	Artvin	Bartın
	Bilecik	Bingöl	Bolu	Burdur	Çankırı	Çorum
	Edirne	Elazığ	Iğdır	Isparta	Karabük	Karaman
	Kırıkkale	Kırklareli	Kırşehir	Konya	Kütahya	Malatya
	Niğde	Tokat	Tunceli	Uşak		
IV	Bitlis	Erzincan	Eskişehir	Gümüşhane	Hakkari	Kastamonu
	Kayseri	Muş	Nevşehir	Sivas	Van	Yozgat
V	Ağrı	Ardahan	Bayburt	Erzurum	Kars	

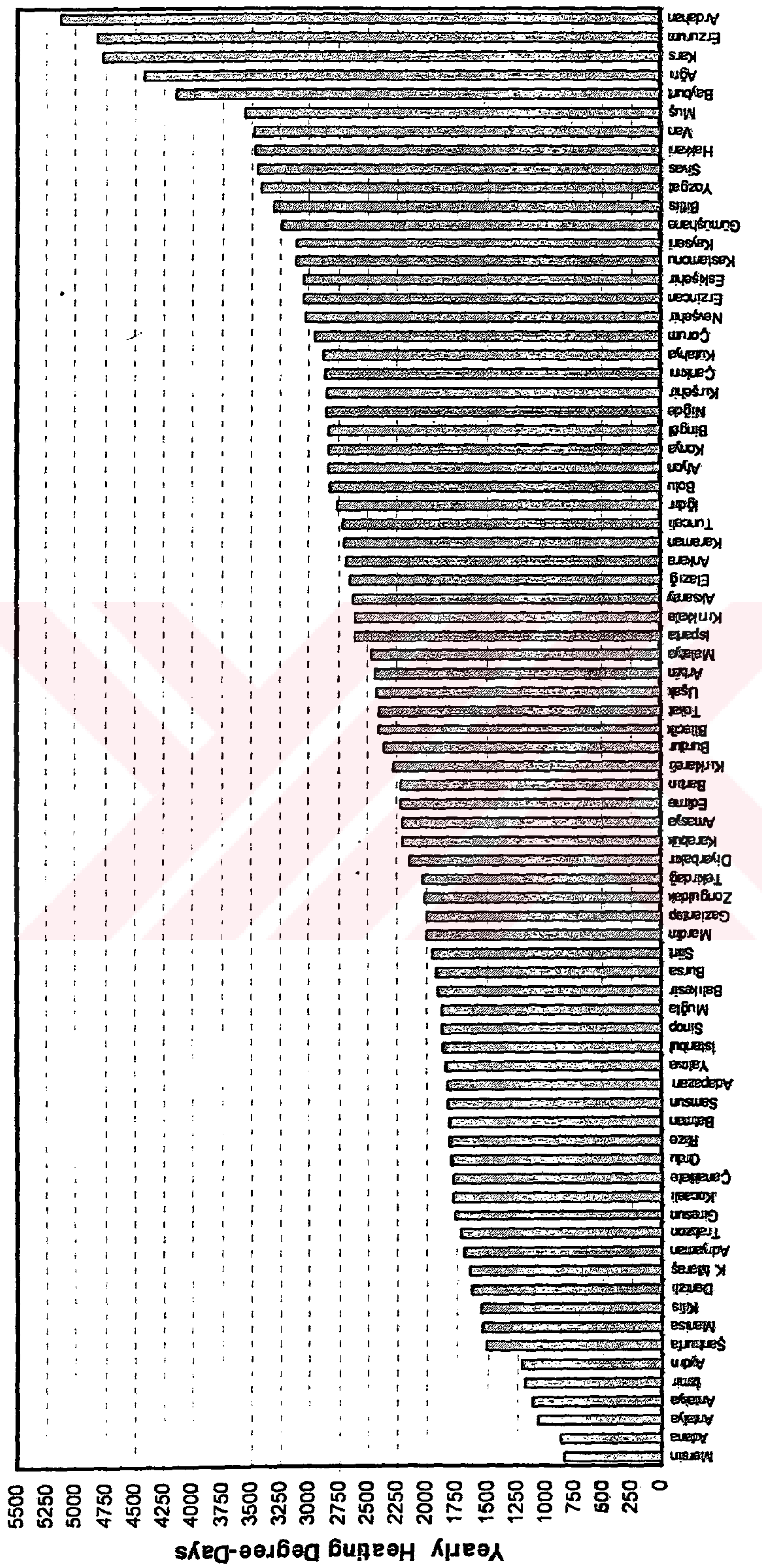


Figure 4.1.7. Yearly heating degree-days at 18 °C base temperature for provinces of Turkey

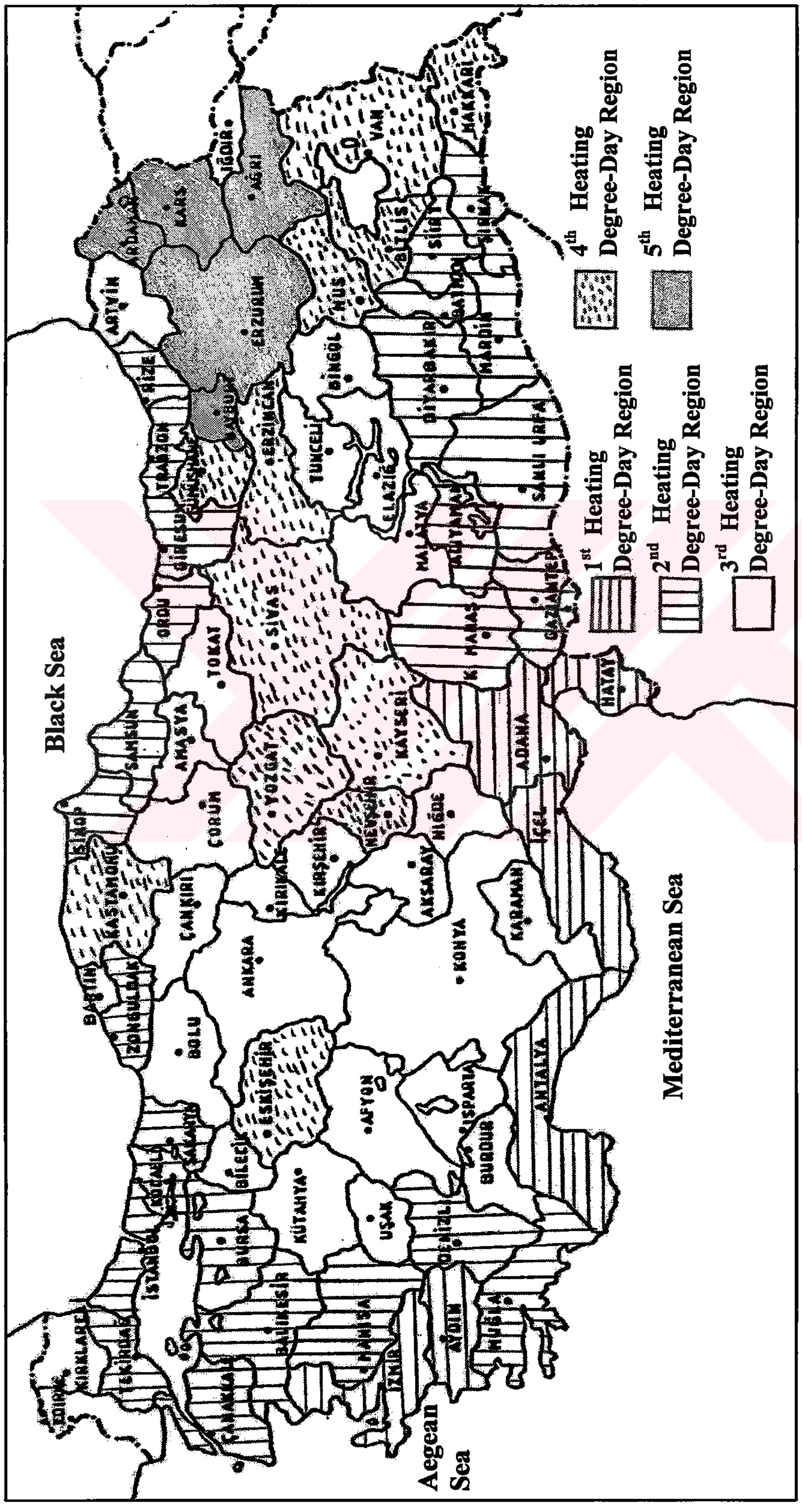


Figure 4.1.8. Heating degree-day regions for Turkey

4.1.2. Cooling Degree-Days

The cooling degree-days for base temperatures of 18, 20, 22, 24, 26 and 28 °C for 78 provinces of Turkey were calculated both monthly and yearly. The monthly cooling degree-days for main provinces of Turkey are given in Table 4.1.4. It can be concluded from the monthly cooling degree-days data provided in this Table that although some provinces such as Adana, İzmir, and Diyarbakır need cooling in four months, the other provinces such as Erzurum, İstanbul and Samsun do not need cooling at all. As it can be expected from definition of the cooling degree-day, when the base temperature is increased, the cooling degree-days get lower values. This can be seen from the table. The cooling even at high base temperatures is required for some provinces such as Adana and Diyarbakır.

Figure 4.1.9. shows the variation of the cooling degree-day values at 22 °C for main provinces of Turkey. The monthly degree-days shown in the Figure exhibit a similar profile for all provinces. As can be seen from the Figure, Adana, Diyarbakır, and İzmir need more cooling than İstanbul, Ankara, and Samsun, whilst there is no need to cooling in Erzurum.

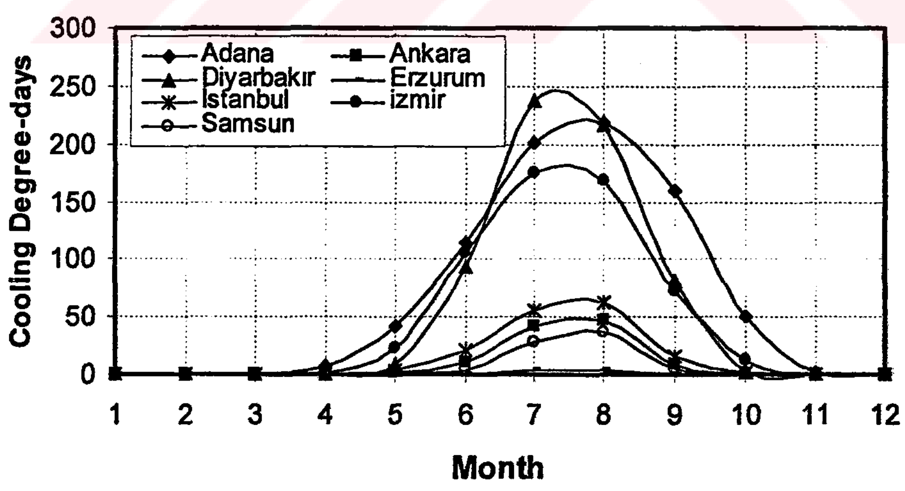


Figure 4.1.9. Variation of monthly cooling degree-days at 22 °C for main provinces

Table 4.1.4. Monthly cooling degree-days for main provinces of Turkey.

Province	Month	Base Temperature [°C]					
		18	20	22	24	26	28
Adana	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	4	1	0	0	0	0
	4	40	17	7	2	0	0
	5	130	80	41	18	7	2
	6	234	174	115	61	20	4
	7	326	264	202	140	79	26
	8	343	281	219	157	95	37
	9	280	220	160	101	48	12
	10	148	94	50	21	6	1
	11	15	5	2	0	0	0
	12	0	0	0	0	0	0
	Total	1520	1136	796	500	255	82
Ankara	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	2	0	0	0	0	0
	5	19	7	2	0	0	0
	6	62	29	10	2	0	0
	7	137	83	42	15	3	0
	8	146	92	46	18	5	1
	9	61	27	9	2	0	0
	10	6	2	0	0	0	0
	11	0	0	0	0	0	0
	12	0	0	0	0	0	0
	Total	433	240	109	37	8	1
Diyarbakır	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	3	0	0	0	0	0
	5	52	24	8	2	0	0
	6	205	147	93	49	20	5
	7	362	300	238	177	117	63
	8	340	278	216	154	94	43
	9	194	136	82	40	11	2
	10	29	11	3	0	0	0
	11	0	0	0	0	0	0
	12	0	0	0	0	0	0
	Total	1185	896	640	422	242	113
Erzurum	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
	6	3	1	0	0	0	0
	7	42	15	4	1	0	0
	8	39	13	3	0	0	0
	9	4	1	0	0	0	0
	10	0	0	0	0	0	0
	11	0	0	0	0	0	0
	12	0	0	0	0	0	0
	Total	88	30	7	1	0	0

Table 4.1.3. (Continued) Monthly cooling degree-days for main provinces of Turkey

Province	Month	Base Temperature [°C]					
		18	20	22	24	26	28
İstanbul	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	3	1	0	0	0	0
	5	25	10	3	1	0	0
	6	103	53	21	5	1	0
	7	170	110	55	17	3	0
	8	180	119	63	21	2	0
	9	88	43	15	3	0	0
	10	18	6	2	0	0	0
	11	1	0	0	0	0	0
	12	0	0	0	0	0	0
	Total	588	342	159	47	6	0
İzmir	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	1	0	0	0	0	0
	4	19	7	2	0	0	0
	5	92	50	22	7	2	0
	6	221	162	105	54	21	5
	7	299	237	176	115	60	20
	8	293	231	169	108	54	17
	9	185	126	72	31	9	2
	10	66	32	13	4	1	0
	11	6	2	0	0	0	0
	12	0	0	0	0	0	0
	Total	1182	847	559	319	147	44
Samsun	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	1	0	0	0	0	0
	4	3	1	0	0	0	0
	5	8	3	1	0	0	0
	6	51	16	3	0	0	0
	7	138	78	28	4	0	0
	8	151	90	37	6	0	0
	9	67	26	6	1	0	0
	10	16	5	1	0	0	0
	11	3	0	0	0	0	0
	12	0	0	0	0	0	0
	Total	438	219	76	11	0	0

The annual cooling degree-days for base temperatures of 18, 20, 22, 24, 26 and 28 °C for 78 provinces of Turkey are given in Table 4.1.5. Analysis of the table reveals that there are significant differences between the values of cooling degree-days for different provinces at the same base temperature. Whilst, there is no need to cooling in Ardahan (located in northeast) for which cooling degree-day is zero, cooling requirement is maximum for Şanlıurfa (located in the southeast) with a cooling degree-day of 940 at 22 °C base temperature.

The value of cooling degree-days increases significantly with the decrease of base temperature as shown in Figure 4.1.10. Therefore, thermal characteristics of the building and preferences of the occupants should be changed to increase the base temperature if possible. Increasing base temperature above the traditionally used base temperature of 22 °C diminishes the need for cooling completely for some provinces (such as Kars, Çorum, Kütahya, Niğde and Samsun), however, significant cooling is still required for some cities especially for those located in the south and the southeast Turkey. Increasing base temperature from 22 °C to 24 °C results in approximately 29% lower cooling degree-days in Şanlıurfa. An increase in cooling degree days occurs at the same level (approximately 33%), when the base temperature is changed from 22 °C down to 20 °C.

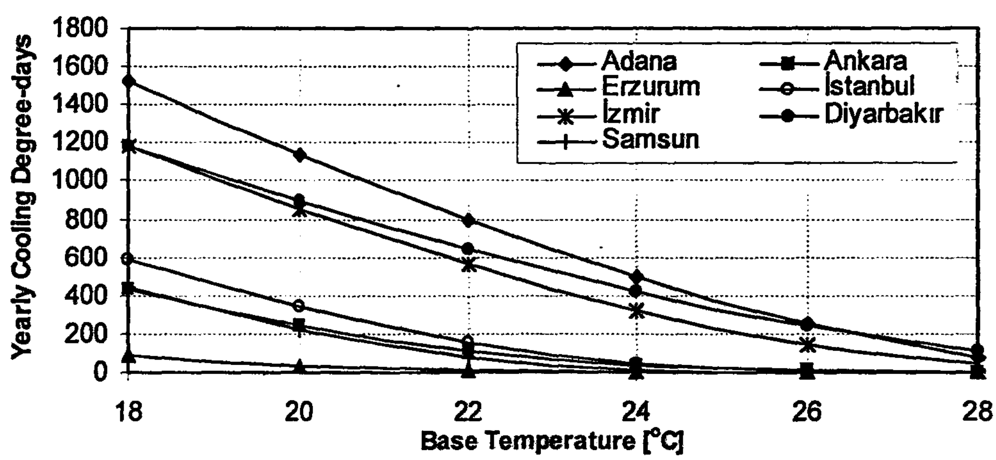


Figure 4.1.10. Variation of yearly cooling degree-days with base temperature for main provinces of Turkey.

Table 4.1.5. The annual cooling degree-days for Turkey

Province	Base Temperature [°C]					
	18	20	22	24	26	28
Adana	1520	1136	796	500	255	82
Adapazarı	585	333	155	51	10	1
Adıyaman	1451	1122	824	570	360	198
Afyon	321	156	58	14	2	0
Ağrı	226	104	35	9	1	0
Aksaray	479	273	131	47	11	2
Amasya	574	331	159	57	14	2
Ankara	433	240	109	37	8	1
Antalya	1178	846	562	330	164	68
Ardahan	25	4	0	0	0	0
Artvin	329	154	58	19	5	0
Aydın	1234	895	601	355	170	55
Balıkesir	695	432	226	91	20	4
Bartın	327	149	44	9	1	0
Batman	1364	1044	763	519	318	163
Bayburt	106	36	8	1	0	0
Bilecik	442	238	101	33	7	1
Bingöl	811	562	361	197	83	21
Bitlis	402	224	105	35	6	0
Bolu	213	85	22	4	0	0
Burdur	586	355	183	71	14	1
Bursa	606	359	177	61	12	2
Çanakkale	717	455	249	103	25	4
Çankırı	364	190	76	22	4	0
Çorum	211	84	24	4	0	0
Denizli	1036	730	469	265	120	36
Diyarbakır	1185	896	640	422	242	113
Edirne	629	381	195	72	16	3
Elazığ	790	543	337	179	75	19
Erzincan	470	274	130	44	8	0
Erzurum	88	30	7	1	0	0
Eskişehir	226	93	27	4	0	0
Gaziantep	1061	774	521	312	157	56
Giresun	501	271	108	23	3	0
Gümüşhane	243	111	40	9	2	0
Hakkari	549	345	184	72	18	2
Hatay	1288	929	614	348	139	24
Iğdır	711	471	276	132	43	7
İskenderun	1433	1033	687	398	175	40

Table 4.1.4. (Continued) The annual cooling degree-days for Turkey

Province	Base Temperature [°C]					
	18	20	22	24	26	28
Isparta	392	210	88	23	4	0
İstanbul	588	342	159	47	6	0
İzmir	1182	847	559	319	147	44
K. Maraş	1262	937	649	405	210	80
Karaman	468	262	119	39	7	0
Kars	67	17	2	0	0	0
Kastamonu	193	79	23	4	0	0
Kayseri	251	112	38	8	1	0
Kilis	1329	992	689	429	224	89
Kırıkkale	487	276	128	43	10	1
Kırklareli	592	358	185	72	20	6
Kırşehir	383	202	85	24	4	0
Kocaeli	665	404	204	76	18	2
Konya	424	232	101	31	5	0
Kütahya	251	110	35	7	0	0
Malatya	897	629	407	229	103	33
Manisa	1164	844	570	343	171	62
Mardin	1353	1037	755	515	315	161
Mersin	1279	907	585	317	124	20
Muğla	861	592	369	198	81	22
Muş	584	373	208	92	25	3
Nevşehir	259	121	47	13	2	0
Niğde	342	168	63	14	2	0
Ordu	512	284	119	30	3	0
Rize	452	228	81	13	1	0
Samsun	438	219	76	11	0	0
Siirt	1341	1026	747	509	311	158
Sinop	460	242	92	16	1	0
Sivas	196	82	27	6	1	0
Şanlıurfa	1601	1254	940	665	429	243
Tekirdağ	504	272	112	26	3	0
Tokat	439	234	97	30	5	0
Trabzon	476	245	91	17	1	0
Tunceli	804	555	353	193	85	24
Uşak	475	270	127	43	9	0
Van	248	109	32	6	1	0
Yalova	524	289	123	32	4	0
Yozgat	160	63	20	4	0	0
Zonguldak	350	157	50	14	2	0

Figure 4.1.11 shows a counter map of the yearly cooling degree-days at 22 °C base temperature for Turkey. It is seen that the cooling requirement is essentially zero in the North, Northeastern, Eastern and the Inner regions of Turkey. However, a substantial amount of cooling is needed in the South and the Southeast Turkey. The counters are close to each other between Adana and Niğde (around Niğde), and in the east.

The correlation observed between elevation and the heating degree-days does not exist in the case of cooling-degree days as shown in figure 4.1.12. However, combined influence of elevation and latitude on the cooling degree-days is clear from Figure 4.1.13. For the provinces having elevations less than 1100 m and located in the South (latitude is less than 39°), cooling is a necessity. The value of the cooling-degree days is generally smaller than 200 at high elevations (>1100 m). This is also the case for the North part of Turkey (latitude >40°).

The combined influence of elevation and longitude on the cooling degree-days as shown in Figure 4.1.14 is not as clear as in the case of elevation and latitude.

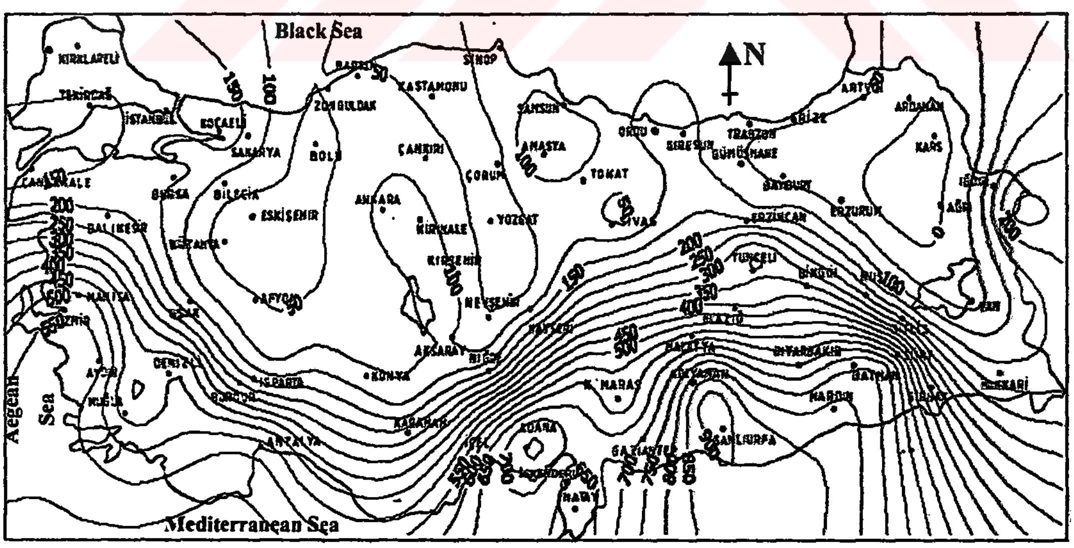


Figure 4.1.11. The counter map of yearly cooling degree-day at 22 °C base temperature for Turkey

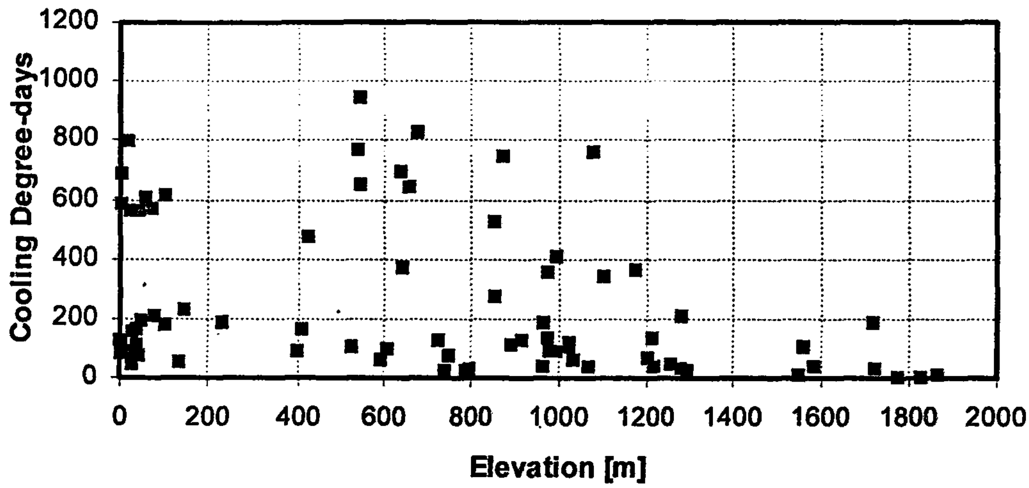


Figure 4.1.12. Variation of yearly cooling degree-days with elevation for Turkey

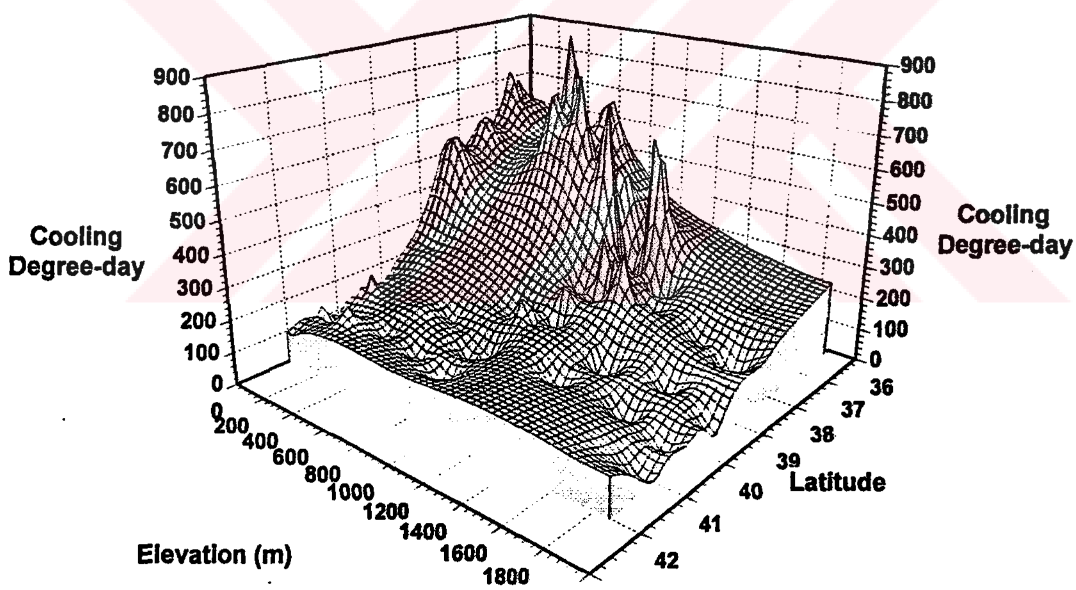


Figure 4.1.13. Variation of yearly cooling degree-days with elevation and latitude for Turkey

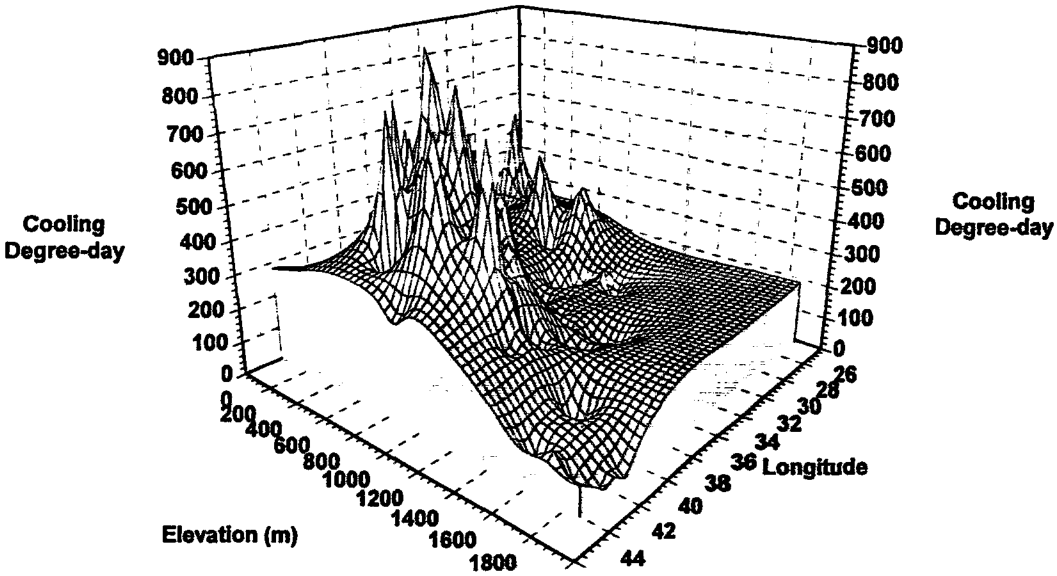


Figure 4.1.14. Variation of yearly cooling degree-days with elevation and longitude for Turkey

Turkey can be divided into 3 different cooling degree-day regions according to the yearly cooling degree-days at 18 °C base temperature obtained in this study. Since the raw data used in this study were obtained from the weather stations located in the city centers, the classification is based on the center of the provinces. Table 4.1.6 gives the proposed regions. The regions were chosen by analyzing the value of cooling degree-days and considering the variation of cooling degree-days throughout Turkey as shown in Figure 4.1.15. While the cooling requirement is very low in the first region, it is significant in the third region. The necessity for cooling is at a moderate level in the second region. 54 provinces are in the 1st region, 7 provinces are in the 2nd, and 17 provinces are in the 3rd. The cooling degree-day regions for Turkey are demonstrated on a map in Figure 4.1.16.

Table 4.1.6. Cooling degree-day regions for Turkey

Region	Province			
I	Adapazarı	Afyon	Ağrı	Aksaray
	Amasya	Ankara	Ardahan	Artvin
	Balıkesir	Bartın	Bayburt	Bilecik
	Bitlis	Bolu	Burdur	Bursa
	Çanakkale	Çankırı	Çorum	Edirne
	Erzincan	Erzurum	Eskişehir	Giresun
	Gümüşhane	Hakkari	Isparta	İstanbul
	Karaman	Kars	Kastamonu	Kayseri
	Kırıkkale	Kırklareli	Kırşehir	Kocaeli
	Konya	Kütahya	Muş	Nevşehir
	Niğde	Ordu	Rize	Samsun
	Sinop	Sivas	Tekirdağ	Tokat
	Trabzon	Uşak	Van	Yalova
	Yozgat	Zonguldak		
II	Bingöl	Denizli	Elazığ	Iğdır
	Malatya	Muğla	Tunceli	
III	Adana	Adıyaman	Antakya	Antalya
	Aydın	Batman	Diyarbakır	Gaziantep
	İzmir	Kahramanmaraş	Kilis	Manisa
	Mardin	Mersin	Siirt	Şanlıurfa

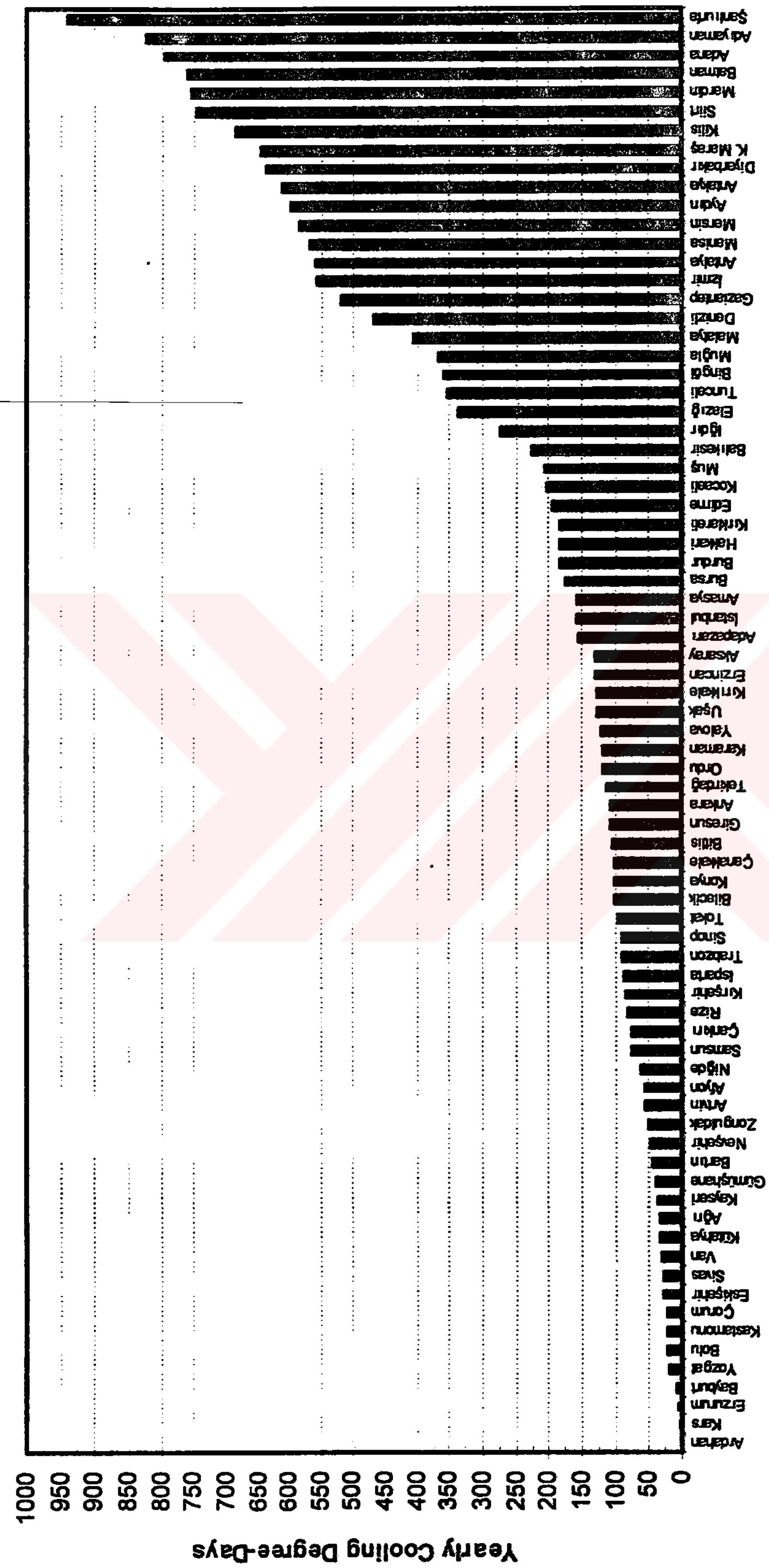


Figure 4.1.15. Variation of cooling degree-days at 22 °C base temperature for provinces of Turkey

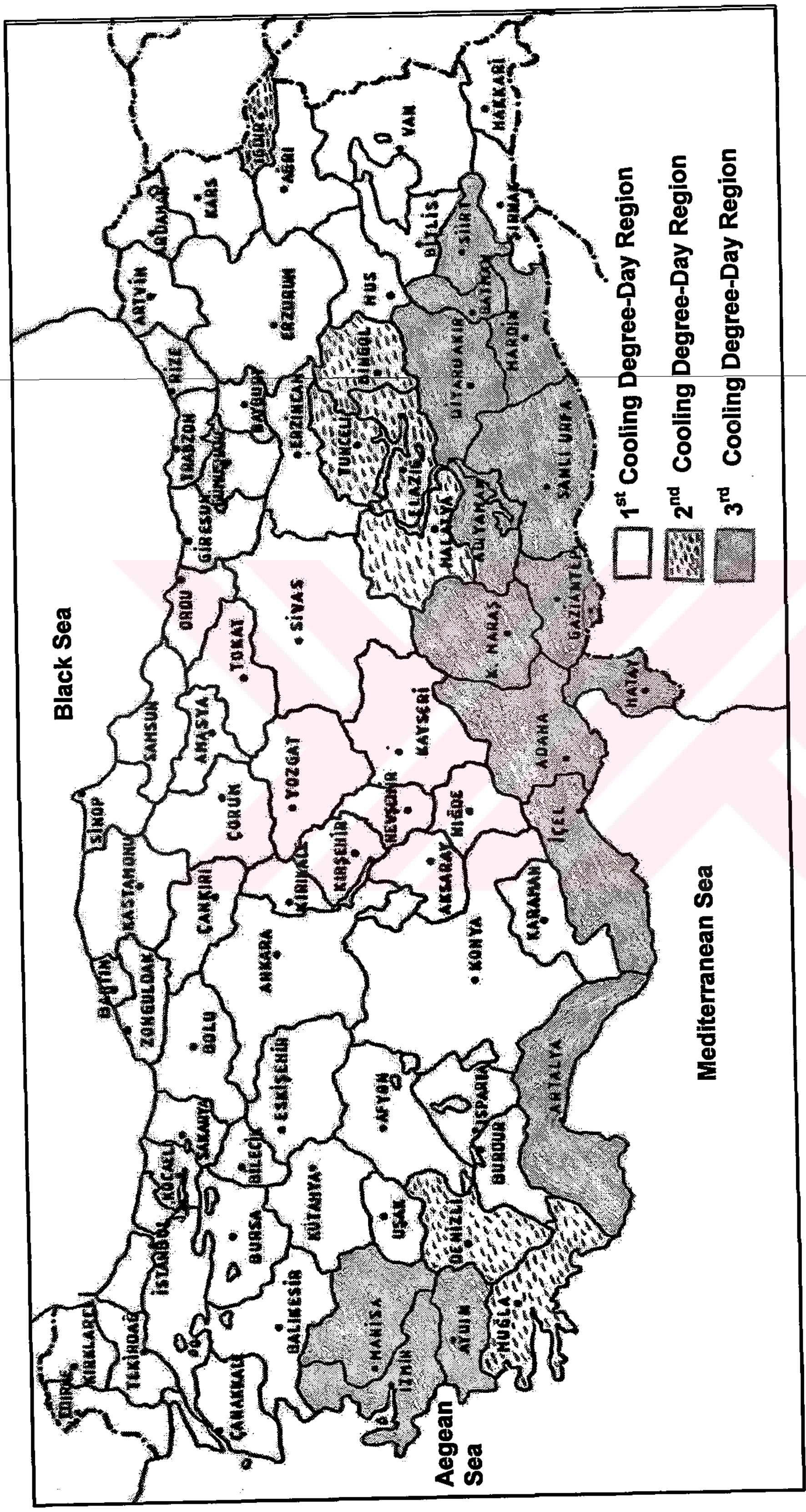


Figure 4.1.14. Cooling degree-day regions for Turkey

4.2. Bin Data for Outdoor Dry-Bulb Temperature

The bin method can estimate both heating and cooling loads of buildings. However the bin method requires primarily bin data. Bin data are the number of hourly temperature occurrence in each bin (equally sized intervals of temperature) for each period of the day.

Bin data for dry-bulb temperature from -36 °C to 45 °C with 3 °C increments were calculated in six daily 4-h shifts (1-4, 5-8, 9-12, 13-16, 17-20, and 21-24 hours) for each province of Turkey. The analysis based on the dry-bulb temperature database given in Table 3.1.2. Bin data is calculated in three steps. Firstly, the number of hours within each temperature bin for every month of the year was computed. The calculations were carried out separately for every year of the period considered. Secondly, averaging over years considered, the bin data were obtained for six separate time periods of the day for each month for each weather station. Finally, using these data, the monthly total and yearly total bin data were calculated.

Although the bin data were calculated for each month of the year for 78 provinces in the present study, it is not practical to present all of them in the thesis due to space limitations. Monthly bin data are given in Table 4.2.1 as an example for Adana in 4-h periods. Also given in this table at the last row of the data group for each month is the monthly total number of hours. It can be seen from Table 4. 2. 1 that the bin 10.5 °C (9/12 °C) has the maximum number of occurrences in January, February, March, and December, whilst the bin 25.5 °C (24/27 °C) has the maximum number of occurrences in July, August and September.

Figure 4.2.1 shows distribution of monthly total number of hours (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 hours, whilst the maximum bin observed is 40.5 °C (39 °C/42 °C) with a yearly total value of 5 hours. Heating and cooling seasons can be estimated from Figure 4.2.1. 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 from cooling to heating occur in 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.

The contribution of daily time periods on number of occurrences for Adana is shown in figure 4.2.2. As it is expected, the relatively higher temperatures occurs in the time periods of 9-12 and 13-16 o'clock.

In Table 4.2.2, the yearly total number of hourly occurrences (N_{bin}) of dry-bulb temperatures in bins of 3 °C for each six time periods of the day, i.e., hours 1-4, 5-8, 9-12, 13-16, 17-20, and 21-24, are presented for only 7 main provinces of Turkey that representing the climatic conditions of their regions.

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 4.2.3 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). It can be concluded from data in Table 4.2.2 and 4.2.3 that there are big differences in the temperature range between provinces.

Table 4.2.1. Bin data for in six daily 4-h shifts for Adana

Month	Time	Temperature [°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
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
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

Table 4.2.1. (Continued) Bin data for in six daily 4-h shifts for Adana

Month	Time	Temperature [°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
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
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

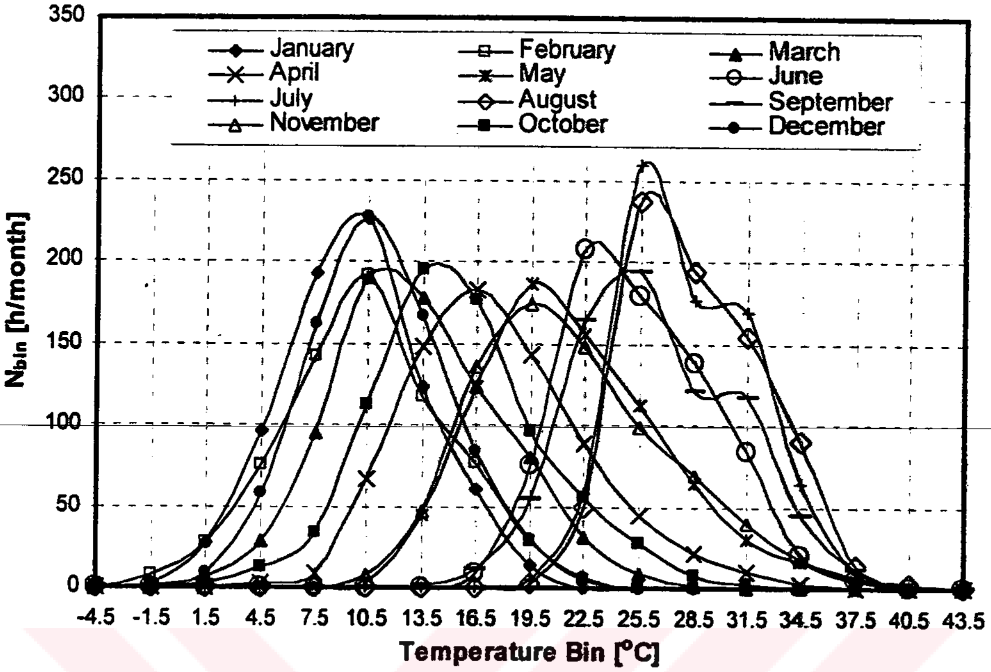


Figure 4.2.1. Monthly distribution of N_{bin} values for Adana

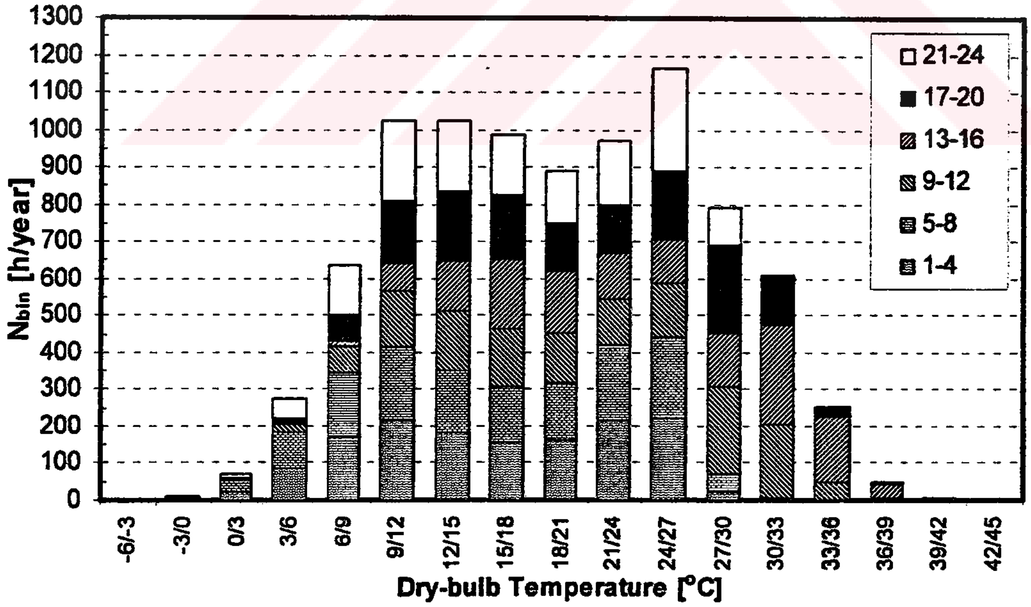


Figure 4.2.2. The effect of the time period of the day on annual bin data for Adana

Table 4. 2. 2. The bin data of dry-bulb temperature for main provinces in Turkey

		Temperature Range [°C]																								
Province	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

Table 4. 2.2. (Continued) The bin data of dry-bulb temperature for main provinces in Turkey

Province	Time	Temperature Range [°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
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
	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. 2. 3. The annual total bin data of dry-bulb temperature for all provinces in Turkey

Province	Temperature Range [°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

Table 4. 2. 3. (Continued) The annual total bin data of dry-bulb temperature for all provinces in Turkey

Province	Temperature Range [°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

Table 4. 2. 3. (Continued) The annual total bin data of dry-bulb temperature for all provinces in Turkey

Province	Temperature Range [°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
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
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

Yearly total bin data for some representative cities of Turkey are shown in Figure 4.2.3. Although the yearly variation of dry-bulb temperatures have the similar trend, the number of occurrences are very different for each province. The difference in climatic conditions of extreme provinces (*e.g.* Adana and Erzurum) can be clearly seen from data presented this 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, this is -3/0 in Adana.

Cumulative distribution of yearly bin data for the same provinces is shown in Figure 4.2.4. From the figure, one can get approximately the number of hours for heating 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 having moderate internal and external heat gains located in Erzurum needs no cooling, but the same building requires more cooling than heating in Adana.

Figure 4.2.5 shows average frequency distribution of temperature bins. The frequency values were obtained by averaging N_{bin} values of 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 hours. Increase of frequency with temperature bin at low temperature bins is slower than the decrease of frequency at high temperature bins.

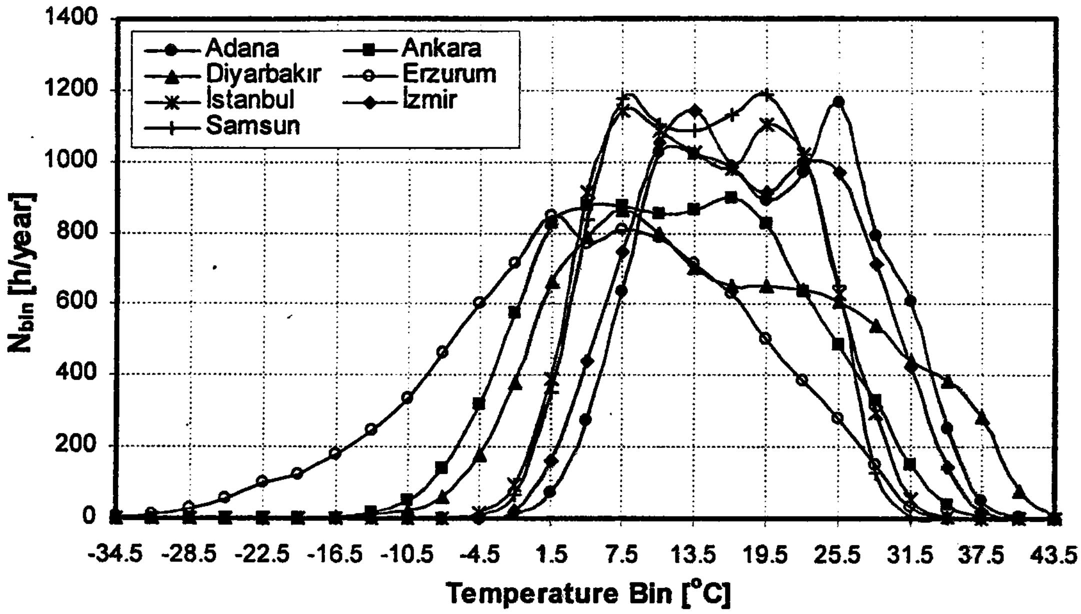


Figure 4.2.3. Yearly total number of hours of dry-bulb temperature for representative weather stations of Turkey

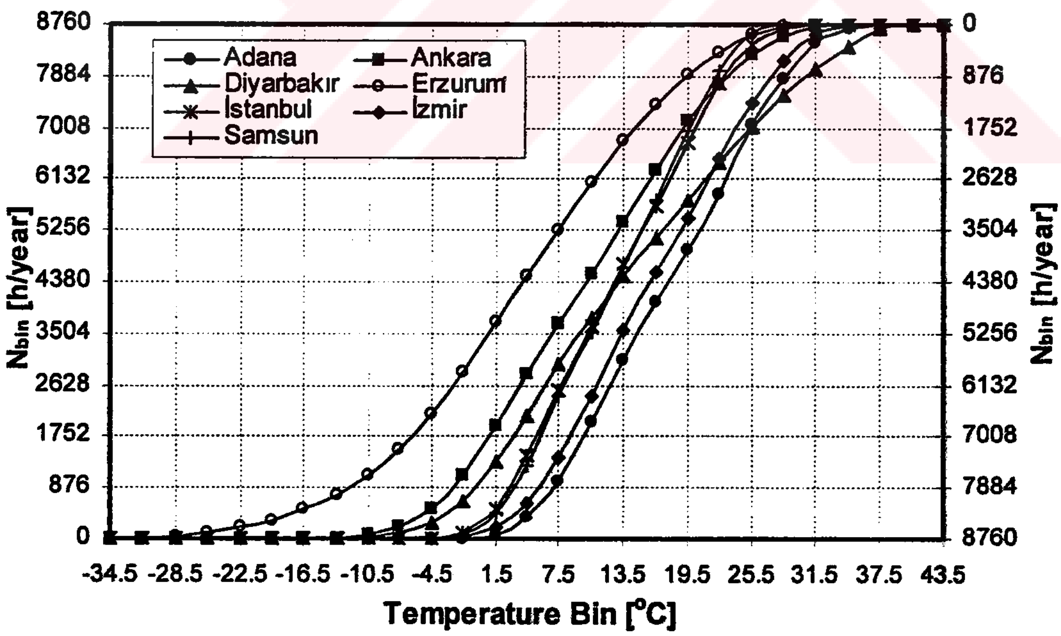


Figure 4.2.4. Cumulative distribution of yearly total bin data for representative weather stations of Turkey

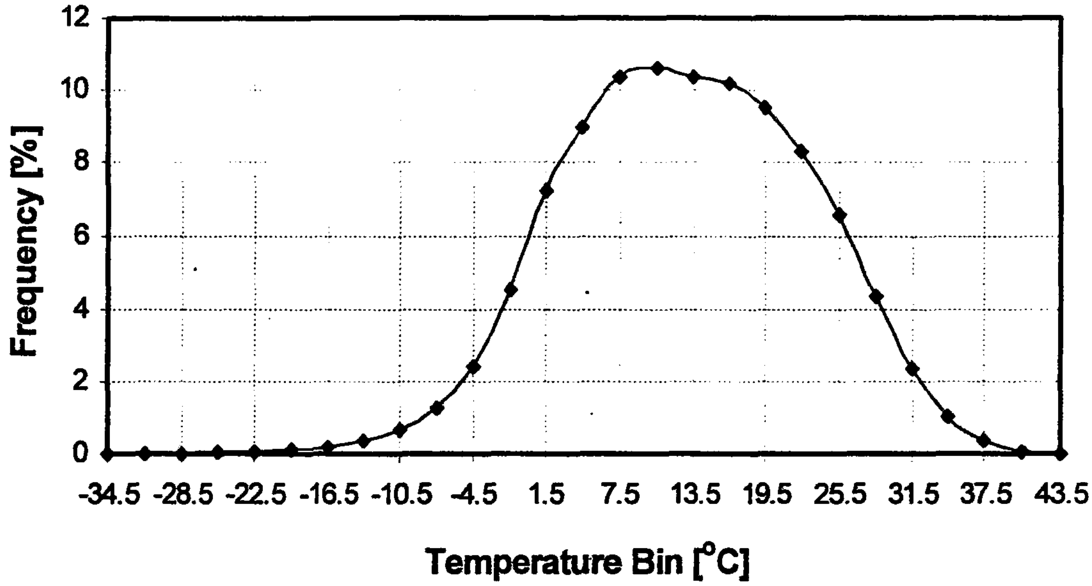
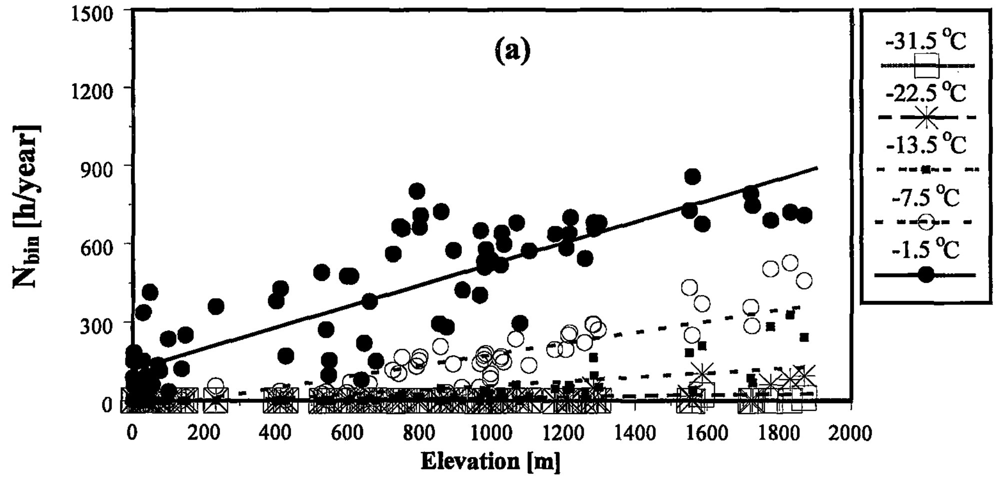
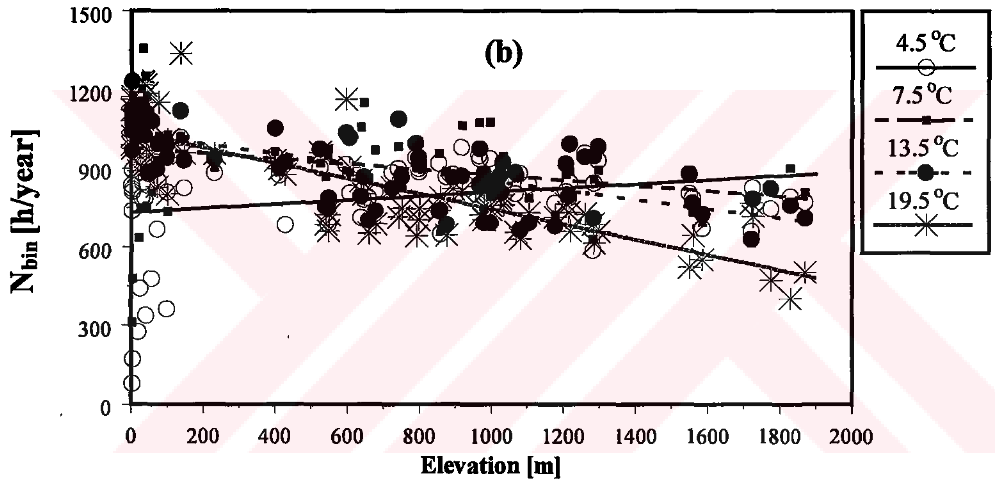


Figure 4.2.5. Average frequency distribution of N_{bin} values for Turkey

The effect of elevation on bin data for Turkey is shown in Figure 4.2.6. 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 m and 1869 m. A correlation between N_{bin} and elevation is evident from Figure 4.2.6-*a* 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 (Figure 4.2.6-*b*) and N_{bin} decreases with the increase of elevation at high temperature bins (Figure 4.2.6-*c*).





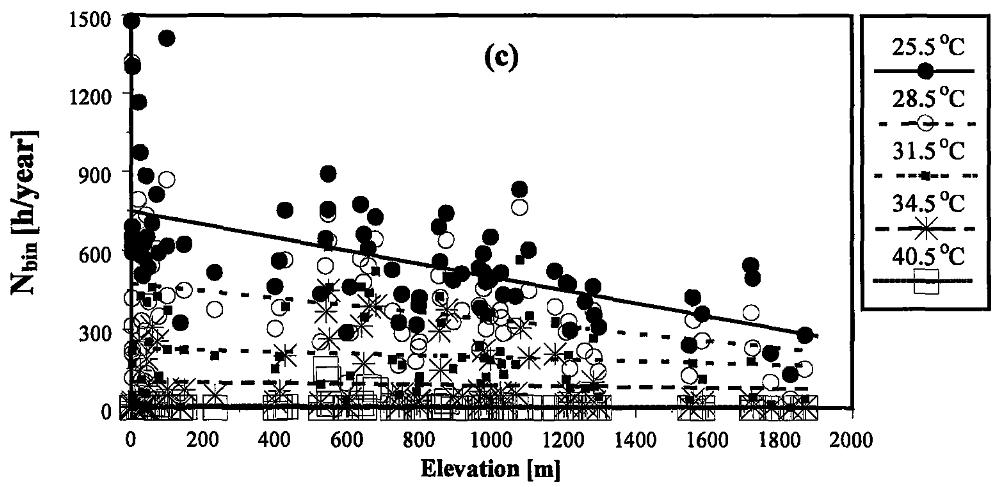


Figure 4.2.6. Variation of yearly total N_{bin} with elevation (***a:*** low temperature bins, ***b:*** medium temperature bins, ***c:*** high temperature bins)

The combined influence of latitude and longitude on bin data for Turkey is shown in the form of three-dimensional graphs in Figure 4.2.7 for some selected temperature bins. N_{bin} is usually zero at low temperature bins (Figure 4.2.7-a and b). However, it has small values in eastern Turkey and especially at north-eastern region. This means that winter is quite severe in the cities located in this region. At relatively higher temperature bins (Figures 4.2.7-c and d), N_{bin} starts to increase in inner and eastern Turkey. The most repeated bins are moderate ones (Figures 4.2.7-e, f and g) 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 (Figure 4.2.7-h), although N_{bin} is still high in southern and southeastern Turkey. At high temperature bins (Figure 4.2.7-i), 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.

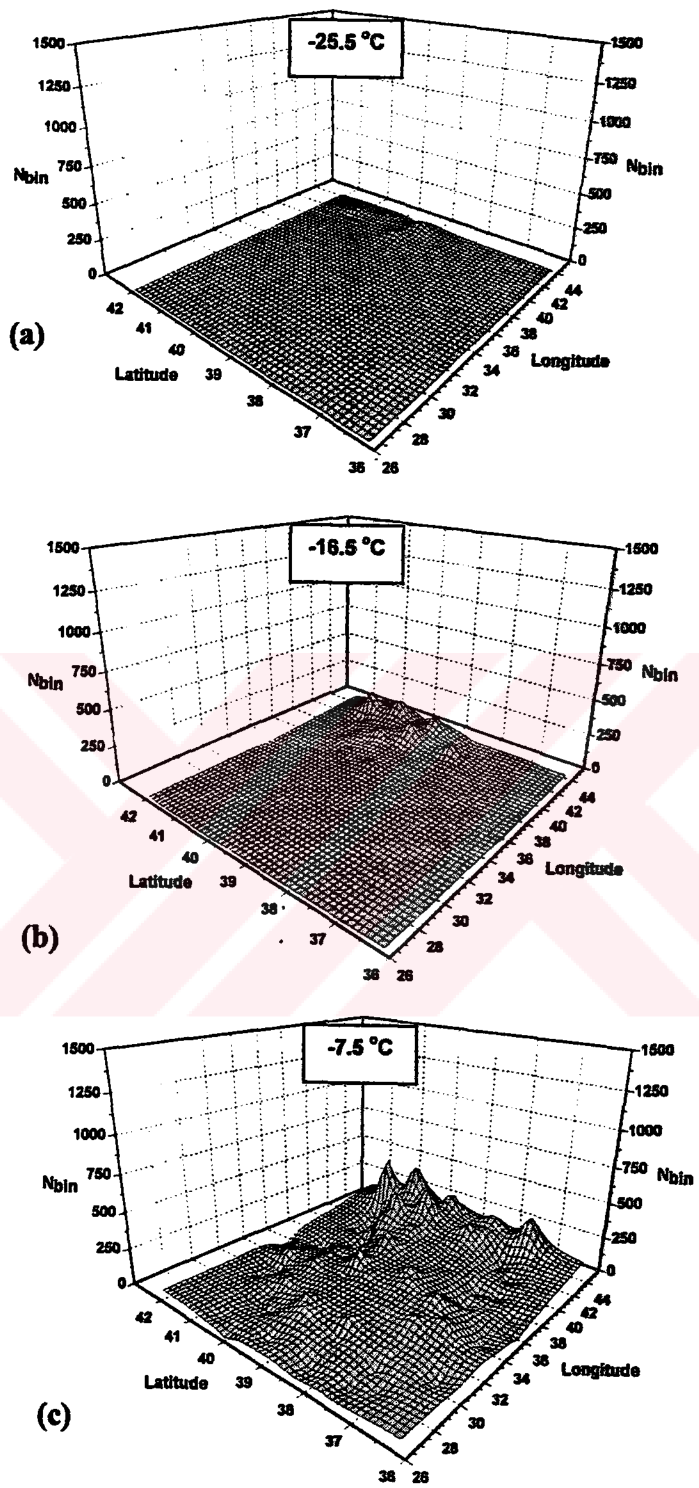


Figure 4.2.7. Variation of yearly total N_{bin} with latitude and longitude for various temperature bins (temperature bins are **a***:* -25.5 °C, **b**: -16.5 °C, **c***:* -7.5 °C)

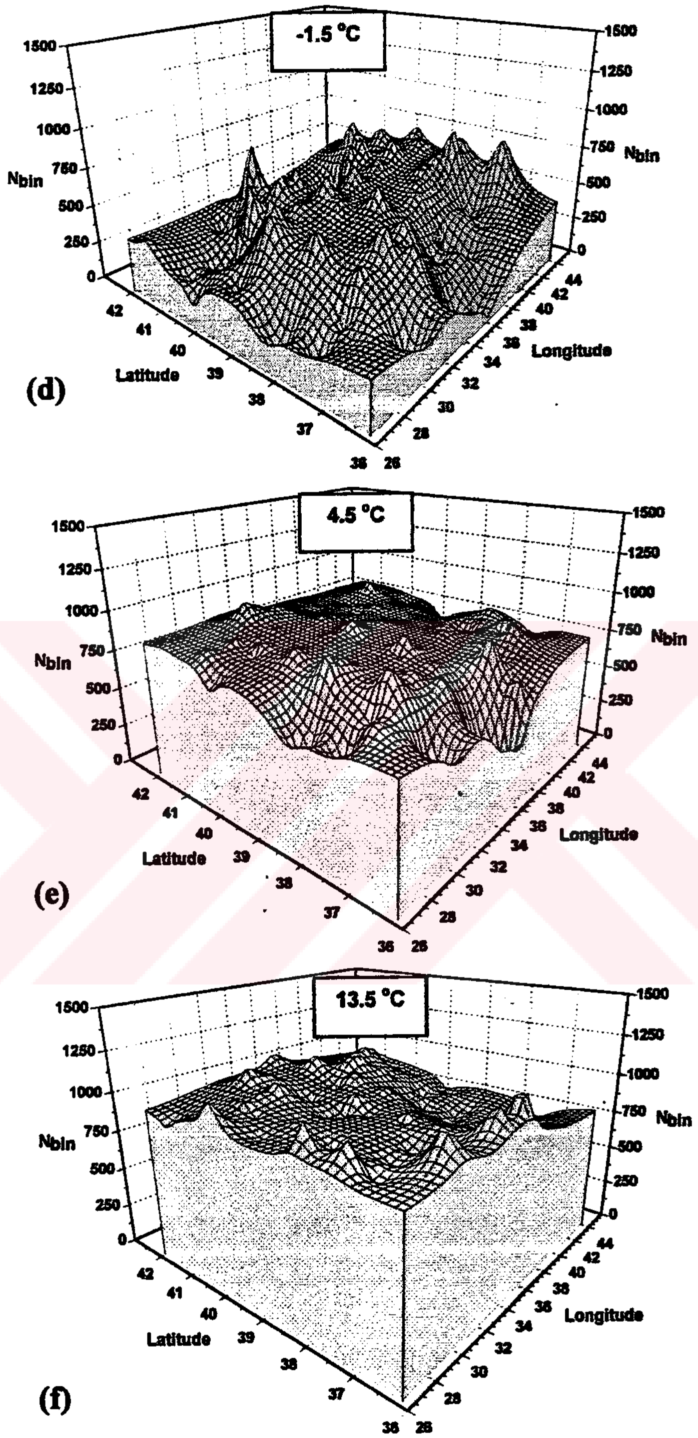


Figure 4.2.7. (Continued) Variation of yearly total N_{bin} with latitude and longitude for various temperature bins (temperature bins are **d:** 1.5 °C, **e:** 4.5 °C, **f:** 13..5 °C)

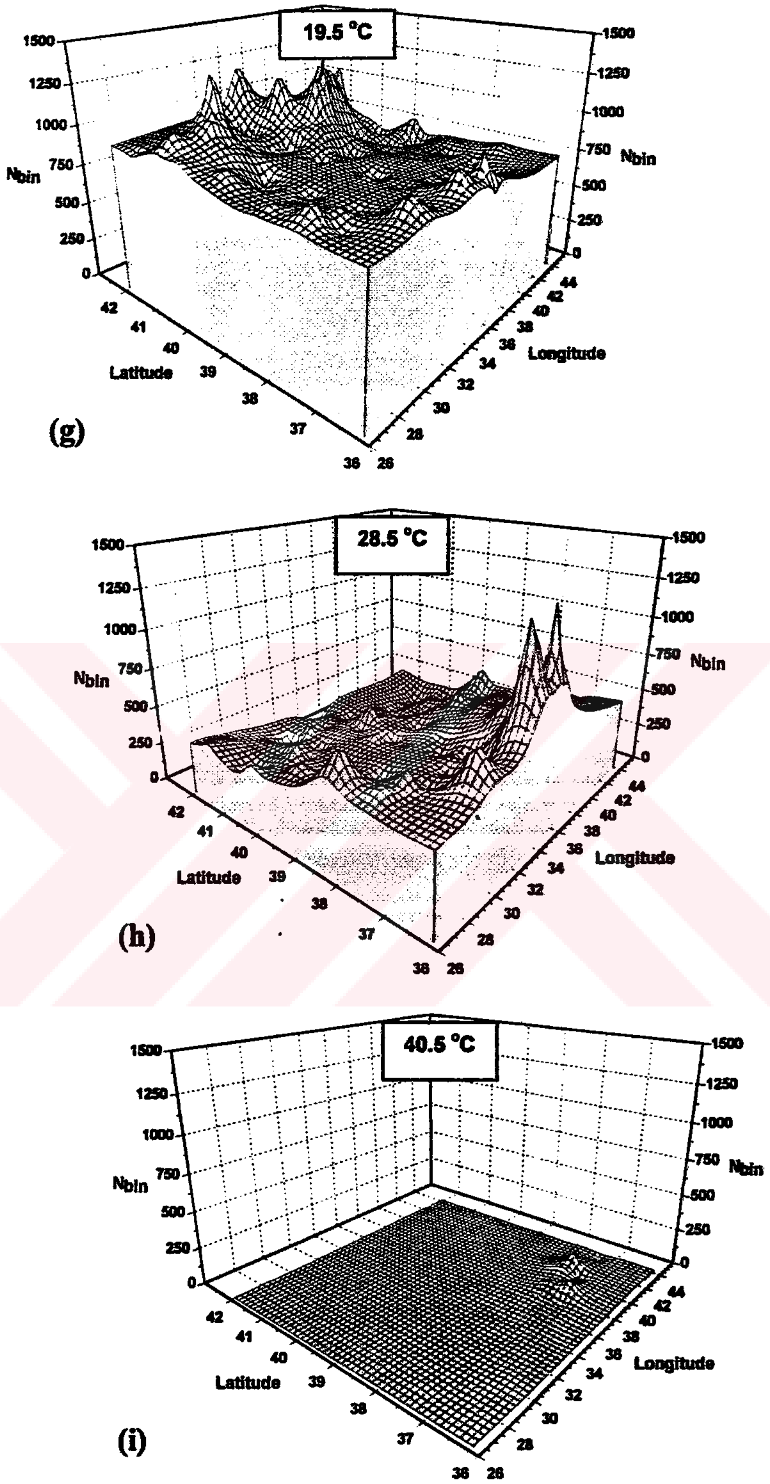


Figure 4.2.7. (Continued) Variation of yearly total N_{bin} with latitude and longitude for various temperature bins (temperature bins are **g:** 19.5 °C, **h:** 28.5 °C, **i:** 40..5 °C)

4.3. New Outdoor Design Conditions For Turkey

Outdoor design conditions indicate the extreme conditions for thermal load calculations. The selection of design conditions depends on the assignment of design requirements and probability involved.

In Turkey, heating and cooling load calculations are performed using the method given in technical publications of the Chamber of Mechanical Engineers (MMO, 1997; Özkul, 1985) and in technical publication of Ministry of Public Works and Settlement (Önen, 1985). The design conditions given in these publications especially heating values are based on old weather data (Gülferi, 1966) and have not been updated for the last 35 years. Another point is that the design conditions for some locations are not available.

In this study, new outdoor design conditions have been developed both for cooling and heating systems for all provinces of Turkey according to the format recommended by ASHRAE (ASHRAE, 1993 and ASHRAE, 1997). The design conditions were obtained analyzing the hourly temperatures for all the provinces considered in this study. The detailed information for the hourly temperature database is given in Table 3.1.2. Significance levels in percentage frequency as suggested by ASHRAE (ASHRAE, 1997) are considered more systematic and flexible for risk analysis. Therefore, outdoor design temperatures for all provinces were determined at 0.4%, 1% and 2% frequency levels for cooling and at 99.6% and 99% frequency levels for heating.

Table 4.3.1 gives cooling design conditions for Turkey. Dry-bulb (DB) temperature corresponding to 0.4 %, 1% and 2% annual cumulative frequency of occurrence and the mean coincident wet-bulb (MWB) temperature are given in the Table. Table 4.3.1 also provides the mean, median and standard deviation (StdD) of the annual maximum (Max) dry-bulb temperatures. The mean daily ranges are shown in the last column of the Table. Ardahan, Sinop, and Rize have the minimum outdoor dry bulb temperatures at 0.4% frequency level. Their values are 26.6 °C, 27.4 °C, and 27.6 °C respectively. The maximum outdoor design temperatures at 0.4% frequency are in Batman (40.8 °C DB), Şanlıurfa (40.0 °C DB), and Diyarbakır (39.7 °C DB).

The maximum daily range of dry bulb temperature is in Batman (18.2 °C). Giresun and İskenderun have the minimum daily range of dry bulb temperature (6.1 °C).

Table 4.3.2 presents heating design conditions for Turkey. Dry-bulb (DB) temperature corresponding to 99.6% and 99% annual cumulative frequency of occurrence and the mean, median and standard deviation (StdD) of the annual minimum (Min) dry-bulb temperatures are shown in the Table. Ağrı, Erzurum, Ardahan, and Kars have the minimum dry-bulb temperatures at 99.6% frequency level. 99.6% frequency level for Ağrı, Erzurum, Ardahan, and Kars are –28 °C, -26.2 °C, -25.7 °C and –23.7 °C respectively. İskenderun (5.2 °C), Mersin (3.3 °C), Adana (1.9 °C), and Antalya (1.8 °C) have the maximum dry-bulb temperatures at 99.6% frequency level.

Common practice in HVAC design is to take the 2 % values in summer and 99% values in winter for comfort air-conditioning. For critical processes, the 0.4% for summer and the 99.6% for winter should be used as the design temperatures.

Table.4.3.1. Cooling design conditions for Turkey

Province	Cooling DB/MWB [°C]						Max DB [°C]			Daily Range of DB [°C]
	0.4%		1%		2%					
	DB	MWB	DB	MWB	DB	MWB	Mean	Median	StdD	
Adana	36.4	21.2	34.9	21.5	33.8	21.9	40.5	40.8	1.2	11.0
Adapazarı	32.4	22.8	30.6	22.3	29.2	21.9	37.1	36.6	1.6	11.3
Adıyaman	39.4	21.5	38.3	21.3	37.2	21.1	42.0	41.9	1.6	14.4
Afyon	32.0	19.5	30.7	19.2	29.2	18.8	35.0	35.1	1.4	15.2
Ağrı	31.8	20.8	30.4	20.5	28.9	20.0	34.7	35.1	1.6	17.9
Aksaray	33.0	20.5	31.7	20.0	30.4	19.6	36.4	36.2	1.1	14.8
Amasya	34.5	19.8	32.6	19.4	31.0	19.0	39.5	39.6	1.5	15.5
Ankara	33.0	18.5	31.4	18.3	29.9	18.0	36.3	36.2	1.5	14.5
Antakya	35.0	20.8	32.9	21.0	31.5	21.6	40.5	40.8	1.6	9.0
Antalya	37.7	21.1	35.9	21.0	34.1	20.8	41.8	41.7	1.1	13.1
Ardahan	26.6	17.9	25.1	17.4	23.5	16.9	30.8	30.7	1.6	16.3
Artvin	30.0	18.4	27.8	18.0	26.1	17.6	36.5	36.0	2.0	9.4
Aydın	37.8	23.2	36.4	23.0	35.1	22.7	41.6	41.6	1.6	16.1
Balıkesir	34.6	21.8	32.7	21.4	31.3	21.1	39.1	39.4	1.8	12.9
Bartın	30.9	20.9	29.3	20.6	27.9	20.6	35.8	35.2	2.4	13.0
Batman	40.8	23.9	39.7	23.7	38.5	23.3	43.4	43.5	1.4	18.2
Bayburt	29.7	17.8	28.1	17.3	26.4	16.9	33.3	33.4	1.0	16.4
Bilecik	31.9	20.8	30.3	20.3	28.8	19.9	36.4	36.3	1.5	12.8
Bingöl	36.2	20.8	35.1	20.6	33.8	20.2	39.0	39.2	1.3	16.2
Bitlis	32.3	20.1	31.2	19.8	29.9	19.5	34.9	35.0	1.3	15.8
Bolu	30.6	19.4	28.9	19.3	27.3	19.0	35.4	35.4	1.7	14.7
Burdur	33.5	19.1	32.3	18.9	31.1	18.6	36.3	36.2	0.8	15.0
Bursa	33.5	20.4	32.0	20.3	30.7	20.1	37.7	37.3	1.6	13.7
Çanakkale	32.3	23.7	31.0	23.3	30.0	22.9	35.6	35.6	1.8	10.8
Çankırı	33.5	20.6	31.8	20.2	30.2	19.8	37.4	37.8	1.8	17.9
Çorum	32.2	18.8	30.4	18.3	28.8	17.9	35.9	35.8	1.4	17.6
Denizli	36.0	21.9	34.8	21.8	33.6	21.6	38.9	38.8	1.4	13.9
Diyarbakır	39.7	22.3	38.7	22.0	37.5	21.7	42.1	42.5	1.2	17.1
Edirne	34.0	21.9	32.8	21.6	31.5	21.1	37.7	37.7	2.1	14.7
Elazığ	35.8	19.8	34.6	19.6	33.3	19.3	38.6	38.8	1.3	15.3
Erzincan	33.6	20.8	32.1	20.5	30.8	20.1	36.6	36.9	1.2	16.0
Erzurum	29.5	18.0	28.1	17.8	26.7	17.3	32.6	32.3	1.3	17.6
Eskişehir	32.4	18.4	30.7	18.2	29.2	17.9	35.9	36.0	1.7	17.1
Gaziantep	36.7	21.0	35.8	20.9	34.7	20.7	39.6	39.5	1.2	14.9
Giresun	27.7	22.6	26.8	22.7	26.0	22.5	31.4	30.9	2.0	6.1
Gümüşhane	32.2	18.4	30.0	17.9	27.9	17.6	36.3	36.1	2.0	15.0
Hakkari	32.0	20.1	30.9	19.8	29.8	19.3	34.6	34.7	1.6	12.4
Iğdır	34.9	21.1	33.8	20.8	32.6	20.4	38.3	38.0	1.4	16.0
İskenderun	31.8	23.0	30.7	23.6	30.1	24.0	36.5	36.2	1.8	6.1

Table.4.3.1. (Continued) Cooling design conditions for Turkey

Province	Cooling DB/MWB [°C]									
	0.4%		1%		2%		Max DB [°C]			Daily Range of DB [°C]
	DB	MWB	DB	MWB	DB	MWB	Mean	Median	StdD	
Isparta	32.6	19.6	31.3	19.3	30.1	18.9	35.1	35.0	1.0	15.8
İstanbul	30.4	21.9	29.2	21.6	28.1	21.4	34.6	33.7	2.1	9.0
İzmir	35.2	22.8	33.8	22.5	32.6	22.3	39.0	38.6	1.3	10.7
Kahramanmaraş	37.6	22.3	36.3	22.2	34.9	21.9	40.2	40.0	1.7	13.6
Karaman	33.3	19.4	32.0	19.2	30.7	18.9	36.7	36.7	1.1	16.3
Kars	28.5	20.1	27.0	19.6	25.5	19.3	31.8	31.8	1.4	16.6
Kastamonu	31.1	19.5	29.4	19.0	27.7	18.5	35.3	35.2	1.6	15.8
Kayseri	33.3	20.5	31.8	20.1	30.3	19.7	36.8	36.8	1.5	18.9
Kilis	37.7	19.6	36.5	19.5	35.3	19.2	40.8	40.4	1.7	15.3
Kırıkkale	33.6	20.1	31.9	19.7	30.5	19.3	36.8	36.9	1.3	14.2
Kırklareli	33.4	21.8	31.9	21.3	30.6	20.9	37.3	37.3	2.3	13.4
Kırşehir	32.0	20.6	30.6	20.2	29.2	19.9	35.4	35.5	1.1	14.2
Kocaeli	32.3	22.1	30.7	21.7	29.4	21.4	36.6	36.0	1.6	10.3
Konya	32.7	19.0	31.3	18.8	30.0	18.6	35.5	35.6	1.1	14.1
Kütahya	31.5	17.8	29.9	17.4	28.5	17.1	35.0	34.8	1.6	15.5
Malatya	36.0	20.7	34.7	20.3	33.4	20.0	39.2	39.7	1.7	14.5
Manisa	37.3	21.9	35.9	21.7	34.6	21.5	41.5	41.9	1.7	14.1
Mardin	36.5	20.5	35.5	20.4	34.4	20.1	39.4	39.5	1.1	10.4
Mersin	31.1	25.6	30.5	25.8	30.0	25.8	35.1	34.9	1.7	6.5
Muğla	35.5	20.7	34.2	20.5	33.0	20.3	38.2	38.3	1.4	13.8
Muş	34.2	20.6	33.0	20.3	31.7	19.9	37.4	37.5	1.3	17.0
Nevşehir	31.1	19.0	29.5	18.6	28.1	18.2	34.4	34.3	1.3	15.3
Niğde	31.4	19.3	30.1	19.0	28.9	18.7	34.8	34.8	1.3	14.8
Ordu	28.6	23.3	27.8	23.2	27.0	22.9	32.4	31.3	2.3	8.2
Rize	27.6	22.3	26.9	22.3	26.3	22.0	32.1	31.7	1.9	6.7
Samsun	27.8	22.6	27.0	22.8	26.3	22.7	32.2	32.0	1.5	7.3
Siirt	38.1	21.2	37.1	21.0	36.1	20.7	40.7	41.0	1.3	13.5
Sinop	27.4	21.1	26.5	21.1	25.6	20.9	30.4	30.2	1.2	6.3
Sivas	31.7	18.8	29.9	18.5	28.2	18.1	35.3	34.9	1.8	16.3
Şanlıurfa	40.0	22.1	39.1	21.7	38.0	21.4	42.5	42.6	1.2	14.2
Tekirdağ	29.1	22.9	28.0	22.8	27.2	22.6	33.9	33.5	1.5	9.1
Tokat	32.6	20.3	31.0	19.7	29.4	19.3	37.3	37.0	1.6	14.4
Trabzon	27.7	23.0	26.9	22.9	26.2	22.6	31.6	30.5	2.7	6.3
Tunceli	36.3	21.1	35.1	20.9	33.9	20.7	38.9	39.2	1.3	15.5
Uşak	32.8	19.7	31.6	19.4	30.4	19.2	35.8	36.0	1.4	14.8
Van	29.6	18.7	28.5	18.4	27.5	18.1	32.7	32.8	1.9	13.2
Yalova	30.2	22.8	29.0	22.7	28.0	22.5	35.0	34.5	2.1	11.4
Yozgat	30.0	19.7	28.4	19.4	26.8	19.0	33.2	33.3	1.5	13.5
Zonguldak	27.7	19.6	26.2	19.5	25.0	19.5	32.4	32.4	1.6	6.9

Table 4.3.2. Heating design conditions for Turkey

	Heating DB [°C]		Min DB [°C]				Heating DB [°C]		Min DB [°C]		
Province	**99.6%**	**99%**	**Mean**	**Median**	**StdD**	**Province**	**99.6%**	**99%**	**Mean**	**Median**	**StdD**
Adana	1.9	3.2	-1.2	-1.1	1.6	Isparta	-7.9	-6.4	-12.4	-11.8	2.8
Adapazarı	-2.1	-1.1	-5.5	-5.9	2.1	İstanbul	-1.1	-0.3	-3.6	-3.0	2.2
Adıyaman	-2.6	-1.3	-5.2	-4.9	2.5	İzmir	1.0	1.9	-1.4	-1.4	1.6
Afyon	-9.8	-8.0	-15.2	-15.6	2.6	K. Maraş	-2.4	-1.2	-5.7	-5.5	2.3
Ağrı	-28	-25.4	-33.5	-33.2	3.8	Karaman	-12.5	-10.1	-17.9	-18.2	5.1
Aksaray	-11.2	-9.1	-15.7	-15.1	5.1	Kars	-23.7	-21.0	-28.5	-28.9	2.2
Amasya	-6.4	-4.7	-10.7	-9.3	3.9	Kastamonu	-10.4	-8.2	-14.7	-14.6	2.5
Ankara	-9.4	-7.8	-12.6	-12.0	3.2	Kayseri	-16.2	-13.2	-20.5	-20.0	4.2
Antakya	0.3	1.7	-2.6	-2.8	1.5	Kilis	-0.8	0.2	-4.4	-4.3	2.4
Antalya	1.8	2.8	-0.8	-0.8	1.3	Kırıkkale	-8.9	-7.4	-12.6	-11.1	3.6
Ardahan	-25.7	-23	-31	-31.5	3.0	Kırklareli	-6.6	-5.0	-9.6	-9.0	2.3
Artvin	-5.1	-3.9	-8.2	-8.1	1.9	Kırşehir	-12.3	-9.9	-16.9	-17.1	4.3
Aydın	-0.5	0.5	-3.2	-3.0	1.4	Kocaeli	-1.4	-0.5	-4.0	-4.2	2.0
Balıkesir	-3.8	-2.6	-7.7	-7.2	2.7	Konya	-11.6	-9.6	-15.7	-15.2	4.8
Bartın	-4.8	-3.2	-9.6	-8.1	3.3	Kütahya	-9.5	-7.8	-14.9	-13.7	3.1
Batman	-6.5	-4.7	-9.8	-7.7	4.4	Malatya	-8.4	-6.7	-11.9	-11.7	2.7
Bayburt	-18.9	-16.5	-23.9	-24.5	3.3	Manisa	-1.9	-0.8	-4.9	-4.4	1.6
Bilecik	-5.4	-4.2	-9.2	-9.4	2.5	Mardin	-4.5	-3.2	-8.3	-8.0	2.9
Bingöl	-12.7	-10.8	-16.7	-16.2	4.6	Mersin	3.3	4.4	0.5	1.0	1.9
Bitlis	-13.0	-10.8	-17.2	-17.2	3.5	Muğla	-3.3	-2.1	-5.9	-5.6	1.7
Bolu	-9.8	-7.8	-15.3	-15.3	3.3	Muş	-21.6	-18.9	-26.8	-27.0	5.0
Burdur	-6.1	-4.9	-10.0	-9.6	1.6	Nevşehir	-11.6	-9.5	-16.2	-16.4	3.7
Bursa	-3.4	-2.0	-8.0	-6.3	3.9	Niğde	-12.9	-10.6	-17.7	-17.3	4.2
Çanakkale	-2.4	-1.3	-4.9	-4.7	1.7	Ordu	-0.4	0.5	-3.0	-3.2	1.8
Çankırı	-10.8	-8.9	-14.7	-14.3	3.5	Rize	-0.2	0.7	-2.7	-3.0	1.7
Çorum	-10.9	-8.7	-16.0	-15.5	4.3	Samsun	-0.8	0.2	-3.2	-3.3	1.9
Denizli	-2.4	-1.4	-5.8	-5.1	2.0	Siirt	-5.7	-3.8	-8.6	-8.1	4.0
Diyarbakır	-8.7	-6.4	-12.1	-11.2	5.2	Sinop	0.2	1.1	-2.1	-1.9	2.1
Edirne	-7.3	-5.5	-10.9	-9.6	3.8	Sivas	-17.2	-14.4	-21.8	-22.0	3.4
Elazığ	-8.9	-7.4	-12.3	-11	3.8	Şanlıurfa	-1.6	-0.3	-4.6	-4.8	2.4
Erzincan	-14.4	-12.1	-18.5	-18.3	4.1	Tekirdağ	-3.8	-2.6	-7.0	-6.4	2.3
Erzurum	-26.2	-23.1	-31.9	-33.0	4.1	Tokat	-8.5	-6.4	-13.5	-11.3	4.8
Eskişehir	-9.8	-8.2	-15.5	-16.1	2.2	Trabzon	-0.1	0.9	-2.4	-2.4	1.7
Gaziantep	-4.5	-3.1	-7.9	-7.4	2.4	Tunceli	-12.5	-10.2	-16.5	-15.3	4.5
Giresun	0.2	1.0	-1.7	-1.6	1.5	Uşak	-6.3	-4.9	-10.0	-9.8	1.9
Gümüşhane	-13.4	-11.1	-18.0	-17.8	3.6	Van	-13.4	-11.6	-17.7	-17.8	3.7
Hakkari	-14.2	-12.4	-17.8	-16.8	2.7	Yalova	-1.0	-0.1	-4.7	-4.6	2.2
Iğdır	-12.5	-10.7	-16.3	-15.9	3.7	Yozgat	-13.2	-10.9	-17.3	-17.4	2.8
İskenderun	5.2	6.4	2.2	2.4	1.9	Zonguldak	-1.3	-0.4	-4.0	-3.9	1.7

The 0.4%, 1%, and 2% frequency level of outdoor design dry-bulb temperatures and mean coincident wet-bulb temperatures as cooling design conditions for all provinces in Turkey are depicted on psychrometric charts in Figures 4.3.1, 4.3.2, and 4.3.3, respectively. As seen from the Figures, the design conditions are not concentrated in a specific region of the chart. Instead, they scatter considerably on the chart. This is an expected result, because Turkey has different climate regions.

Figures 4.3.4, 4.3.5 and 4.3.6 show the 0.4%, %1, and %2 cooling design conditions for main provinces of Turkey, respectively. In these Figures, the values of the other design parameters such as humidity ratio and enthalpy are also given.

The counter map of dry-bulb temperatures at 0.4% frequency level as cooling design conditions for Turkey is shown in Figure 4.3.7. The maximum outdoor dry-bulb temperatures occur in Southeastern region, whilst the minimum dry-bulb temperatures are in northeastern region. The mean coincident wet-bulb temperatures at 0.4% frequency level for Turkey is also depicted on a counter map (Figure 4.3.8). The counter map of cooling design conditions at 1% and 2% frequency level for both dry-bulb and mean coincident wet-bulb temperatures are shown in Figures 4.3.9, 4.3.10, 4.3.11, and 4.3.12, respectively.

The counter maps of the outdoor dry-bulb temperatures as winter design conditions at 99.6% and 99% annual cumulative frequency of occurrences for Turkey are depicted in Figure 4.3.13 and Figure 4.3.14, respectively. As seen in these Figures, the lower heating design temperatures appear in eastern and north-eastern regions. For coastal regions, design conditions are high when compared with inner regions.

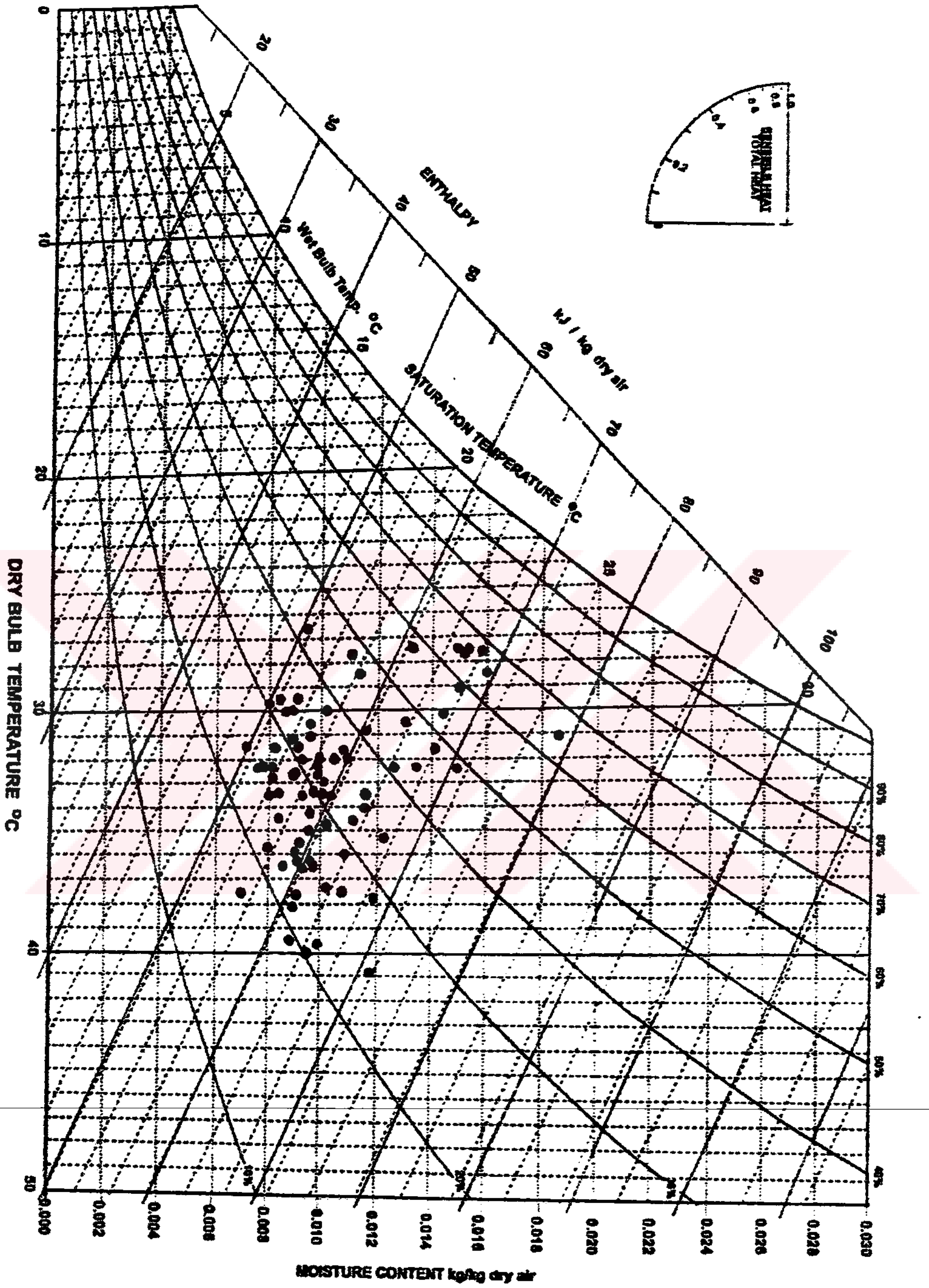


Figure 4.3.1. Cooling design conditions at 0.4% frequency level for all provinces of Turkey on psychrometric chart

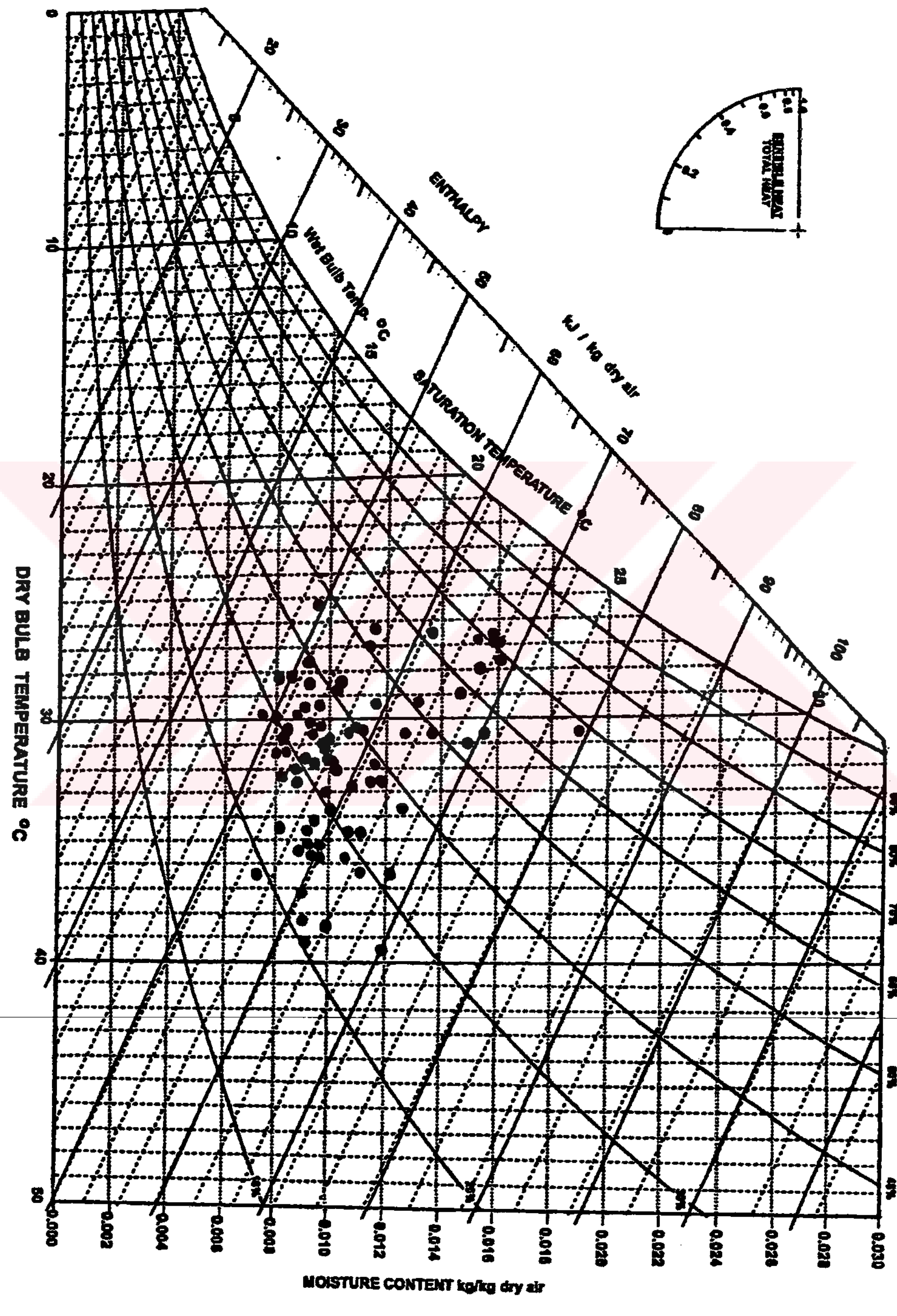


Figure 4.3.2. Cooling design conditions at 1% frequency level for all provinces of Turkey on psychrometric chart

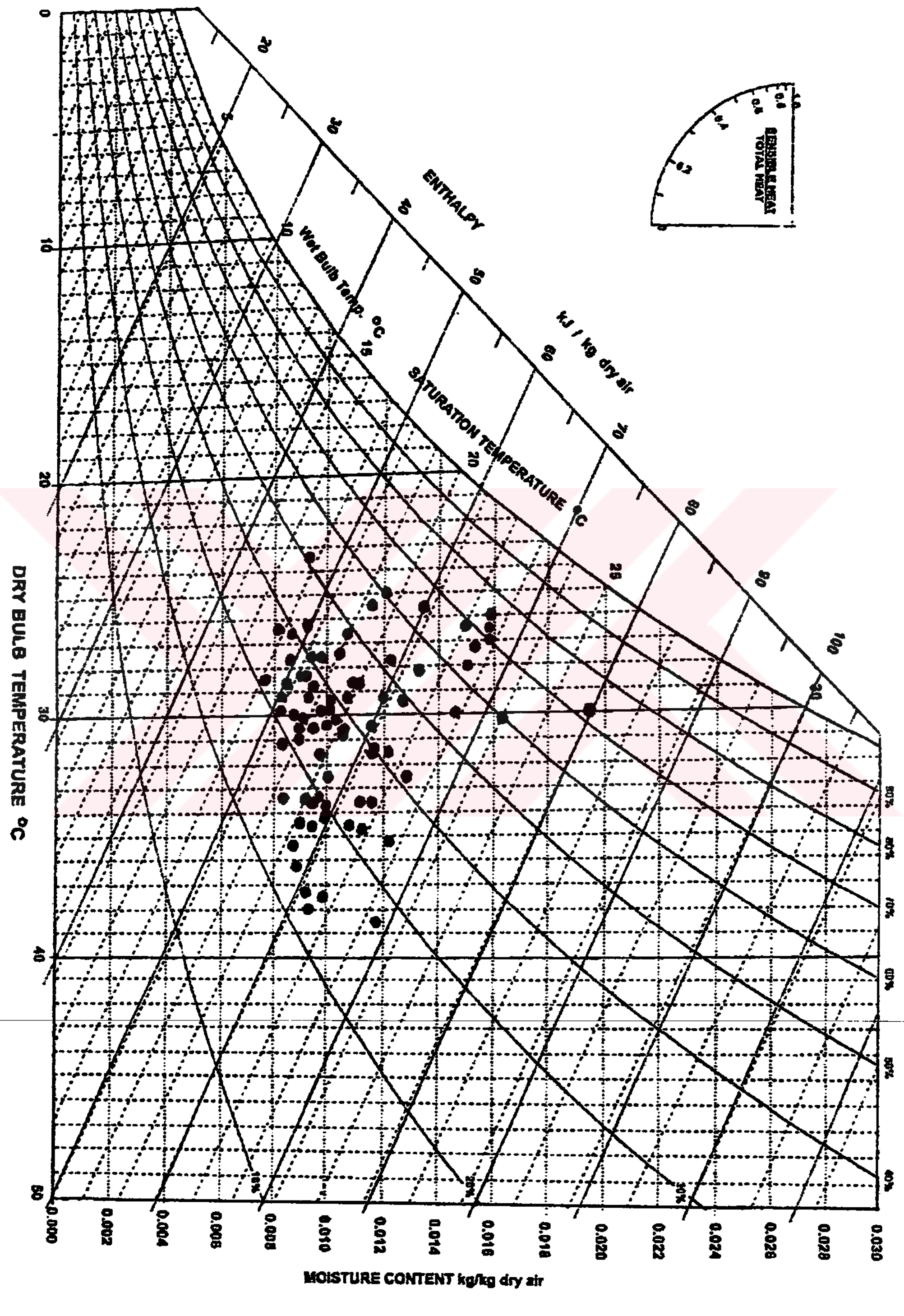


Figure 4.3.3. Cooling design conditions at 2% frequency level for all provinces of Turkey on psychrometric chart

No:	DB	WB	DP	RH	HR	SV	EN
1	36.40	21.20	13.69	25.52	9.661	0.891	61.22
2	33.00	18.50	9.872	23.87	7.453	0.878	52.10
3	39.70	22.30	14.08	21.89	9.917	0.900	65.24
4	29.50	18.00	11.30	32.13	8.222	0.869	50.52
5	30.40	21.90	18.25	48.01	13.04	0.878	63.76
6	35.20	22.80	17.52	34.95	12.43	0.891	67.13
7	27.80	22.60	20.54	64.48	15.10	0.873	66.37

DB : Dry-bulb Temperature [°C]
WB : Wet-bulb Temperature [°C]
DP : Dew Point Temperature [°C]
RH : Relative Humidity [%]
HR : Humidity Ratio [gr/kg-dry air]
SV : Specific Volume [m³/kg]
EN : Enthalpy [kJ/kg]

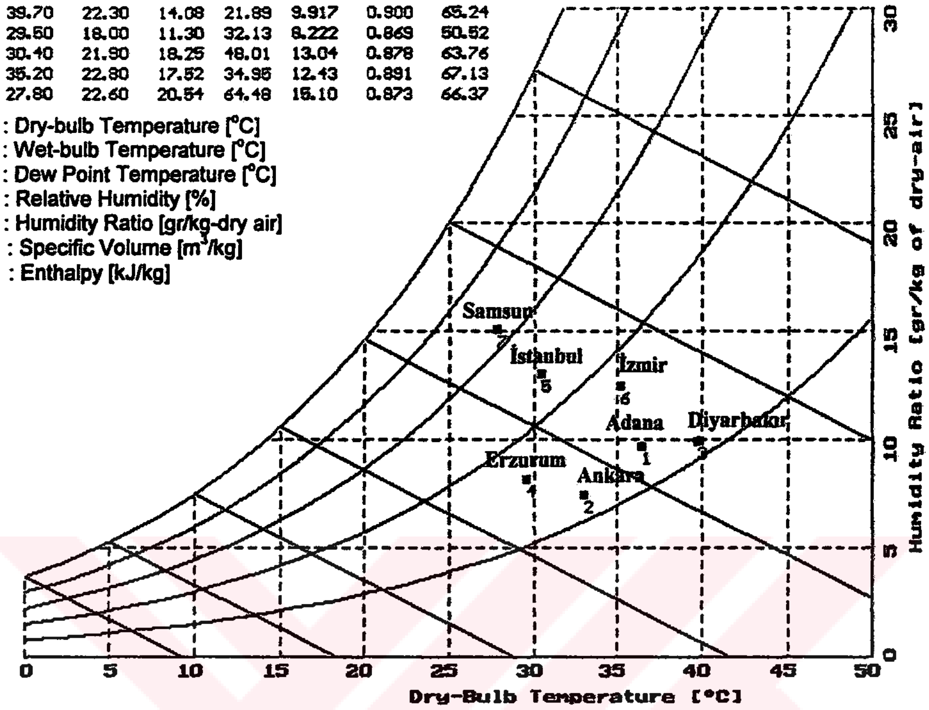


Figure 4.3.4. Cooling design conditions at 0.4% frequency level for main provinces of Turkey on psychrometric chart

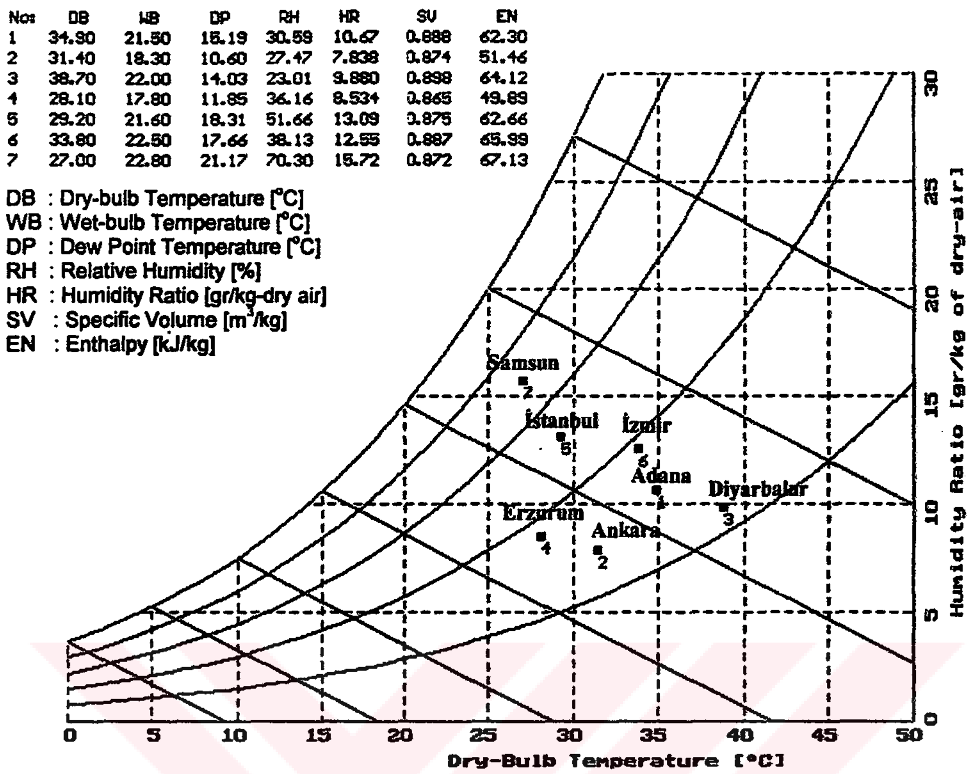
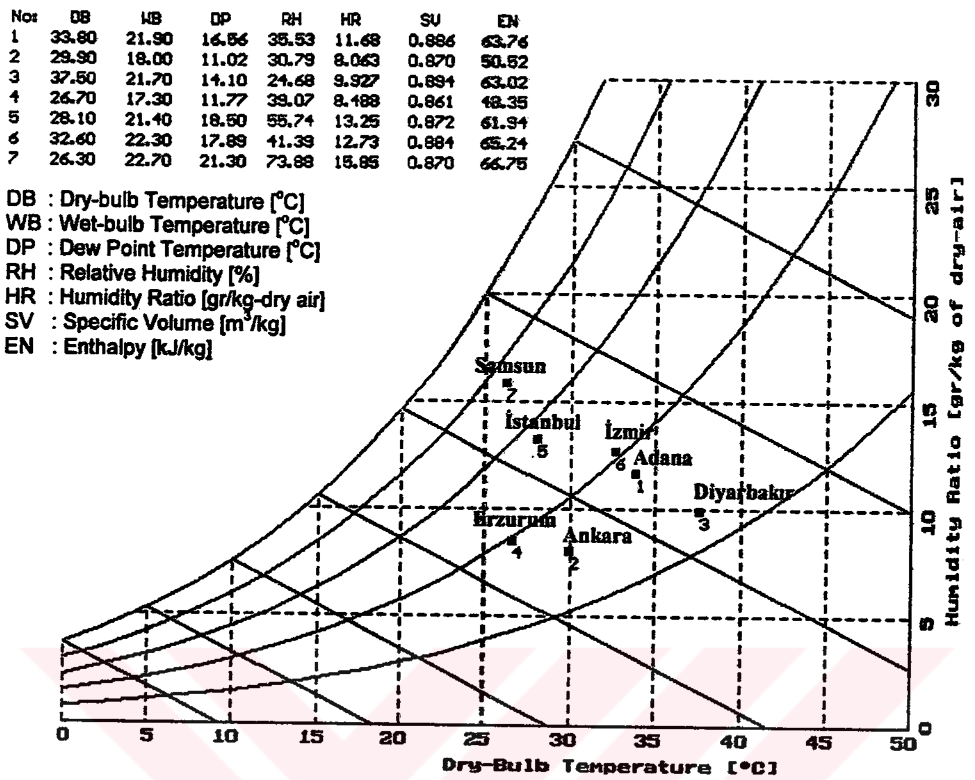


Figure 4.3.5. Cooling design conditions at 1% frequency level for main provinces of Turkey on psychrometric chart



No:	DB	WB	DP	RH	HR	SV	EN
1	33.80	21.90	16.56	35.53	11.68	0.886	63.76
2	29.90	18.00	11.02	30.79	8.063	0.870	50.52
3	37.50	21.70	14.10	24.68	9.927	0.894	63.02
4	26.70	17.30	11.77	39.07	8.488	0.861	48.35
5	28.10	21.40	18.50	55.74	13.25	0.872	61.94
6	32.60	22.30	17.89	41.39	12.73	0.884	65.24
7	26.30	22.70	21.30	73.88	15.85	0.870	66.75

Figure 4.3.6. Cooling design conditions at 2% frequency level for main provinces of Turkey on psychrometric chart

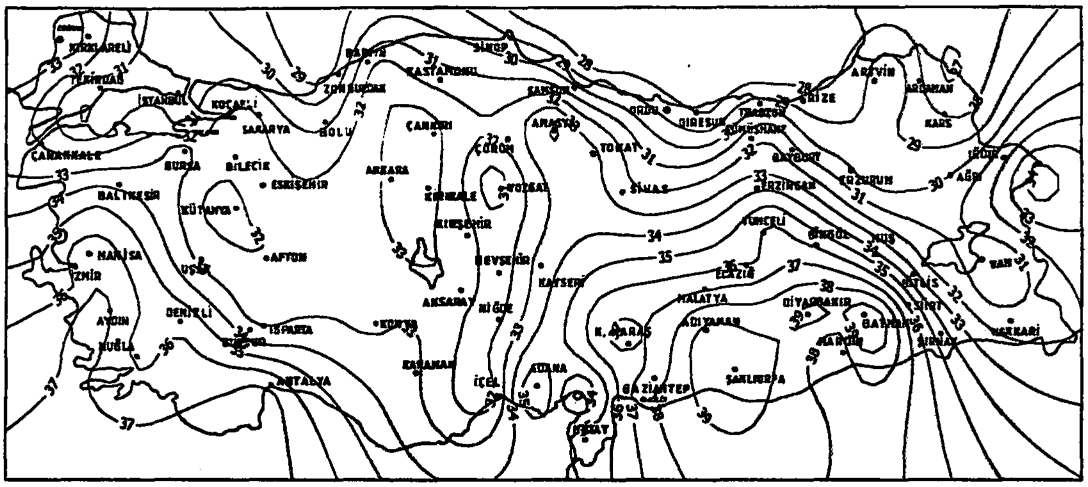


Figure 4.3.7. The counter map of 0.4% frequency level of outdoor dry-bulb temperatures as cooling design conditions for Turkey

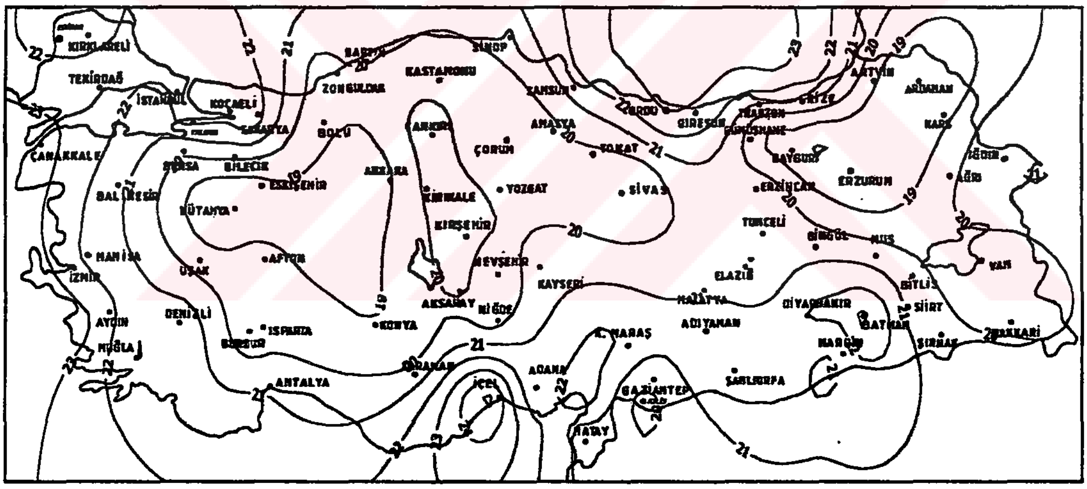


Figure 4.3.8. The counter map of 0.4% frequency level of the mean coincident wet-bulb temperatures as cooling design conditions for Turkey

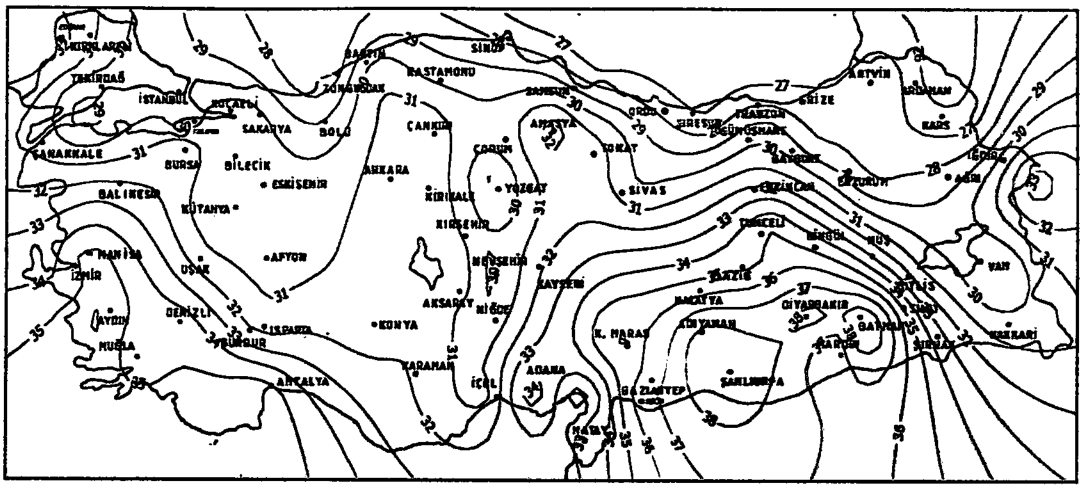


Figure 4.3.9. The counter map of 1% frequency level of outdoor dry-bulb temperatures as cooling design conditions for Turkey

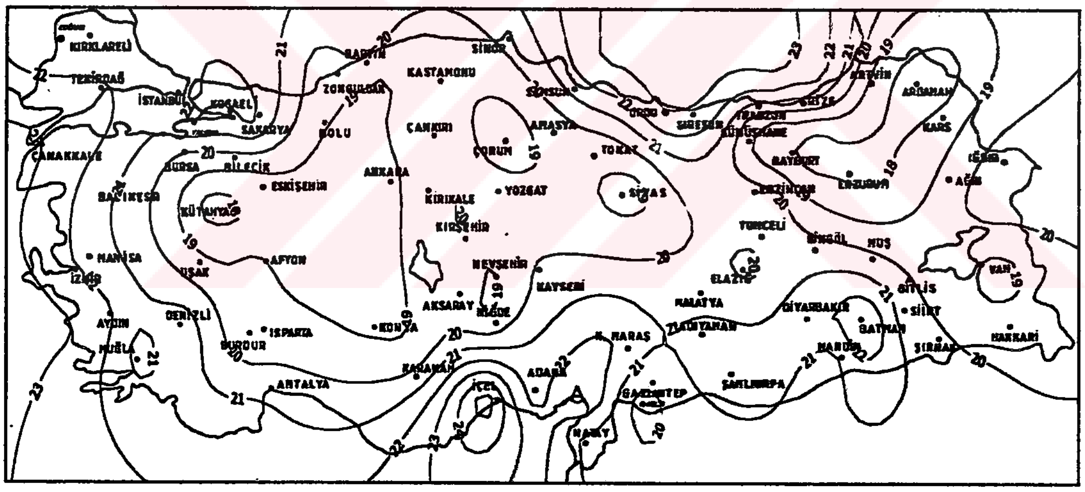


Figure 4.3.10. The counter map of 1% frequency level of the mean coincident wet-bulb temperatures as cooling design conditions for Turkey

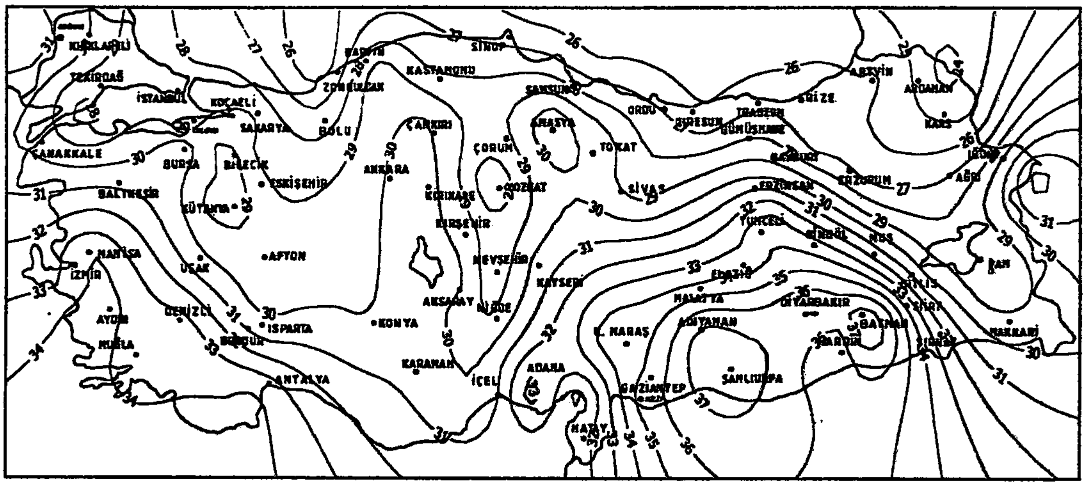


Figure 4.3.11. The counter map of 2% frequency level of outdoor dry-bulb temperatures as cooling design conditions for Turkey

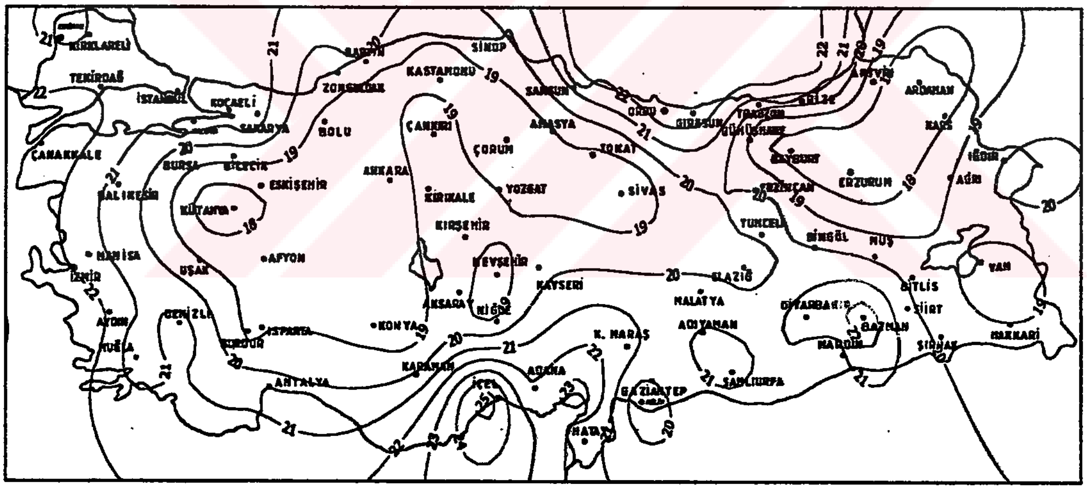


Figure 4.3.12. The counter map of 2% frequency level of the mean coincident wet-bulb temperatures as cooling design conditions for Turkey

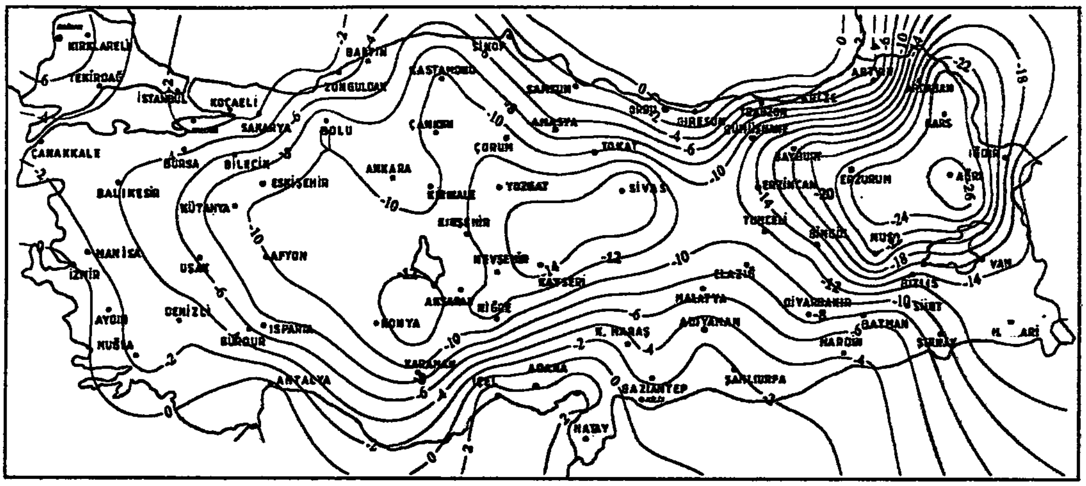


Figure 4.3.13. The counter map of outdoor dry-bulb temperatures as winter design conditions at 99.6% frequency level for Turkey

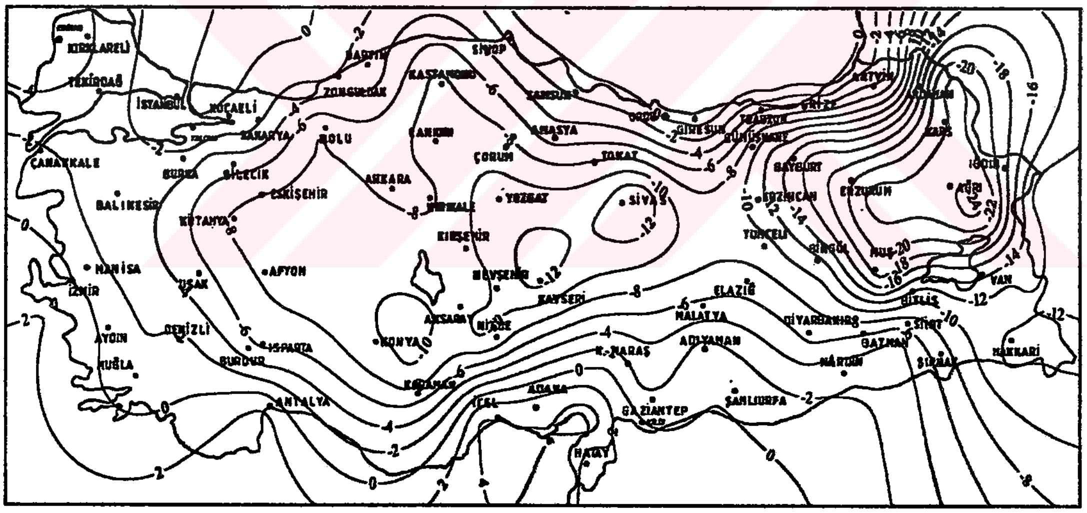


Figure 4.3.14. The counter map of outdoor dry-bulb temperatures as winter design conditions at 99% frequency level for Turkey

The design conditions provided in Table 4.3.1 and 4.3.2 were obtained by direct analysis of the observations from the indicated locations. The values can be used as estimate of the weather conditions at the recording station for several years into the future. In fact, there are several sources of uncertainty which affect the accuracy of using the design conditions. The most important of these factors is spatial representativeness. Data representing the psychrometric conditions are generally properties of air masses, rather than local features, tend to vary on regional scales. Significant variations can occur with changes in local elevation, across large metropolitan areas, or in the vicinity of large bodies of water. Weather conditions vary from year to year, and to some extent, from decade to decade, due to the inherent variability of climate. Similarly, values representing design conditions vary depending on the period of record used in the analysis (ASHRAE, 1997).

Some independent studies (TTMD, 2000; Üner, 1998) have been performed to expose climatic design conditions of Turkey in recent years. Turkish Society of HVAC & Sanitary Engineers (TTMD) has published the results of a project on weather data of Turkey. In the project, the design conditions of only four provinces (İstanbul, Ankara, İzmir, and Antalya) were provided according to the format of ASHRAE (1997).The design conditions were based on the hourly weather databases. Üner (1998) presented weather data of main cities of Turkey according to ASHRAE (1993). The researcher determined design conditions using Typical Meteorological Years (TMY) data generated from 7 years meteorological data. The design conditions for some locations of Turkey are also available in ASHRAE-Handbook 1993 and 1997.

A comparison of the design data provided in this study with the data available in the literature given above is presented in the Table 4.3.3. A good agreement is evident between this study, ASHRAE (1997) and TTMD for cooling design conditions. However the values given in ASHRAE (1993) are always greater than the others.

In the case of heating design conditions, the values of TTMD are close the results of this study. However the temperatures given in ASHRAE (1997) and ASHRAE (1993) are generally lower than the others.

The differences between the design temperatures could be the result of the time period source and process of the data used. The design values proposed in this study rely on a database that covers recent years and long time period. A very careful attention is given to the process and elimination of erroneous data.

Table 4.3.3. Comparison of design data recommended in this study with the data available in literature

			Adana	Ankara	Erzurum	Eskişehir	İstanbul	İzmir	Malatya	Van	Antalya
Cooling Design Conditions	0.4% DB/MWB	This Study	36.3/21.2	33.0/18.5	29.5/18.0	32.4/18.4	30.3/21.9	35.1/22.8	36.0/20.7	29.6/18.7	37.7/21.1
		ASHRAE97	36.1/21.7	32.2/17.2	28.9/16.1	32.2/20.0	30.0/21.1	35.6/22.2	36.1/20.0	28.9/18.9	-
		TTMD	-	33.2/18.2	-	-	30.4/20.5	35.2/22.1	-	-	37.6/21.0
	1% DB/MWB	This Study	34.9/21.5	31.4/18.3	28.1/17.8	30.6/18.2	29.1/21.6	33.7/22.5	34.7/20.3	28.4/18.4	35.9/21.0
		ASHRAE97	34.4/21.7	30.0/17.2	27.8/15.6	30.6/19.4	28.9/20.6	33.9/21.7	35.0/19.4	27.8/18.9	-
		TTMD	-	31.7/17.6	-	-	29.1/21.0	33.9/22.7	-	-	35.9/21.5
		ASHRAE93	38.0/26.0	34.0/20.0	-	-	33.0/24.0	37.0/24.0	-	-	-
		Üner	36.0/-	33.8/-	29.5/-	-	30.7/-	35.9/-	36.0/-	29.3/-	37.8/-
	2% DB/MWB	This Study	33.8/21.9	29.9/18.0	26.7/17.3	29.1/17.9	28.0/21.4	32.5/22.3	33.4/20.0	27.4/18.1	34.1/20.8
		ASHRAE97	33.3/22.2	28.9/16.7	26.1/15.0	29.4/18.9	28.3/20.6	32.8/21.1	33.9/18.9	26.7/18.3	-
		TTMD	-	30.0/17.1	-	-	28.1/20.6	32.6/22.8	-	-	34.2/21.3
	Max DB	This Study	40.5	36.3	32.6	35.9	34.6	39	39.2	32.7	41.8
		ASHRAE97	39.4	35.0	31.1	35.6	35.0	38.3	38.9	32.2	-
		TTMD	-	36.0	-	-	33.3	37.9	-	-	40.8
Heating Design Conditions	99.6% DB	This Study	1.9	-9.4	-26.2	-9.8	-1.1	1.0	-8.4	-13.4	1.8
		ASHRAE97	0.0	-16.7	-30.6	-11.1	-3.3	-2.2	-12.2	-14.4	-
		TTMD	-	-10.0	-	-	-2.0	0.3	-	-	1.4
	99% DB	This Study	3.2	-7.8	-23.1	-8.2	-0.3	1.9	-6.7	-11.6	2.8
		ASHRAE97	1.1	-13.3	-27.2	-8.9	-1.7	-0.6	-8.9	-12.8	-
		TTMD	-	-7.9	-	-	-0.5	1.6	-	-	2.5
		ASHRAE93	1.1	-13.0	-	-	-2.0	-3.0	-	-	-
		Üner	0.9	-11.2	-31.8	-	-1.5	0.0	-11.3	-14.0	0.9
	Min DB	This Study	-1.2	-12.6	-31.9	-15.5	-3.6	-1.4	-11.9	-17.7	-0.8
		ASHRAE97	-3.3	-18.9	-33.3	-14.4	-6.1	-4.4	-16.1	-16.7	-
		TTMD	-	-13.3	-	-	-3.6	-1.3	-	-	-0.2

4.4. Analysis of Current Outdoor Design Conditions for Turkey

Currently, the weather data provided by the Chamber of Mechanical Engineers (MMO, 1997; Özkul, 1985) and Ministry of Public Works and Settlement (Önen,1985) are effectively used as outdoor design conditions in load calculations. The design conditions given in these publications are based on old databases (Gülferi, 1966) and have not been updated for the last 35 years. The methods used in determining design data are also controversial, because the database is old, and design values were determined by hand calculations, and no variable risk factors are considered. The design data are not detailed and not accurate enough for design calculations and building energy analysis. In addition, cooling design conditions for some provinces are not available. Cooling design data for 26 provinces are not available in the publication of Ministry of Public Works and Settlement (Önen,1985). Cooling design data for 14 provinces are not available in the publication of the Chamber of Mechanical Engineers (Özkul,1985). Cooling design data for 10 provinces are not available in literature.

The current summer design conditions of all locations are shown on psychrometric diagram in Figure 4.4.1. As seen from this Figure, the data are scattered.

The frequency level of current design conditions of all provinces is evaluated using the weather database (Table 3.1.1) on which this study is based. The determination of frequency level is based on annual percentile values as suggested by ASHARE (ASHRAE, 1997). The annual percentile values for the dry-bulb temperatures of each location were calculated. Table 4.4.1 shows the number of occurrence in hours and frequency level of both current cooling and heating design conditions for each weather station. In the Table, the differences between current data and the data provided in this study were also shown.

The frequency levels of current cooling design conditions are between 0.0% and 3.09%. The current design conditions usually overestimate the cooling dry-bulb temperature. For 69 of 78 provinces, the frequency level of the current dry-bulb temperature is smaller than the minimum risk level (0.4%) proposed by ASHRAE

(1997). This means that HVAC systems are oversized and run at part load conditions in most of the time if the current design data are used. The frequency level of the current dry-bulb temperature is in the range between 0.4% and 2% proposed by ASHRAE (1997) in 4 provinces. These are Erzurum, Artvin, Kahramanmaraş, and Adıyaman. On the other hand, frequency level is higher than the maximum frequency level of 2% in 5 provinces. These are Muş, Amasya, Nevşehir, Bingöl and Tokat.

The annual cumulative frequencies for the current heating design conditions are in the range of 97.61% and 100%. The frequency levels of current heating design temperatures are between the levels recommended by ASHRAE (1997) for only 11 provinces. Only 8 locations have frequency levels lower than the recommended level. For the remaining locations (59 provinces), the frequency levels are higher than the maximum level (99.6%) recommended by ASHRAE (1997). Some locations such as Adıyaman, Hakkari, Kahramanmaraş, and Kilis have zero risk factor, because very low values were chosen for the current heating design temperatures for these locations.

The Table 4.4.1 also shows the differences between the values of the current data and the data provided in this study. The current cooling design conditions of seven locations are even lower than the values of 0.4% frequency level. The others generally have high values. The current values of wet-bulb temperature for Kahramanmaraş, Muş, Nevşehir, Ordu, and Tokat are lower than the values recommended in this study. But the values of wet-bulb temperature for the remaining locations are at very high values. In general, It was concluded that both dry-bulb and wet-bulb temperature used currently as cooling design data for locations are at very high values according to the data base used in the present study.

The current heating design conditions of eleven locations are higher than the data provided in this study. But in the other locations, the current design data are at very low values. The differences between the values are in the range of 0.3 and 11.6. It can be said that the heating design data currently used are very low values in general.

The current design data and the data obtained in this study are shown together in Figures 4.4.2, 4.4.3, and 4.4.4 for 0.4%, 1%, and 2% frequency levels, respectively. As seen from these Figures, the current design data and the data obtained in this study are not in a good agreement. They locate at different regions on psychrometric chart although some data points are in a common region. The most striking difference between the two data sets is very high moisture content of the current design data. The dry-bulb temperatures in the current design data are also higher than the data obtained in this study.

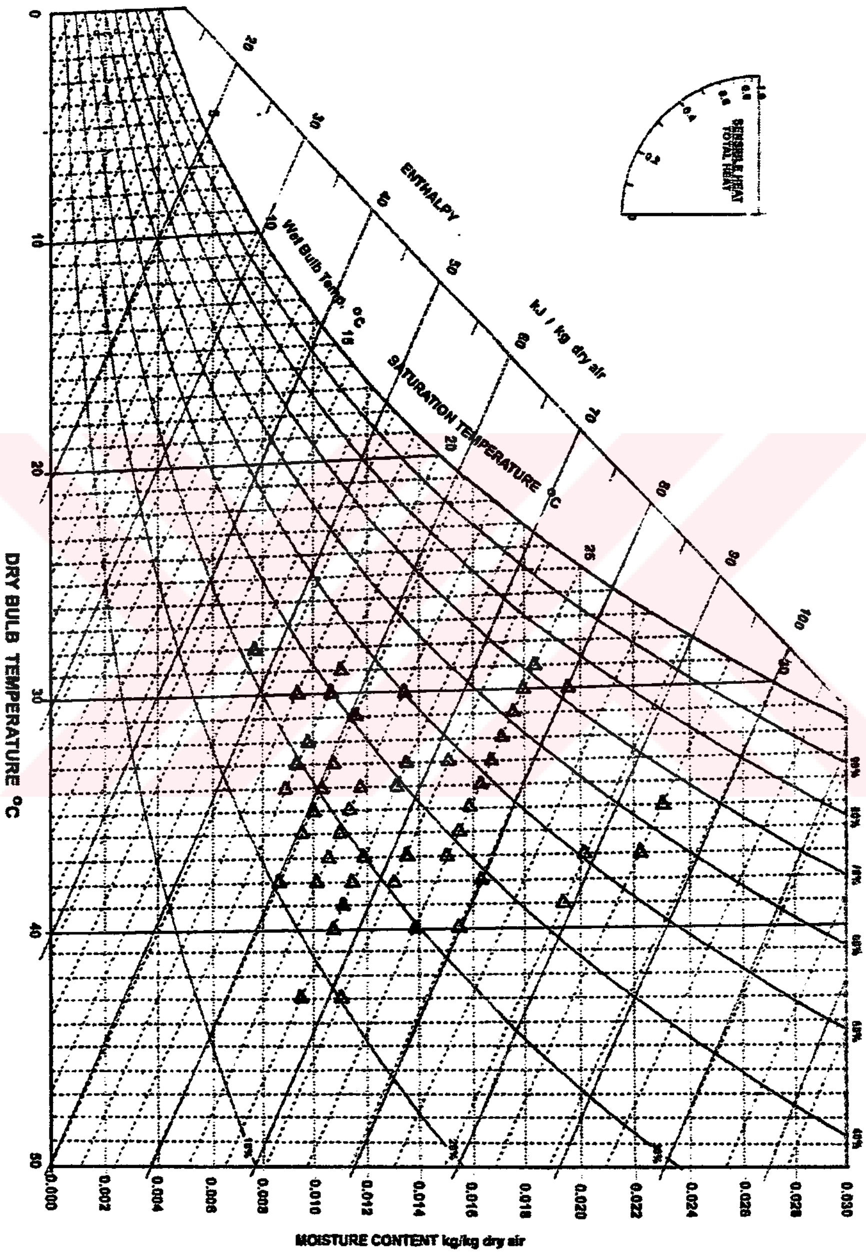


Figure 4.4.1. Current design conditions for Turkey on psychrometric chart

Table 4.4.1. Comparison of the current design conditions with the data obtained in this study

	Cooling Design Conditions																Heating Design Conditions						
	Current				This Study						Difference with Current						Current			This Study FL [%]		Difference with Current	
					0.4%		1%		2%		0.4%		1%		2%								
Location	DB	WB	FL [%]	NOO [h]	DB	MWB	DB	MWB	DB	MWB	ΔDB	ΔWB	ΔDB	ΔWB	ΔDB	ΔWB	DB	FL [%]	NOO [h]	99.6	99	Δ99.6	Δ99
Adana	38	26	0.2	17	36.4	21.2	34.9	21.5	33.8	21.9	1.6	4.8	3.1	4.5	4.2	4.1	0.0	99.82	16	1.9	3.2	-1.9	-3.2
Adapazarı	35	25	0.09	8	32.4	22.8	30.6	22.3	29.2	21.9	2.6	2.2	4.4	2.7	5.8	3.1	-3.0	99.65	31	-2.1	-1.1	-0.9	-1.9
Adıyaman	38	22	1.6	140	39.4	21.5	38.3	21.3	37.2	21.1	-1.4	0.5	-0.3	0.7	0.8	0.9	-9.0	100	0	-2.6	-1.3	-6.4	-7.7
Afyon	34	21	0.1	9	32.0	19.5	30.7	19.2	29.2	18.8	2.0	1.5	3.3	1.8	4.8	2.2	-12.0	99.75	22	-9.8	-8.0	-2.2	-4.0
Ağrı	34	25	0.11	10	31.8	20.8	30.4	20.5	28.9	20.0	2.2	4.2	3.6	4.5	5.1	5.0	-24.0	98.12	164	-28.0	-25.4	4.0	1.4
Aksaray	-	-	0	-	33.0	20.5	31.7	20.0	30.4	19.6	-	-	-	-	-	-	-15.0	99.83	15	-11.2	-9.1	-3.8	-5.9
Amasya	31	21	2.21	194	34.5	19.8	32.6	19.4	31.0	19.0	-3.5	1.2	-1.6	1.6	0.0	2.0	-12.0	99.93	6	-6.4	-4.7	-5.6	-7.3
Ankara	34	20	0.25	22	33.0	18.5	31.4	18.3	29.9	18.0	1.0	1.5	2.6	1.7	4.1	2.0	-12.0	99.78	19	-9.4	-7.8	-2.6	-4.2
Antakya	37	28	0.21	18	35.0	20.8	32.9	21.0	31.5	21.6	2.0	7.2	4.1	7.0	5.5	6.4	0.0	99.47	46	0.3	1.7	-0.3	-1.7
Antalya	39	28	0.24	21	37.7	21.1	35.9	21.0	34.1	20.8	1.3	6.9	3.1	7.0	4.9	7.2	3.0	98.52	129	1.8	2.8	1.2	0.2
Ardahan	-	-	0	-	26.6	17.9	25.1	17.4	23.5	16.9	-	-	-	-	-	-	-21.0	97.97	178	-25.7	-23.0	4.7	2.0
Artvin	30	26	0.48	42	30.0	18.4	27.8	18.0	26.1	17.6	0.0	7.6	2.2	8.0	3.9	8.4	-9.0	99.97	3	-5.1	-3.9	-3.9	-5.1
Aydın	40	26	0.11	9	37.8	23.2	36.4	23.0	35.1	22.7	2.2	2.8	3.6	3.0	4.9	3.3	-3.0	99.94	5	-0.5	0.5	-2.5	-3.5
Balıkesir	37	25	0.11	10	34.6	21.8	32.7	21.4	31.3	21.1	2.4	3.2	4.3	3.6	5.7	3.9	-3.0	98.97	90	-3.8	-2.6	0.8	-0.4
Bartın	-	-	-	-	30.9	20.9	29.3	20.6	27.9	20.6	-	-	-	-	-	-	-3.0	98.69	114	-4.8	-3.2	1.8	0.2
Batman	-	-	-	-	40.8	23.9	39.7	23.7	38.5	23.3	-	-	-	-	-	-	-9.0	99.66	29	-6.5	-4.7	-2.5	-4.3
Bayburt	-	-	-	-	29.7	17.8	28.1	17.3	26.4	16.9	-	-	-	-	-	-	-15.0	97.94	181	-18.9	-16.5	3.9	1.5
Bilecik	34	23	0.14	13	31.9	20.8	30.3	20.3	28.8	19.9	2.1	2.2	3.7	2.7	5.2	3.1	-9.0	99.94	5	-5.4	-4.2	-3.6	-4.8
Bingöl	33	21	3.09	270	36.2	20.8	35.1	20.6	33.8	20.2	-3.2	0.2	-2.1	0.4	-0.8	0.8	-18.0	99.86	12	-12.7	-10.8	-5.3	-7.2
Bitlis	34	22	0.14	13	32.3	20.1	31.2	19.8	29.9	19.5	1.7	1.9	2.8	2.2	4.1	2.5	-15.0	99.74	23	-13.0	-10.8	-2.0	-4.2
Bolu	33	23	0.12	11	30.6	19.4	28.9	19.3	27.3	19.0	2.4	3.6	4.1	3.7	5.7	4.0	-15.0	99.92	7	-9.8	-7.8	-5.2	-7.2
Burdur	36	21	0.03	2	33.5	19.1	32.3	18.9	31.1	18.6	2.5	1.9	3.7	2.1	4.9	2.4	-9.0	99.93	6	-6.1	-4.9	-2.9	-4.1

Table 4.4.1. (Continued) Comparison of the current design conditions with the data obtained in this study

Location	Cooling Design Conditions																Heating Design Conditions						
	Current				This Study						Difference with Current						Current			This Study FL [%]		Difference with Current	
					0.4%		1%		2%		0.4%		1%		2%								
	DB	WB	FL [%]	NOO [h]	DB	MWB	DB	MWB	DB	MWB	ΔDB	ΔWB	ΔDB	ΔWB	ΔDB	ΔWB	DB	FL [%]	NOO [h]	99.6	99	Δ99.6	Δ99
Bursa	37	25	0.04	3	33.5	20.4	32.0	20.3	30.7	20.1	3.5	4.6	5.0	4.7	6.3	4.9	-6.0	99.87	12	-3.4	-2.0	-2.6	-4.0
Çanakkale	34	25	0.14	12	32.3	23.7	31.0	23.3	30.0	22.9	1.7	1.3	3.0	1.7	4.0	2.1	-3.0	99.58	37	-2.4	-1.3	-0.6	-1.7
Çankırı	37	23	0.04	4	33.5	20.6	31.8	20.2	30.2	19.8	3.5	2.4	5.2	2.8	6.8	3.2	-15.0	99.88	11	-10.8	-8.9	-4.2	-6.1
Çorum	35	22	0.1	8	32.2	18.8	30.4	18.3	28.8	17.9	2.8	3.2	4.6	3.7	6.2	4.1	-15.0	99.83	15	-10.9	-8.7	-4.1	-6.3
Denizli	38	24	0.12	10	36.0	21.9	34.8	21.8	33.6	21.6	2.0	2.1	3.2	2.2	4.4	2.4	-6.0	99.96	4	-2.4	-1.4	-3.6	-4.6
Diyarbakır	43	23	0.01	1	39.7	22.3	38.7	22.0	37.5	21.7	3.3	0.7	4.3	1.0	5.5	1.3	-9.0	99.46	47	-8.7	-6.4	-0.3	-2.6
Edirne	37	25	0.06	6	34.0	21.9	32.8	21.6	31.5	21.1	3.0	3.1	4.2	3.4	5.5	3.9	-9.0	99.76	21	-7.3	-5.5	-1.7	-3.5
Elazığ	38	21	0.07	7	35.8	19.8	34.6	19.6	33.3	19.3	2.2	1.2	3.4	1.4	4.7	1.7	-12.0	99.75	22	-8.9	-7.4	-3.1	-4.6
Erzincan	36	22	0.06	5	33.6	20.8	32.1	20.5	30.8	20.1	2.4	1.2	3.9	1.5	5.2	1.9	-18.0	99.77	20	-14.4	-12.1	-3.6	-5.9
Erzurum	30	19	0.42	37	29.5	18.0	28.1	17.8	26.7	17.3	0.5	1.0	1.9	1.2	3.3	1.7	-21.0	97.61	209	-26.2	-23.1	5.2	2.1
Eskişehir	34	22	0.16	14	32.4	18.4	30.7	18.2	29.2	17.9	1.6	3.6	3.3	3.8	4.8	4.1	-12.0	99.75	22	-9.8	-8.2	-2.2	-3.8
Gaziantep	39	23	0.06	6	36.7	21.0	35.8	20.9	34.7	20.7	2.3	2.0	3.2	2.1	4.3	2.3	-9.0	99.97	3	-4.5	-3.1	-4.5	-5.9
Giresun	29	25	0.16	14	27.7	22.6	26.8	22.7	26.0	22.5	1.3	2.4	2.2	2.3	3.0	2.5	-3.0	99.98	2	0.2	1.0	-3.2	-4.0
Gümüşhane	33	23	0.3	27	32.2	18.4	30.0	17.9	27.9	17.6	0.8	4.6	3.0	5.1	5.1	5.4	-12.0	99.04	84	-13.4	-11.1	1.4	-0.9
Hakkari	34	20	0.13	11	32.0	20.1	30.9	19.8	29.8	19.3	2.0	-0.1	3.1	0.2	4.2	0.7	-24.0	100	0	-14.2	-12.4	-9.8	-11.6
Iğdır	36	25	0.21	19	34.9	21.1	33.8	20.8	32.6	20.4	1.1	3.9	2.2	4.2	3.4	4.6	-18.0	99.92	7	-12.5	-10.7	-5.5	-7.3
İskenderun	37	29	0.01	1	31.8	23.0	30.7	23.6	30.1	24.0	5.2	6.0	6.3	5.4	6.9	5.0	3.0	99.87	11	5.2	6.4	-2.2	-3.4
Isparta	34	21	0.16	14	32.6	19.6	31.3	19.3	30.1	18.9	1.4	1.4	2.7	1.7	3.9	2.1	-9.0	99.67	29	-7.9	-6.4	-1.1	-2.6
İstanbul	33	24	0.06	5	30.4	21.9	29.2	21.6	28.1	21.4	2.6	2.1	3.8	2.4	4.9	2.6	-3.0	99.78	19	-1.1	-0.3	-1.9	-2.7
İzmir	37	24	0.14	13	35.2	22.8	33.8	22.5	32.6	22.3	1.8	1.2	3.2	1.5	4.4	1.7	0.0	99.66	30	1.0	1.9	-1.0	-1.9
K. Maraş	36	22	1.39	122	37.6	22.3	36.3	22.2	34.9	21.9	-1.6	-0.3	-0.3	-0.2	1.1	0.1	-9.0	100	0	-2.4	-1.2	-6.6	-7.8
Karaman	-	-	-	-	33.3	19.4	32.0	19.2	30.7	18.9	-	-	-	-	-	-	-12.0	99.14	75	-12.5	-10.1	0.5	-1.9

Table 4.4.1. (Continued) Comparison of the current design conditions with the data obtained in this study

Location	Cooling Design Conditions																Heating Design Conditions						
	Current				This Study						Difference with Current						Current			This Study		Difference with Current	
					0.4%		1%		2%		0.4%		1%		2%					FL [%]			
	DB	WB	FL [%]	NOO [h]	DB	MWB	DB	MWB	DB	MWB	ΔDB	ΔWB	ΔDB	ΔWB	ΔDB	ΔWB	DB	FL [%]	NOO [h]	99.6	99	Δ99.6	Δ99
Kars	30	20	0.17	15	28.5	20.1	27.0	19.6	25.5	19.3	1.5	-0.1	3.0	0.4	4.5	0.7	-27.0	99.87	12	-23.7	-21.0	-3.3	-6.0
Kastamonu	34	22	0.09	8	31.1	19.5	29.4	19.0	27.7	18.5	2.9	2.5	4.6	3.0	6.3	3.5	-12.0	99.72	25	-10.4	-8.2	-1.6	-3.8
Kayseri	36	22	0.05	4	33.3	20.5	31.8	20.1	30.3	19.7	2.7	1.5	4.2	1.9	5.7	2.3	-15.0	99.3	61	-16.2	-13.2	1.2	-1.8
Kilis	-	-	-	-	37.7	19.6	36.5	19.5	35.3	19.2	-	-	-	-	-	-	-6.0	99.99	1	-0.8	0.2	-5.2	-6.2
Kırıkkale	-	-	-	-	33.6	20.1	31.9	19.7	30.5	19.3	-	-	-	-	-	-	-12.0	99.79	19	-8.9	-7.4	-3.1	-4.6
Kırklareli	35	25	0.2	17	33.4	21.8	31.9	21.3	30.6	20.9	1.6	3.2	3.1	3.7	4.4	4.1	-9.0	99.84	14	-6.6	-5.0	-2.4	-4.0
Kırşehir	35	21	0.03	3	32.0	20.6	30.6	20.2	29.2	19.9	3.0	0.4	4.4	0.8	5.8	1.1	-12.0	99.32	60	-12.3	-9.9	0.3	-2.1
Kocaeli	36	25	0.03	3	32.3	22.1	30.7	21.7	29.4	21.4	3.7	2.9	5.3	3.3	6.6	3.6	-3.0	99.8	18	-1.4	-0.5	-1.6	-2.5
Konya	34	21	0.17	15	32.7	19.0	31.3	18.8	30.0	18.6	1.3	2.0	2.7	2.2	4.0	2.4	-12.0	99.34	58	-11.6	-9.6	-0.4	-2.4
Kütahya	33	21	0.18	16	31.5	17.8	29.9	17.4	28.5	17.1	1.5	3.2	3.1	3.6	4.5	3.9	-12.0	99.78	19	-9.5	-7.8	-2.5	-4.2
Malatya	38	21	0.13	11	36.0	20.7	34.7	20.3	33.4	20.0	2.0	0.3	3.3	0.7	4.6	1.0	-12.0	99.91	8	-8.4	-6.7	-3.6	-5.3
Manisa	40	25	0.08	7	37.3	21.9	35.9	21.7	34.6	21.5	2.7	3.1	4.1	3.3	5.4	3.5	-3.0	99.8	18	-1.9	-0.8	-1.1	-2.2
Mardin	38	23	0.15	13	36.5	20.5	35.5	20.4	34.4	20.1	1.5	2.5	2.5	2.6	3.6	2.9	-6.0	99.65	31	-4.5	-3.2	-1.5	-2.8
Mersin	35	29	0.01	1	31.1	25.6	30.5	25.8	30.0	25.8	3.9	3.4	4.5	3.2	5.0	3.2	3.0	99.42	51	3.3	4.4	-0.3	-1.4
Muğla	37	22	0.19	16	35.5	20.7	34.2	20.5	33.0	20.3	1.5	1.3	2.8	1.5	4.0	1.7	-3.0	99.27	64	-3.3	-2.1	0.3	-0.9
Muş	32	20	2.07	181	34.2	20.6	33.0	20.3	31.7	19.9	-2.2	-0.6	-1.0	-0.3	0.3	0.1	-18.0	97.96	178	-21.6	-18.9	3.6	0.9
Nevşehir	28	17	2.39	209	31.1	19.0	29.5	18.6	28.1	18.2	-3.1	-2.0	-1.5	-1.6	-0.1	-1.2	-15.0	99.83	15	-11.6	-9.5	-3.4	-5.5
Niğde	34	20	0.05	5	31.4	19.3	30.1	19.0	28.9	18.7	2.6	0.7	3.9	1.0	5.1	1.3	-15.0	99.64	31	-12.9	-10.6	-2.1	-4.4
Ordu	30	22	0.1	9	28.6	23.3	27.8	23.2	27.0	22.9	1.4	-1.3	2.2	-1.2	3.0	-0.9	-3.0	99.93	6	-0.4	0.5	-2.6	-3.5
Rize	30	26	0.07	6	27.6	22.3	26.9	22.3	26.3	22.0	2.4	3.7	3.1	3.7	3.7	4.0	-3.0	99.94	5	-0.2	0.7	-2.8	-3.7
Samsun	32	26	0.02	2	27.8	22.6	27.0	22.8	26.3	22.7	4.2	2.4	5.0	2.2	5.7	2.3	-3.0	99.85	13	-0.8	0.2	-2.2	-3.2
Siirt	40	23	0.09	8	38.1	21.2	37.1	21.0	36.1	20.7	1.9	1.8	2.9	2.0	3.9	2.3	-9.0	99.78	19	-5.7	-3.8	-3.3	-5.2

Table 4.4.1. (Continued) The comparison of current design conditions with the data recommended in this study

	Cooling Design Conditions																		Heating Design Conditions						
	Current				This Study						Difference with Current						Current			This Study FL [%]		Difference with Current	
					0.4%		1%		2%		0.4%		1%		2%								
Location	DB	WB	FL [%]	NOO [h]	DB	MWB	DB	MWB	DB	MWB	ΔDB	ΔWB	ΔDB	ΔWB	ΔDB	ΔWB	DB	FL [%]	NOO [h]	99.6	99	Δ99.6	Δ99
Sinop	30	25	0.02	2	27.4	21.1	26.5	21.1	25.6	20.9	2.6	3.9	3.5	3.9	4.4	4.1	-3.0	99.92	7	0.2	1.1	-3.2	-4.1
Sivas	33	20	0.24	21	31.7	18.8	29.9	18.5	28.2	18.1	1.3	1.2	3.1	1.5	4.8	1.9	-18.0	99.56	38	-17.2	-14.4	-0.8	-3.6
Şanlıurfa	43	24	0.02	2	40.0	22.1	39.1	21.7	38.0	21.4	3.0	1.9	3.9	2.3	5.0	2.6	-6.0	99.97	2	-1.6	-0.3	-4.4	-5.7
Tekirdağ	33	25	0.02	2	29.1	22.9	28.0	22.8	27.2	22.6	3.9	2.1	5.0	2.2	5.8	2.4	-6.0	99.77	20	-3.8	-2.6	-2.2	-3.4
Tokat	29	20	2.71	238	32.6	20.3	31.0	19.7	29.4	19.3	-3.6	-0.3	-2.0	0.3	-0.4	0.7	-15.0	99.9	9	-8.5	-6.4	-6.5	-8.6
Trabzon	31	25	0.07	6	27.7	23.0	26.9	22.9	26.2	22.6	3.3	2.0	4.1	2.1	4.8	2.4	-3.0	99.93	7	-0.1	0.9	-2.9	-3.9
Tunceli	37	22	0.3	26	36.3	21.1	35.1	20.9	33.9	20.7	0.7	0.9	1.9	1.1	3.1	1.3	-18.0	99.89	9	-12.5	-10.2	-5.5	-7.8
Uşak	35	22	0.09	8	32.8	19.7	31.6	19.4	30.4	19.2	2.2	2.3	3.4	2.6	4.6	2.8	-9.0	99.87	12	-6.3	-4.9	-2.7	-4.1
Van	33	20	0.04	4	29.6	18.7	28.5	18.4	27.5	18.1	3.4	1.3	4.5	1.6	5.5	1.9	-15.0	99.63	32	-13.4	-11.6	-1.6	-3.4
Yalova	-	-	-	-	30.2	22.8	29.0	22.7	28.0	22.5	-	-	-	-	-	-	-3.0	99.86	12	-1.0	-0.1	-2.0	-2.9
Yozgat	32	20	0.12	10	30.0	19.7	28.4	19.4	26.8	19.0	2.0	0.3	3.6	0.6	5.2	1.0	-15.0	99.69	27	-13.2	-10.9	-1.8	-4.1
Zonguldak	32	25	0.01	1	27.7	19.6	26.2	19.5	25.0	19.5	4.3	5.4	5.8	5.5	7.0	5.5	-3.0	99.79	19	-1.3	-0.4	-1.7	-2.6

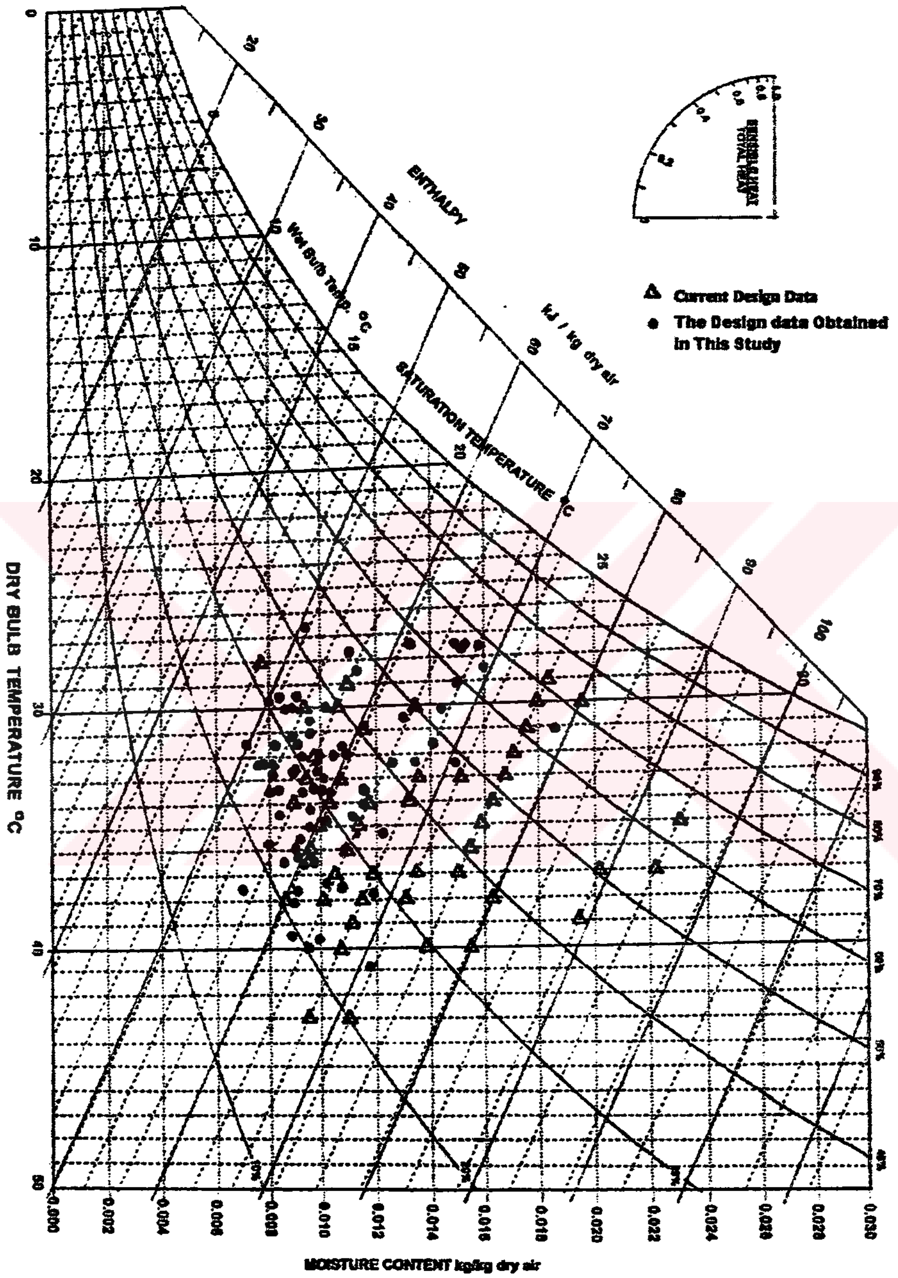


Figure 4.4.2. Current design conditions and the conditions obtained in this study at 0.4% frequency level for Turkey on psychrometric chart

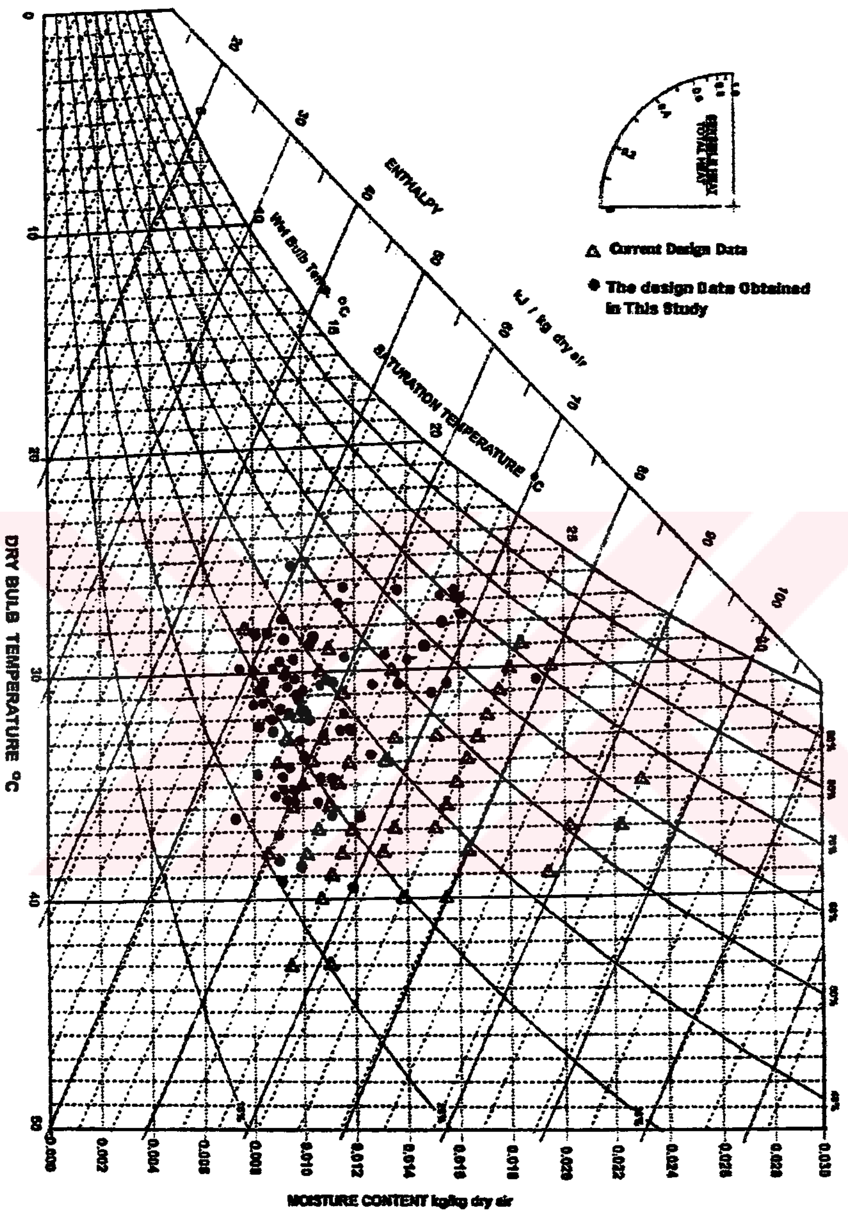


Figure 4.4.3. Current design conditions and the conditions obtained in this study at 1% frequency level for Turkey on psychrometric chart

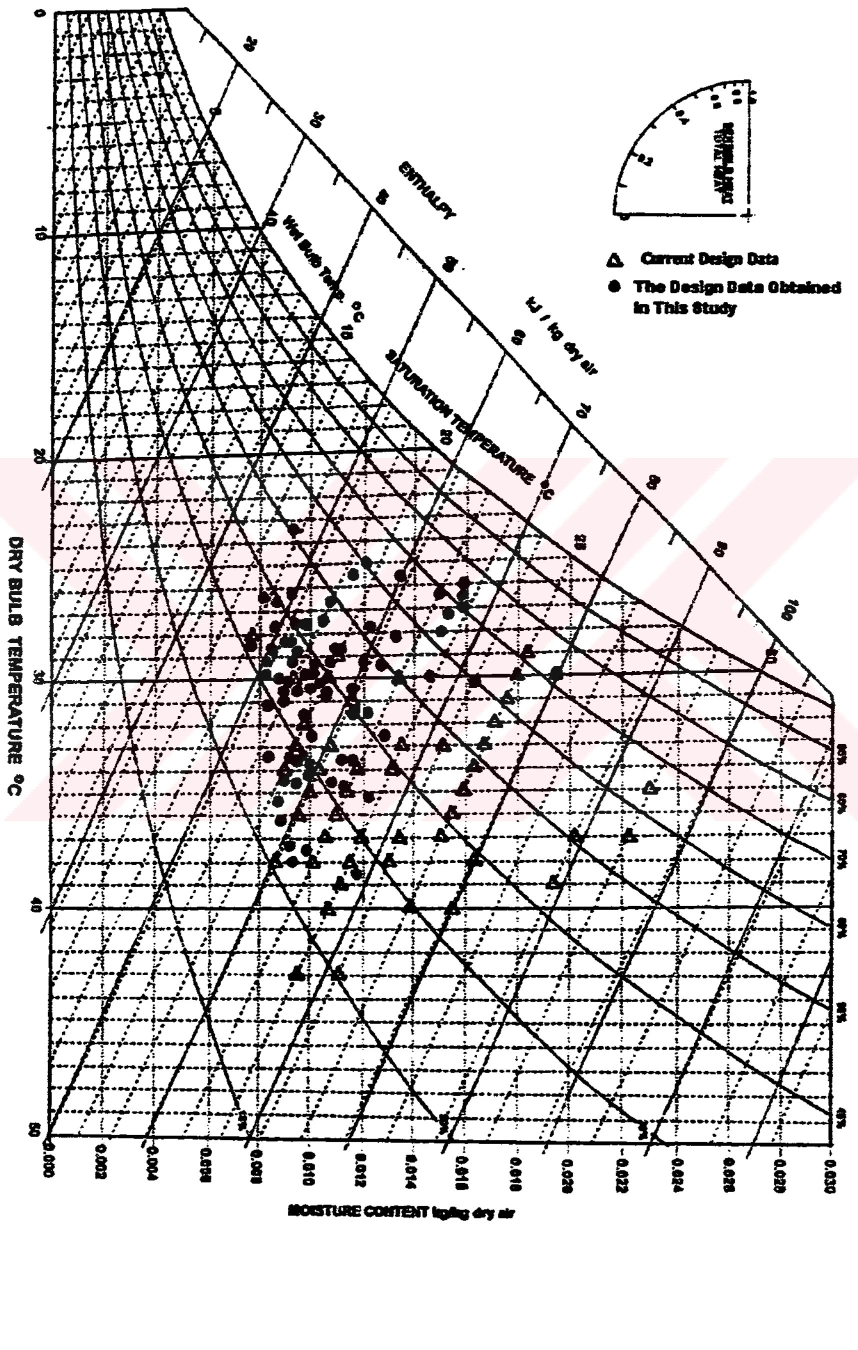


Figure 4.4.4. Current design conditions and the conditions obtained in this study at 2% frequency level for Turkey on psychrometric chart

4. 5. Expression of Typical Weather Variables With Mathematical Equations

Weather data are required for building energy simulations and analysis to serve as an input for driving the thermal models for simulation purposes. The type and format of weather data required depends on the objective of the study and the type of simulation tool. Weather data are originally derived from long-term data and consist of 8760 values of various selected meteorological parameters such as outdoor temperature and solar radiation. The simplest way to obtain the weather data for simulation is to take typical data in the weather library of simulation program used. However, most of the simulation programs used nowadays only provide weather data for limited number of locations, such as in North America and Europe. Simulation programs are not very-well known and not used commonly in Turkey. The weather data files for locations in Turkey are not available. Therefore, an easily attainable weather data source should be available for simulation purposes. Weather data models could be a solution to this problem. The models are usually mathematical models that incorporate the statistical characteristics and distribution of the long-term historical records. The main advantage of the synthetically generation of weather data is the use of mathematical equations in the computer programs and thus, not requiring any weather data file.

In the present study, four typical weather variables namely daily maximum dry-bulb temperature, daily minimum dry-bulb temperature, daily absolute humidity, and hourly dry-bulb temperature are modeled with trigonometric equations using the long-term meteorological data. The information on the database of meteorological data used is given in Table 3.1.2.

Although the weather variables are stochastic and random, the representative equations derived for weather variables in this study have only one parameter. The coefficients of equations were determined in a such way that the minimum errors were obtained.

4.5.1. Daily Maximum Dry-Bulb Temperature

The following equation was determined for daily maximum temperature in °C.

$$T_{\max} = T_1 - (T_1 - T_2)Cos\left[\frac{2\pi}{365}(n-25)\right] \qquad (4.5.1)$$

where n is the number of days from January 1. T_1 and T_2 are coefficients and they were determined for each location separately and statistically . The values for mean absolute error (MAE), mean relative error (MRE), root-mean-square error (RMSE), and correlation coefficient (r) of the obtained equations were also calculated for each province. Table 4.5.1 shows the coefficients obtained and the statistical errors for the equation 4.5.1. for each location.

It can be seen from Table 4.5.1 that correlation coefficients are in the range of 0.81 and 0.95. This means that the equations obtained represent the measured data correctly in general. For some locations, the correlation is very good such as for Adıyaman, Batman, Diyarbakır, Hakkari, and Şanlıurfa. The MAEs are between 2.03 and 4.13 throughout Turkey. RMSEs are in the range of 2.64 and 5.12.

Figure 4.5.1 shows variation of the measured daily maximum temperature and the data obtained from equation 4.5.1 for the main locations in Turkey. Although the measured data fluctuate and vary in a band, the values obtained from the equation follow the variation of the maximum temperature throughout the year.

The monthly mean of daily maximum temperature obtained from Equation 4.5.1 is compared with the measured temperature in Figure 4.5.2. It can be seen that the accuracy of the equation is very high on monthly bases.

Table. 4.5.1. Coefficients and statistical errors for daily maximum temperature equation of each province

Province	T_1	T_2	± MAE [°C]	MRE [%]	RMSE [°C]	r
Adana	25.27	15.28	2.66	12	3.42	0.90
Adapazarı	19.25	9.08	3.81	25	4.80	0.85
Adıyaman	22.76	7.94	2.97	18	3.71	0.94
Afyon	17.00	4.65	3.82	35	4.74	0.88
Ağrı	13.07	-4.49	3.69	141	4.75	0.93
Aksaray	18.32	5.56	3.89	33	4.87	0.88
Amasya	19.70	7.63	4.10	27	5.09	0.86
Ankara	17.57	4.72	3.75	33	4.65	0.89
Antakya	23.25	13.47	2.86	14	3.71	0.88
Antalya	24.01	13.88	2.72	12	3.38	0.90
Ardahan	10.63	-4.20	3.70	193	4.64	0.91
Artvin	16.71	6.70	3.98	30	4.89	0.82
Aydın	24.63	12.86	2.78	13	3.53	0.92
Balıkesir	20.10	8.66	3.70	24	4.62	0.87
Bartın	18.31	8.63	3.59	25	4.58	0.83
Batman	23.54	7.49	2.99	19	3.84	0.95
Bayburt	13.12	-1.15	3.63	258	4.50	0.91
Bilecik	17.45	6.03	3.97	31	4.92	0.85
Bingöl	18.23	1.53	3.13	44	4.00	0.95
Bitlis	15.55	0.36	2.84	77	3.62	0.95
Bolu	16.77	5.74	4.13	34	5.11	0.84
Burdur	19.13	6.45	3.12	22	3.96	0.92
Bursa	19.93	9.00	3.64	23	4.59	0.86
Çanakkale	19.29	8.42	2.72	19	3.47	0.91
Çankırı	17.80	4.18	3.76	33	4.69	0.90
Çorum	17.15	4.93	3.88	34	4.81	0.87
Denizli	22.01	9.88	3.27	19	4.10	0.90
Diyarbakır	22.16	6.25	2.97	21	3.79	0.95
Edirne	19.30	6.72	3.64	27	4.58	0.89
Elazığ	18.68	3.05	3.14	32	3.98	0.94
Erzincan	16.70	2.17	3.61	48	4.52	0.92
Erzurum	11.94	-4.19	3.60	175	4.58	0.93
Eskişehir	16.92	4.35	4.03	38	4.96	0.87
Gaziantep	21.61	7.51	2.97	19	3.72	0.94
Giresun	17.46	9.18	3.00	21	3.89	0.83
Gümüşhane	15.62	2.75	3.96	43	4.88	0.88
Hakkari	14.80	-1.16	3.06	213	3.88	0.95
Iğdır	19.07	3.75	3.32	32	4.29	0.93
Isparta	18.22	5.93	3.18	24	4.00	0.91
İskenderun	23.47	15.44	2.17	10	2.81	0.90

Table. 4.5.1. (Continued) Coefficients and statistical errors for daily maximum temperature equation of each province

Province	T_1	T_2	±MAE [°C]	MRE [%]	RMSE [°C]	r
İstanbul	18.29	8.08	3.01	21	3.79	0.89
İzmir	22.56	11.84	2.73	14	3.43	0.91
K. Maraş	22.38	8.95	3.13	18	3.88	0.93
Karaman	18.46	5.26	3.94	34	4.95	0.88
Kars	11.69	-3.62	3.55	182	4.43	0.93
Kastamonu	15.81	3.72	3.94	39	4.89	0.87
Kayseri	17.54	4.24	4.05	39	5.05	0.88
Kırıkkale	17.85	4.65	3.75	33	4.67	0.89
Kırklareli	18.45	6.13	3.43	27	4.30	0.90
Kırşehir	17.11	4.26	3.85	37	4.79	0.88
Kilis	23.07	9.36	2.92	16	3.69	0.93
Kocaeli	19.15	8.90	3.62	24	4.54	0.85
Konya	17.54	4.54	3.87	36	4.82	0.89
Kütahya	16.75	4.81	3.99	36	4.92	0.86
Malatya	19.10	3.75	3.33	31	4.20	0.93
Manisa	22.74	10.11	3.24	18	4.06	0.91
Mardin	20.23	5.18	2.96	23	3.73	0.94
Mersin	22.98	14.79	2.03	10	2.64	0.91
Muğla	21.06	8.89	2.91	17	3.68	0.92
Muş	15.68	-2.52	3.56	312	4.64	0.94
Nevşehir	15.90	3.47	3.89	42	4.86	0.88
Niğde	17.14	4.64	3.77	36	4.76	0.88
Ordu	18.19	9.53	2.99	20	3.88	0.85
Rize	17.67	9.38	2.68	18	3.45	0.86
Samsun	17.72	9.55	3.07	22	4.04	0.82
Siirt	21.46	6.10	2.92	21	3.72	0.95
Sinop	17.03	8.43	2.89	21	3.73	0.85
Sivas	15.02	1.11	4.06	75	5.06	0.89
Şanlıurfa	23.95	9.37	2.83	16	3.58	0.95
Tekirdağ	17.67	7.52	2.62	20	3.48	0.90
Tokat	18.34	6.64	4.13	31	5.12	0.85
Trabzon	17.70	9.65	2.95	20	3.86	0.83
Tunceli	18.64	2.58	3.17	35	4.04	0.94
Uşak	18.52	6.59	3.39	25	4.25	0.89
Van	14.58	1.08	2.49	48	3.19	0.95
Yalova	19.11	9.49	3.08	20	4.00	0.86
Yozgat	14.31	2.07	3.89	55	4.82	0.87
Zonguldak	16.60	8.34	3.30	25	4.29	0.81

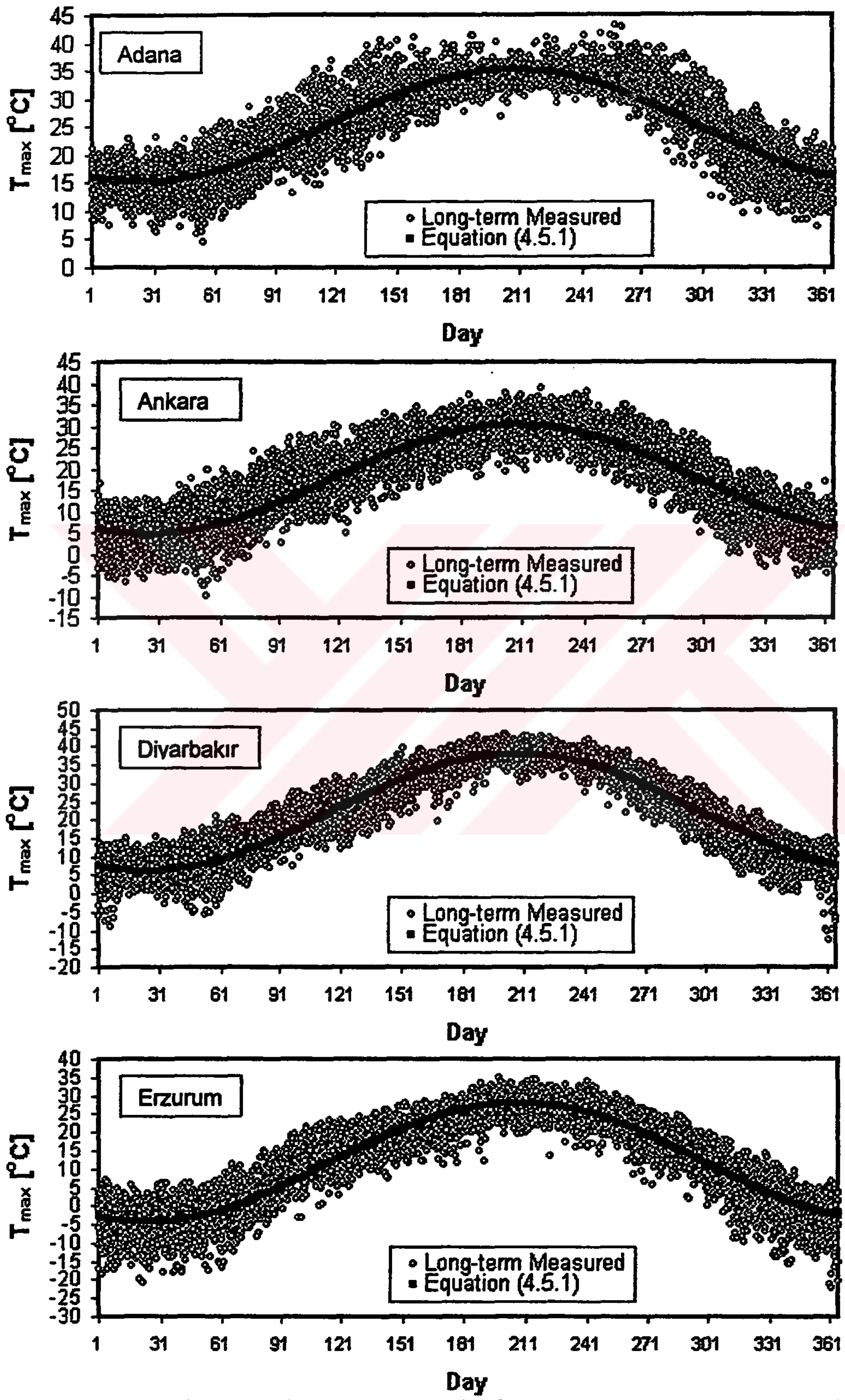


Figure 4.5.1. Variation of daily maximum dry-bulb temperature for main locations

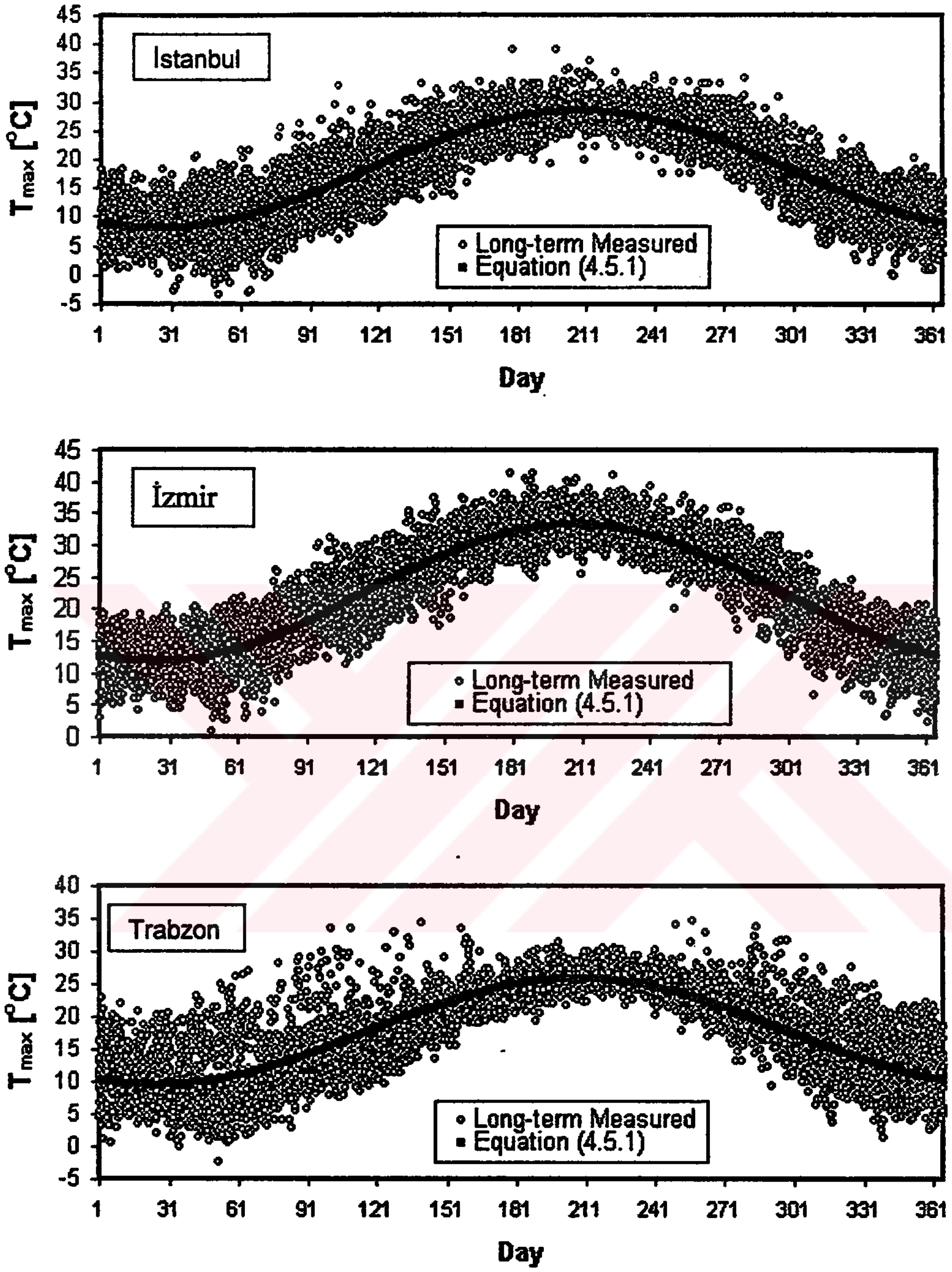
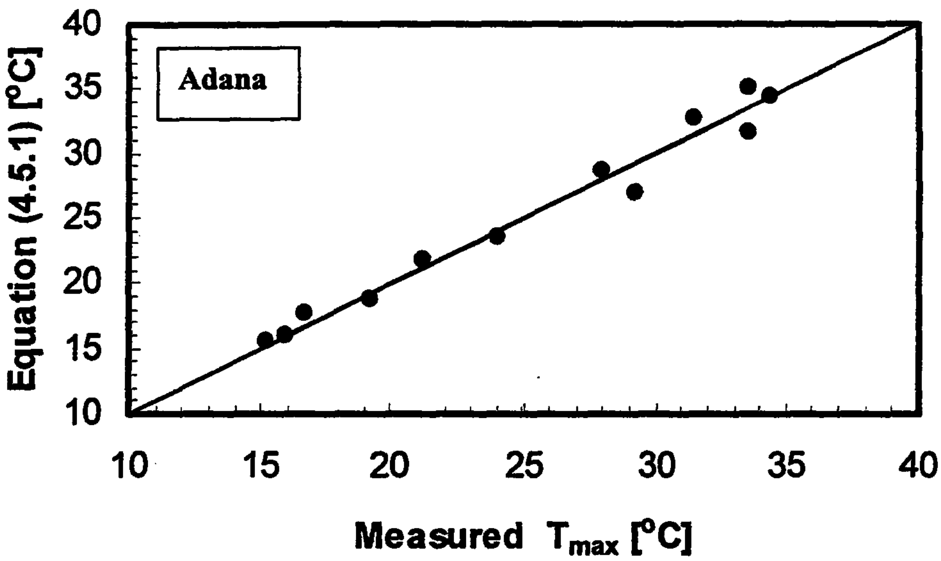


Figure 4.5.1. (Continued) Variation of daily maximum dry-bulb temperature for main locations



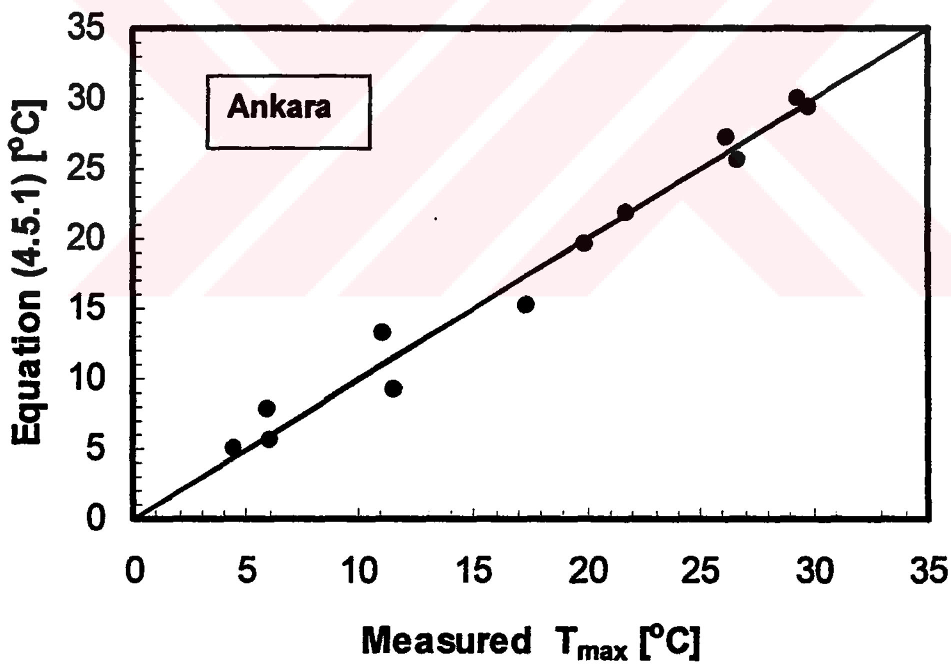
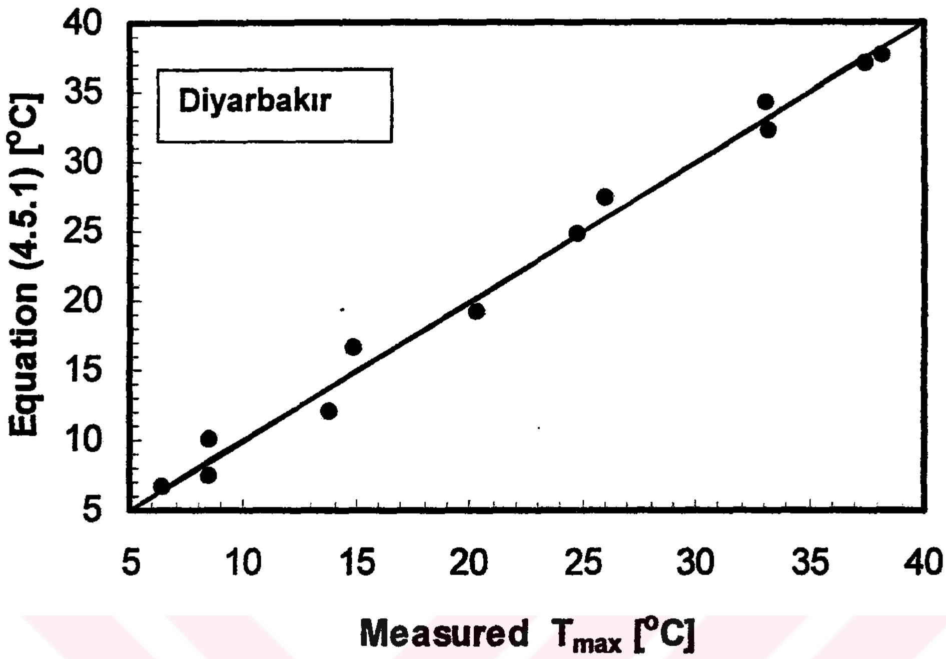


Figure 4.5.2. The monthly mean maximum temperature obtained from Equation 4.5.1 versus the measured monthly mean maximum temperature



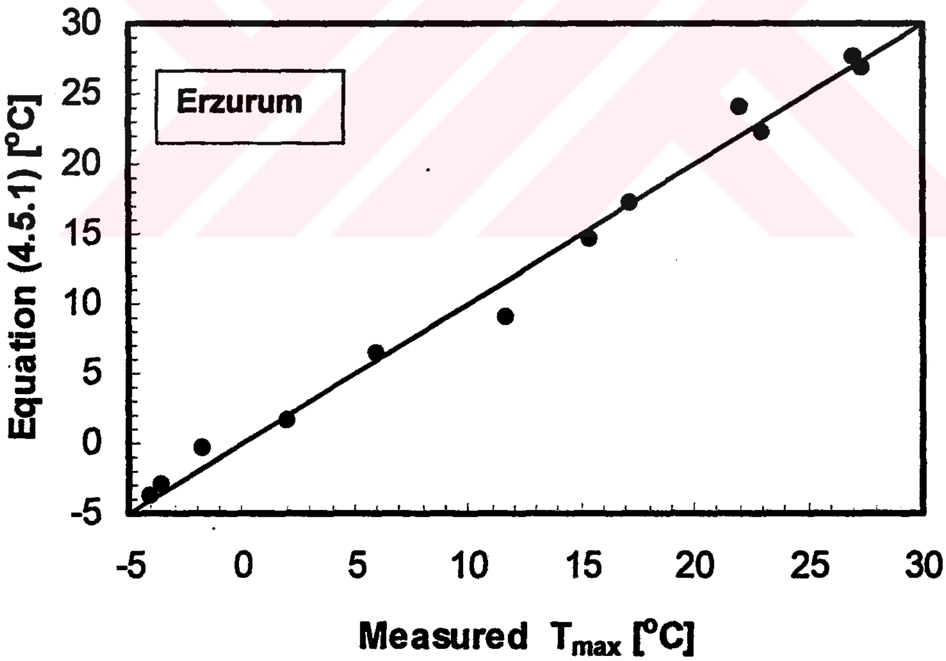


Figure 4.5.2. (Continued) The monthly mean maximum temperature obtained from Equation 4.5.1 versus the measured monthly mean maximum temperature

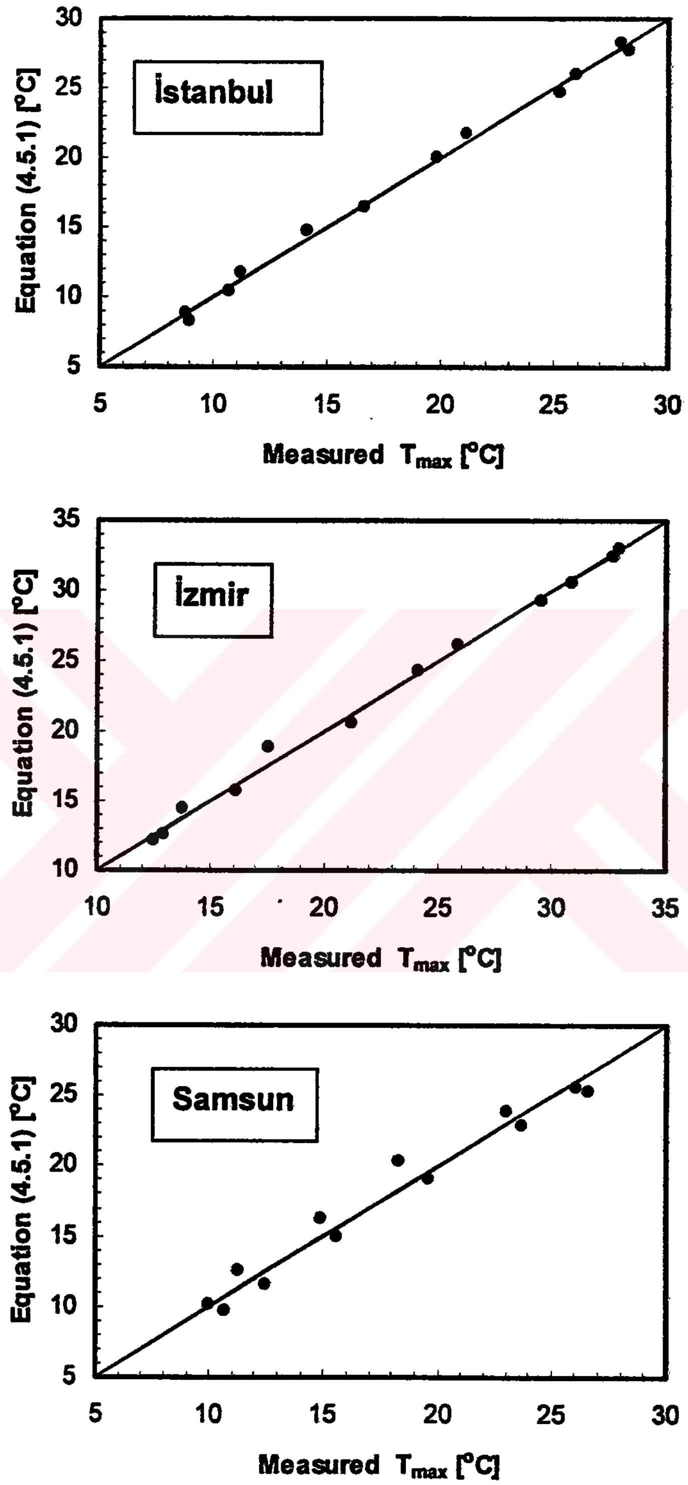


Figure 4.5.2. (Continued) The monthly mean maximum temperature obtained from Equation 4.5.1 versus the measured monthly mean maximum temperature

4.5.2. Daily Minimum Dry-Bulb Temperature

The following equation was determined for daily minimum temperature in °C.

$$T_{\min} = T_3 - (T_3 - T_4)Cos\left[\frac{2\pi}{365}(n-25)\right] \qquad (4.5.2)$$

where n is the number of days from January 1. T_3 and T_4 are the coefficients and they were determined for each province by means of statistical error tests. The statistical errors-mean absolute error (MAE), mean relative error (MRE), and root-mean-square error (RMSE)- and coefficients of the proposed equation were shown in table 4.5.2 for all provinces. Correlation coefficient were also given in the Table.

The correlation coefficients are in the range of 0.81 and 0.94. This means that the equations obtained represent correctly the measured data generally. For some locations, the correlation is very good such as for Adıyaman, Gaziantep, Diyarbakır, Hakkari, Şanlıurfa, Kahramanmaraş, and Siirt. The MAEs are between 1.96 and 4.51, whilst RMSEs are in the range of 2.51 and 5.08 throughout Turkey.

The variation of the measured daily minimum temperature and the data obtained for main provinces in Turkey were depicted in figure 4.5.3. Although the measured data fluctuate and vary in a band, the values obtained from the equation follow the variation of the minimum temperature throughout year almost for all locations.

The monthly mean of daily minimum temperature obtained from Equation 4.5.2 is compared with the measured temperature in Figure 4.5.4. It can be seen that the accuracy of the equation obtained is very high and quite good in predicting the long-term data on monthly bases.

Table. 4.5.2. Coefficients and statistical errors for daily minimum temperature equation of each province.

Province	T_3	T_4	±MAE [°C]	MRE [%]	RMSE [°C]	r
Adana	14.27	5.04	2.08	21	2.65	0.93
Adapazarı	9.78	1.99	2.62	49	3.35	0.86
Adıyaman	11.81	0.65	2.41	65	3.03	0.93
Afyon	5.21	-3.62	2.83	195	3.65	0.86
Ağrı	-0.43	-13.99	4.30	170	5.93	0.85
Aksaray	5.81	-3.88	3.07	291	4.01	0.86
Amasya	7.35	-1.24	2.78	290	3.58	0.86
Ankara	6.14	-3.28	2.81	2368	3.62	0.88
Antakya	13.68	3.73	2.30	28	2.96	0.92
Antalya	12.51	3.95	2.05	24	2.60	0.92
Ardahan	-2.82	-15.39	3.81	109	5.05	0.87
Artvin	7.73	-1.19	2.45	246	3.10	0.90
Aydın	11.50	3.24	2.46	35	3.15	0.88
Balıkesir	9.17	0.50	2.83	110	3.60	0.86
Bartın	7.27	-0.52	2.66	411	3.36	0.85
Batman	9.94	-0.85	2.62	374	3.37	0.91
Bayburt	0.82	-9.90	3.39	150	4.47	0.86
Bilecik	7.81	-0.59	2.70	638	3.45	0.86
Bingöl	6.55	-5.48	2.66	152	3.52	0.92
Bitlis	4.36	-6.42	2.74	241	3.50	0.91
Bolu	4.89	-3.25	2.90	244	3.78	0.84
Burdur	7.20	-2.00	2.54	661	3.25	0.89
Bursa	8.88	0.80	2.74	86	3.53	0.85
Çanakkale	10.79	2.31	2.64	46	3.41	0.87
Çankırı	4.51	-4.56	3.01	709	3.82	0.86
Çorum	3.76	-4.36	3.07	198	3.91	0.83
Denizli	10.76	1.48	2.53	54	3.23	0.90
Diyarbakır	8.60	-3.00	2.72	187	3.51	0.92
Edirne	7.98	-1.10	2.83	606	3.65	0.87
Elazığ	7.23	-4.00	2.72	161	3.46	0.92
Erzincan	4.76	-6.04	3.00	169	3.95	0.89
Erzurum	-1.91	-14.39	4.51	145	5.87	0.83
Eskişehir	3.61	-4.94	3.05	331	3.85	0.84
Gaziantep	9.21	-1.60	2.41	1647	3.02	0.93
Giresun	11.67	3.57	2.25	29	2.84	0.90
Gümüşhane	4.03	-5.75	2.87	157	3.77	0.88
Hakkari	5.09	-8.22	2.59	92	3.41	0.94
Iğdır	5.67	-6.45	2.91	406	3.79	0.91
Isparta	5.46	-3.06	2.79	272	3.56	0.86
İskenderun	16.46	7.93	1.96	15	2.51	0.92

Table. 4.5.2. (Continued) Coefficients and statistical errors for daily minimum temperature equation of each province

Province	T_3	T_4	± MAE [°C]	MRE [%]	RMSE [°C]	r
İstanbul	10.71	2.46	2.34	38	2.95	0.89
İzmir	13.40	4.74	2.43	27	3.09	0.89
Kahramanmaraş	11.31	0.72	2.21	65	2.84	0.94
Karaman	5.20	-4.32	3.29	218	4.35	0.84
Kars	-1.47	-13.89	3.63	142	4.83	0.88
Kastamonu	4.20	-4.27	2.72	232	3.44	0.87
Kayseri	2.78	-6.23	3.49	669	4.56	0.81
Kilis	11.67	1.98	2.34	38	2.98	0.92
Kırıkkale	6.50	-3.04	2.81	199	3.63	0.88
Kırklareli	8.40	-0.53	2.77	691	3.56	0.87
Kırşehir	5.34	-4.61	2.94	171	3.87	0.88
Kocaeli	10.74	2.54	2.45	39	3.11	0.88
Konya	5.26	-4.96	2.86	206	3.72	0.89
Kütahya	4.85	-3.46	2.93	475	3.75	0.84
Malatya	8.33	-2.95	2.65	1056	3.35	0.92
Manisa	11.23	1.91	2.66	48	3.39	0.89
Mardin	12.19	-0.21	2.92	428	3.67	0.92
Mersin	15.34	6.21	1.98	17	2.54	0.93
Muğla	9.37	0.05	2.66	313	3.30	0.89
Muş	3.50	-9.95	3.64	307	5.08	0.88
Nevşehir	4.81	-3.77	3.42	241	4.35	0.81
Niğde	4.95	-4.74	2.90	252	3.91	0.87
Ordu	10.67	2.51	2.23	36	2.82	0.90
Rize	10.82	2.45	2.11	33	2.66	0.91
Samsun	10.67	2.77	2.30	36	2.97	0.88
Siirt	10.99	-0.96	2.36	241	3.05	0.94
Sinop	11.20	3.17	2.19	30	2.73	0.90
Sivas	3.19	-6.50	3.33	201	4.39	0.84
Şanlıurfa	12.59	1.22	2.32	44	2.88	0.94
Tekirdağ	9.97	1.29	2.46	58	3.17	0.89
Tokat	6.86	-1.69	2.94	330	3.84	0.84
Trabzon	11.47	3.49	2.21	30	2.84	0.89
Tunceli	6.84	-4.86	2.89	551	3.77	0.91
Uşak	6.83	-1.81	2.58	236	3.26	0.88
Van	3.73	-7.53	2.57	108	3.41	0.92
Yalova	9.63	1.95	2.52	48	3.19	0.86
Yozgat	3.82	-5.48	3.12	182	4.02	0.85
Zonguldak	10.22	2.58	2.53	41	3.25	0.86

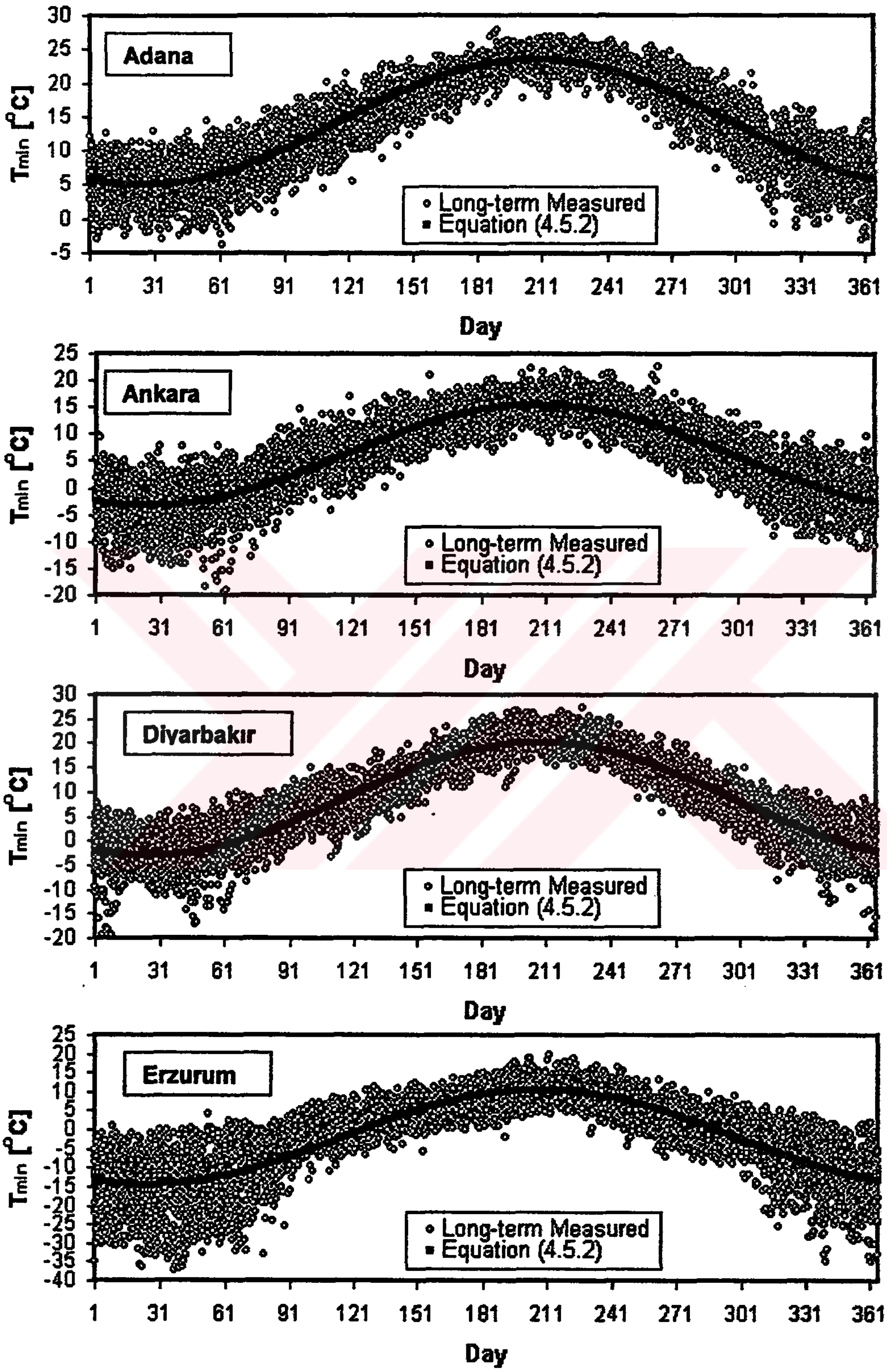


Figure 4.5.3. Variation of daily minimum dry-bulb temperature for main locations

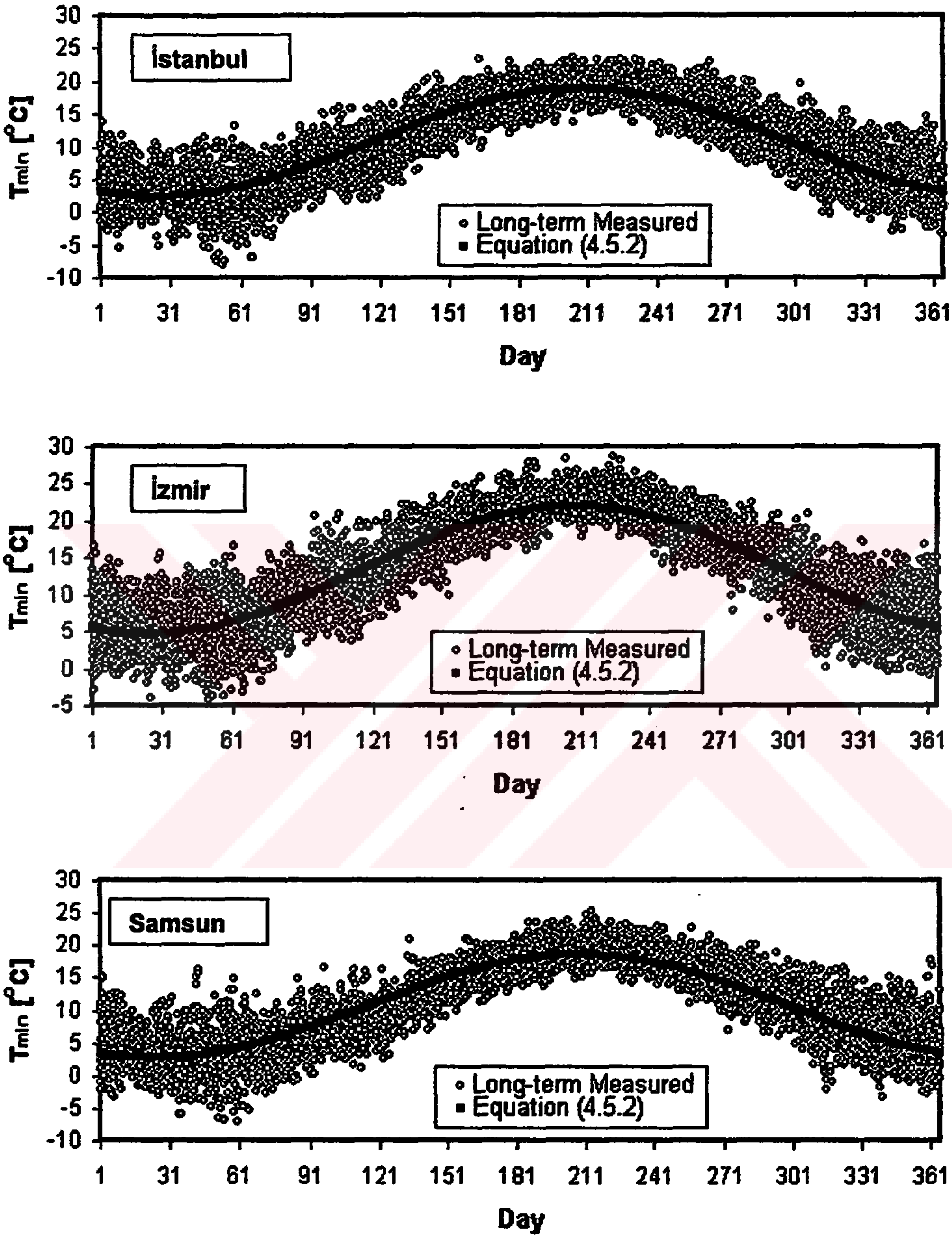


Figure 4.5.3. (Continued) Variation of daily minimum dry-bulb temperature for main locations

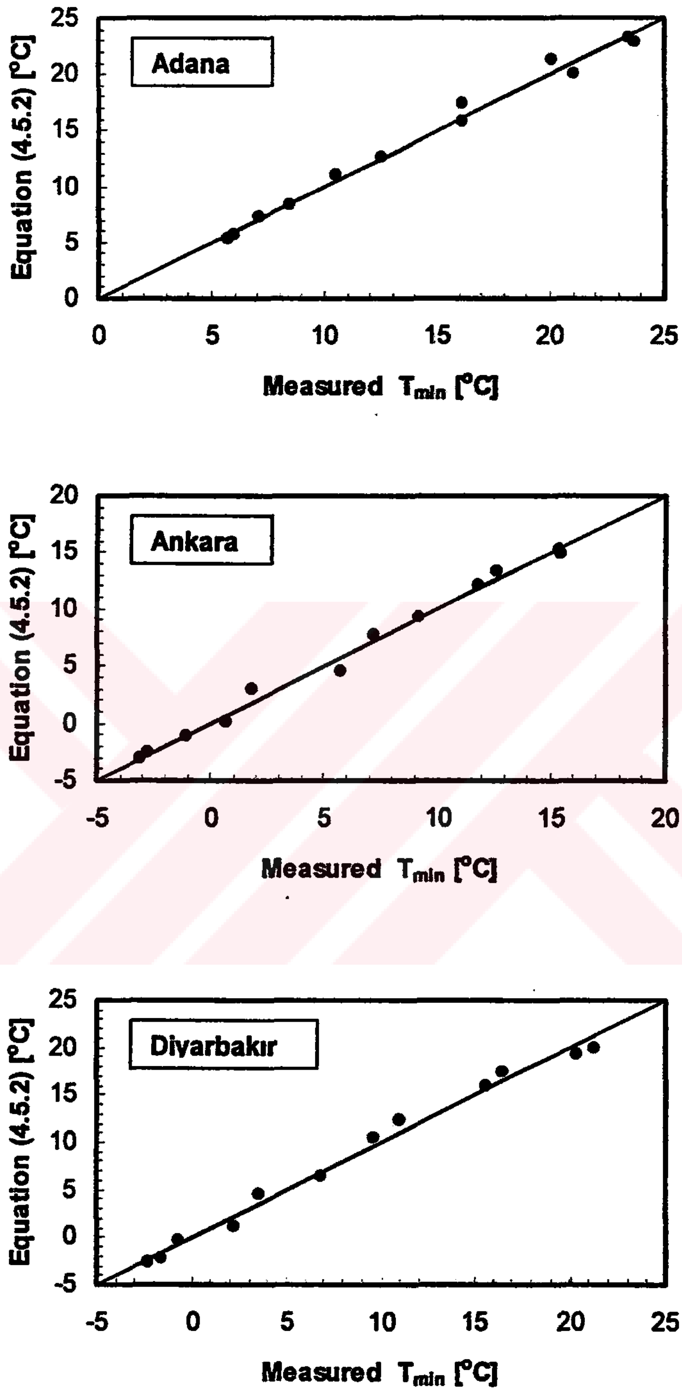


Figure 4.5.4. The monthly mean minimum temperature obtained from equation 4.5.2 versus the measured monthly mean minimum temperature for main locations

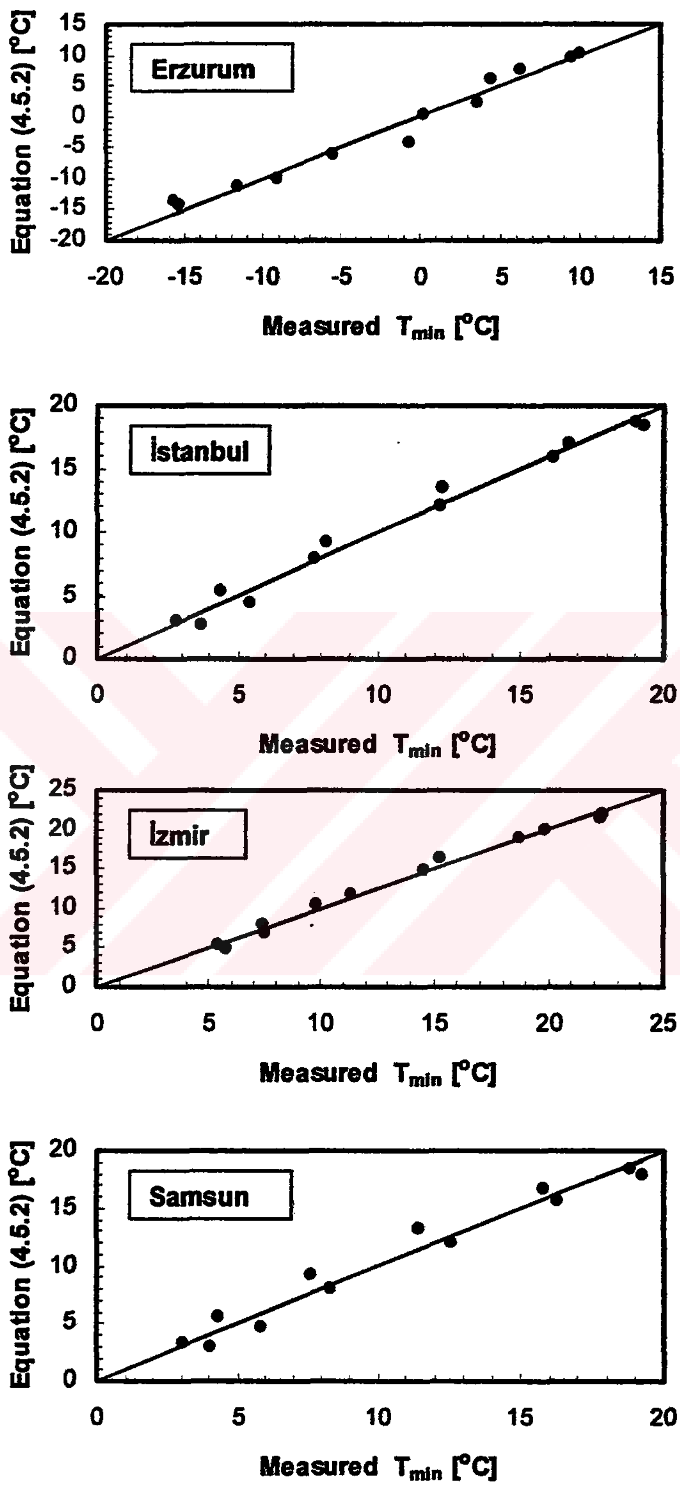


Figure 4.5.4. (Continued) The monthly mean minimum temperature obtained from equation 4.5.2 versus the measured monthly mean minimum temperature for main locations

4.5.3. Daily Mean Humidity Ratio

The following equation was proposed for daily mean humidity ratio for all provinces in gr/kg-dry air :

$$W = W_1 + (W_2 - W_1)\left\{Sin\left[\frac{\pi}{365}(n-25)\right]\right\}^3 \qquad (4.5.3)$$

where n is the number of days from January 1. W_1 and W_2 are the coefficients and they were found for each province by means of statistical errors separately.

The table 4.5.3 provides the coefficients, statistical errors mentioned in previous section, and coefficient of correlations for the proposed equation for each location.

It can be seen from Table 4.5.3 that correlation coefficients are in the range of 0.68 and 0.93. For some locations, the correlation is very good such as for Ardahan, Giresun, Kars, Mersin, and Ordu. The MAEs are between 0.85 and 1.70, whilst RMSEs are in the range of 1.10 and 2.17 throughout Turkey.

Figure 4.5.5. shows the variation of measured and the data obtained for daily mean humidity ratio for main locations in Turkey. Although there are big fluctuations in daily mean humidity ratio almost for all locations, the values obtained from Equation 4.5.3 follow the variation of mean humidity ratio throughout the year as seen from the Figures.

The monthly mean humidity ratio obtained from Equation 4.5.3 versus the measured monthly mean humidity ratio were shown in Figure 4.5.6. It can be seen that the accuracy of the equation is very high on monthly bases.

Table. 4.5.3. Coefficients and errors for daily mean humidity ratio equation of each province

Province	W_1	W_2	±MAE [°C]	MRE [%]	RMSE [°C]	r
Adana	4.66	16.06	1.70	21	2.17	0.89
Adapazarı	4.23	12.82	1.29	18	1.64	0.89
Adıyaman	4.08	8.77	1.39	24	1.75	0.70
Afyon	3.49	9.43	1.11	20	1.39	0.84
Ağrı	2.19	10.08	1.30	28	1.66	0.87
Aksaray	2.96	8.29	0.90	19	1.12	0.87
Amasya	3.13	9.41	1.09	20	1.37	0.86
Ankara	3.17	7.86	0.94	20	1.15	0.83
Antakya	4.91	16.52	1.54	18	1.99	0.91
Antalya	5.01	13.46	1.86	23	2.31	0.88
Ardahan	1.69	8.56	0.84	23	1.06	0.92
Artvin	2.77	10.45	0.98	18	1.26	0.91
Aydın	4.63	11.65	1.40	20	1.73	0.83
Balıkesir	4.53	11.71	1.32	19	1.67	0.84
Bartın	4.07	12.37	1.25	18	1.61	0.88
Batman	4.26	9.96	1.32	20	1.66	0.78
Bayburt	2.30	8.00	0.88	22	1.10	0.88
Bilecik	3.56	10.54	1.12	19	1.42	0.87
Bingöl	3.14	8.64	1.24	25	1.55	0.79
Bitlis	2.90	9.36	1.11	21	1.50	0.84
Bolu	3.22	9.86	1.02	18	1.29	0.88
Burdur	3.49	8.13	1.11	21	1.40	0.77
Bursa	4.03	11.08	1.21	19	1.51	0.86
Çanakkale	4.97	13.87	1.48	19	1.83	0.87
Çankırı	3.05	9.28	1.03	20	1.26	0.87
Çorum	3.06	8.91	0.98	19	1.22	0.87
Denizli	4.38	10.60	1.21	18	1.50	0.83
Diyarbakır	3.87	9.09	1.38	24	1.71	0.74
Edirne	4.06	10.74	1.26	20	1.55	0.84
Elazığ	3.60	8.56	1.22	23	1.51	0.77
Erzincan	2.95	9.67	0.99	20	1.23	0.89
Erzurum	2.01	7.96	0.92	24	1.15	0.88
Eskişehir	3.01	9.04	1.04	20	1.32	0.86
Gaziantep	3.76	10.08	1.36	22	1.73	0.80
Giresun	4.24	13.75	1.16	15	1.50	0.92
Gümüşhane	2.68	9.48	1.00	20	1.26	0.89
Hakkari	2.49	8.20	0.99	22	1.29	0.85
Iğdır	2.18	8.91	0.96	22	1.24	0.89
Isparta	3.09	8.33	0.97	20	1.22	0.84
İskenderun	5.51	17.98	1.62	17	2.07	0.91

Table. 4.5.3. (Continued) Coefficients and errors for daily mean humidity ratio equation of each province

Province	W_1	W_2	±MAE [°C]	MRE [%]	RMSE [°C]	r
İstanbul	4.41	13.05	1.25	17	1.57	0.89
İzmir	5.21	12.31	1.35	18	1.65	0.84
Kahramanmaraş	3.68	12.21	1.45	21	1.87	0.86
Karaman	3.57	8.89	1.08	20	1.35	0.82
Kars	2.00	9.85	0.96	23	1.21	0.92
Kastamonu	2.85	8.56	0.88	19	1.10	0.88
Kayseri	3.18	9.39	1.09	20	1.36	0.86
Kilis	3.86	10.12	1.57	25	1.98	0.76
Kırıkkale	3.21	8.98	1.19	22	1.50	0.81
Kırklareli	3.95	11.06	1.35	22	1.68	0.84
Kırşehir	3.08	8.91	0.96	19	1.19	0.87
Kocaeli	4.45	12.72	1.21	16	1.51	0.89
Konya	3.39	8.68	1.07	20	1.34	0.82
Kütahya	2.78	7.83	0.88	20	1.10	0.86
Malatya	3.21	8.07	1.07	22	1.34	0.80
Manisa	4.70	10.64	1.24	19	1.51	0.82
Mardin	4.04	8.82	1.38	23	1.74	0.68
Mersin	5.38	18.19	1.51	16	1.90	0.93
Muğla	4.31	9.89	1.20	19	1.50	0.80
Muş	2.81	9.07	1.25	26	1.56	0.82
Nevşehir	3.06	8.40	1.00	20	1.24	0.84
Niğde	3.23	8.85	1.03	20	1.28	0.85
Ordu	4.07	13.09	1.06	15	1.34	0.93
Rize	4.16	13.45	1.14	15	1.47	0.92
Samsun	4.12	13.43	1.15	16	1.45	0.92
Siirt	3.74	7.87	1.16	22	1.46	0.72
Sinop	4.06	12.80	1.27	18	1.62	0.89
Sivas	2.85	8.96	1.01	21	1.24	0.87
Şanlıurfa	4.35	9.04	1.42	23	1.80	0.69
Tekirdağ	4.45	13.26	1.34	18	1.67	0.89
Tokat	3.09	9.23	1.01	19	1.29	0.87
Trabzon	3.97	13.19	1.19	17	1.54	0.91
Tunceli	3.00	8.74	1.13	22	1.42	0.83
Uşak	3.44	9.22	1.04	19	1.28	0.85
Van	2.37	7.52	0.85	21	1.08	0.87
Yalova	4.29	13.34	1.21	16	1.52	0.91
Yozgat	3.22	9.55	1.06	20	1.33	0.87
Zonguldak	3.63	11.56	1.18	18	1.50	0.89

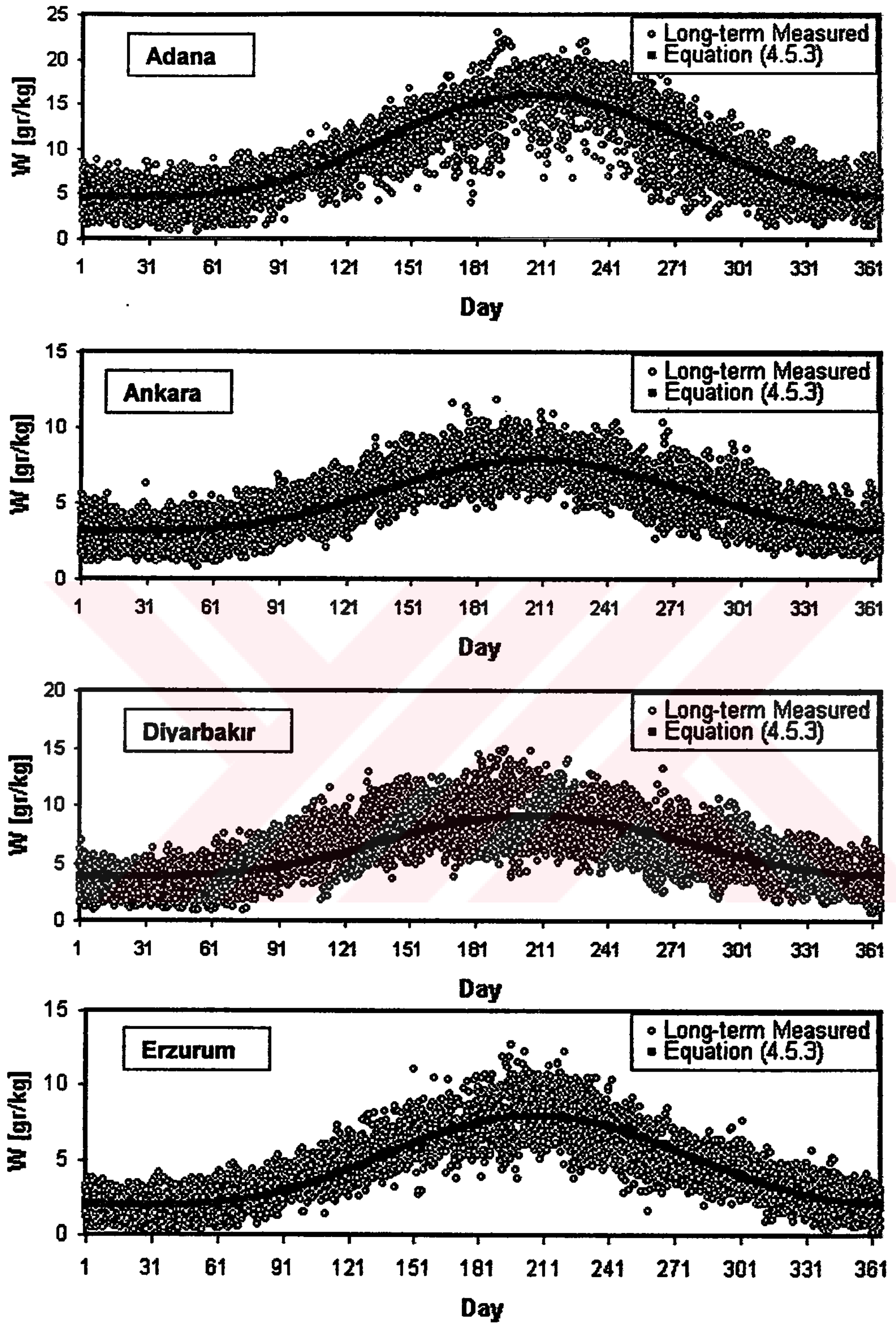


Figure 4.5.6. Variation of daily mean humidity ratio for main locations

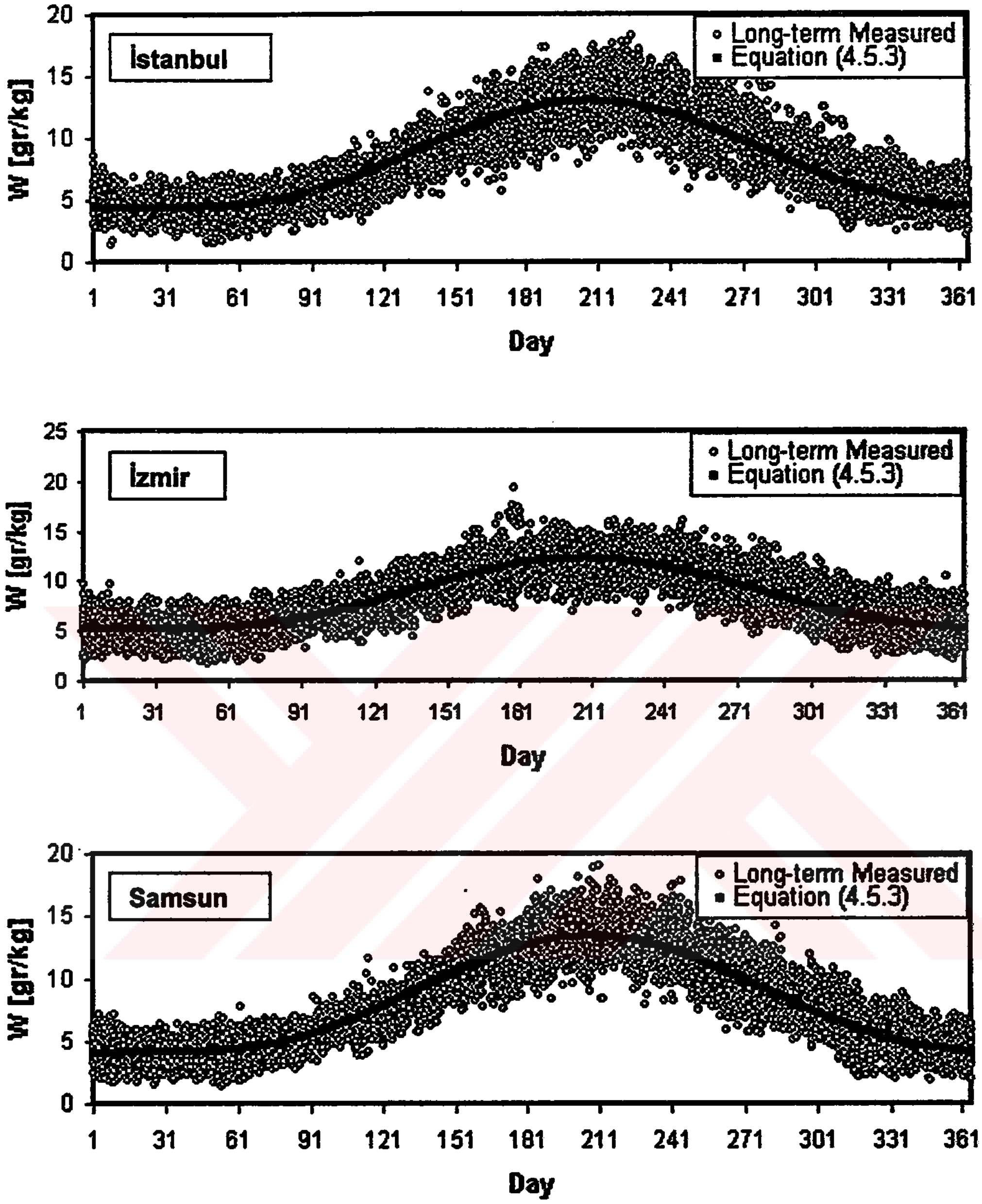


Figure 4.5.5. (Continued) Variation of daily mean humidity ratio for main locations

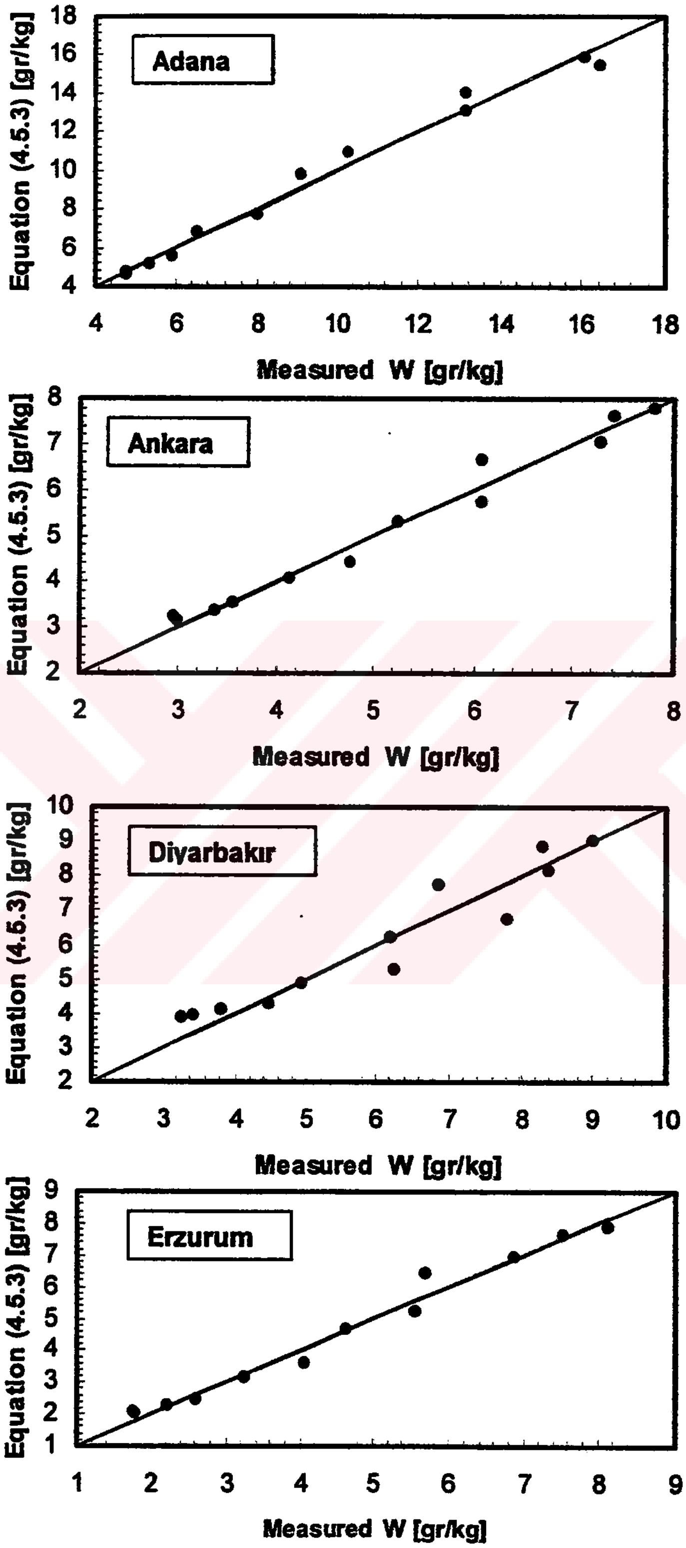


Figure 4.5.6. Comparison of the equation 4.5.3 with measured data bases on monthly values

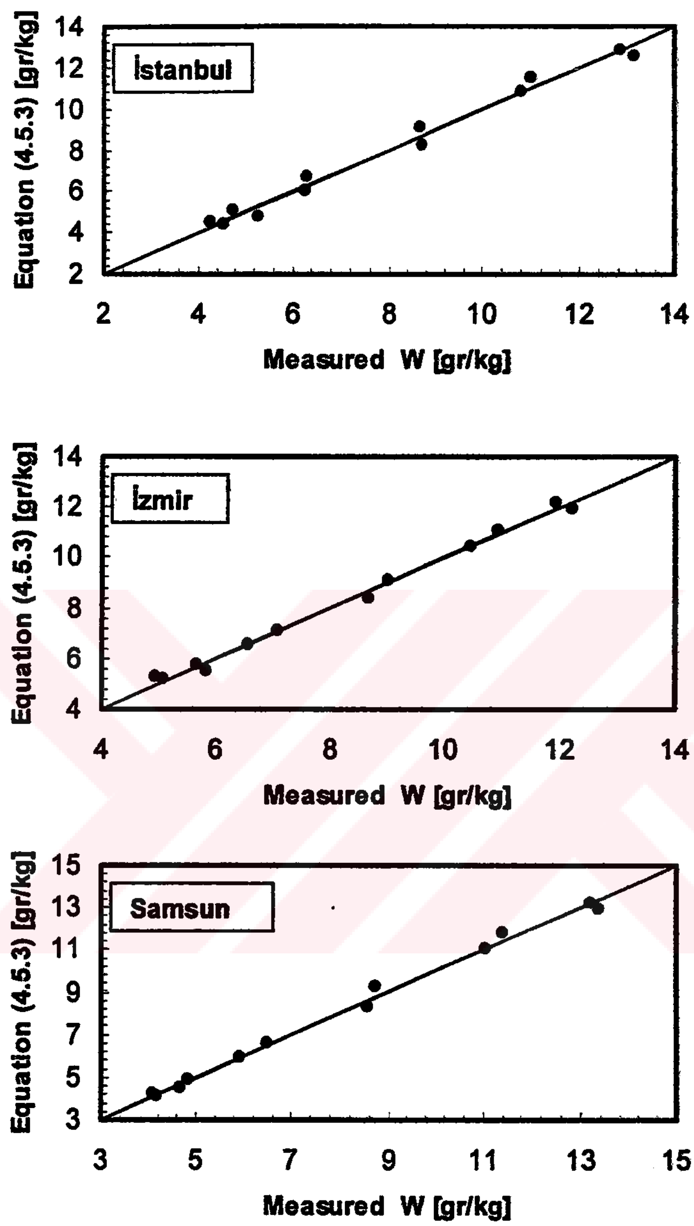


Figure 4.5.6. (Continued) Comparison of the equation 4.5.3 with measured data bases on monthly values

4.5.4. Mathematical Model For Hourly Outdoor Dry-Bulb Temperature

The outdoor dry-bulb temperature varies in 24 h period for a day. This hourly variation of outdoor dry-bulb temperature was expressed with mathematical formulations using the daily minimum and maximum temperatures. The day was divided into two regions for modeling. These regions were determined according to the time at which the daily minimum or maximum temperature occurs. The first region covers the time period occurrence of daily minimum (t_{min}) and maximum temperatures (t_{max}). The second region covers the remaining period. The equations for hourly outdoor dry-bulb (T) were determined for two period of the day separately:

For the 1st period ($t_{max} \geq t \geq t_{min}$) :

$$T = T_{min} + (T_{max} - T_{min}) \left\{ Sin \left[\frac{\pi}{2} \left(\frac{t - t_{min}}{t_{max} - t_{min}} \right) \right] \right\}^{1.4} \tag{4.5.4.a}$$

For the 2nd period ($t_{min} \geq t \geq t_{max}$) :

$$T = T_{max} - (T_{max} - T_{min}) \left\{ Sin \left[\frac{\pi}{2} \left(\frac{t - t_{min}}{24 + t_{min} - t_{max}} \right) \right] \right\}^{1.2} \tag{4.5.4.b}$$

in which T_{max} and T_{min} are the daily maximum and minimum temperature and can be calculated from equations 4.5.1 and 4.5.2 or can be directly taken from the measured data if available. t_{min} is the time for the occurrence of the daily minimum temperature and t_{max} is the time for the occurrence of the daily maximum temperature (Oğulata and Yılmaz, 1989; Yılmaz and Bulut 1996):

$$t_{min} = 12 - \frac{t_d}{2} \tag{4.5.5}$$

$$t_{max} = 12 + \frac{t_{min}(12 - t_{min})}{13.5} \tag{4.5.6}$$

where t_d is the daylength and can be calculated as follows:

$$t_d = \frac{2}{15} ArcCos[-\tan\phi \tan\delta] \tag{4.5.7}$$

where ϕ is the local latitude and it was given in Table 3.1.1 for locations considered in this study; δ is the solar declination angle:

$$\delta = 23.45 Sin\left[\frac{2\pi}{365}(n+284)\right] \tag{4.5.8}$$

where n is the number of days from January 1.

The root mean square error of the mathematical model for hourly outdoor dry-bulb temperature is in the range from 2.40 to 4.42. The hourly variation of outdoor dry-bulb temperature on 23rd July for main provinces of Turkey is shown in Figure 4.5.7. Although outdoor dry-bulb temperature varies from year to year, the mathematical model follows the variation of the outdoor dry-bulb temperature during day. The outdoor dry-bulb temperature vary approximately in a band of ±10 °C during a day for all provinces. The mathematical model always produces values within the band.

Figure 4.5.8 shows hourly variation of outdoor dry-bulb temperature on the certain days of year for Adana. The days chosen are the monthly average days.

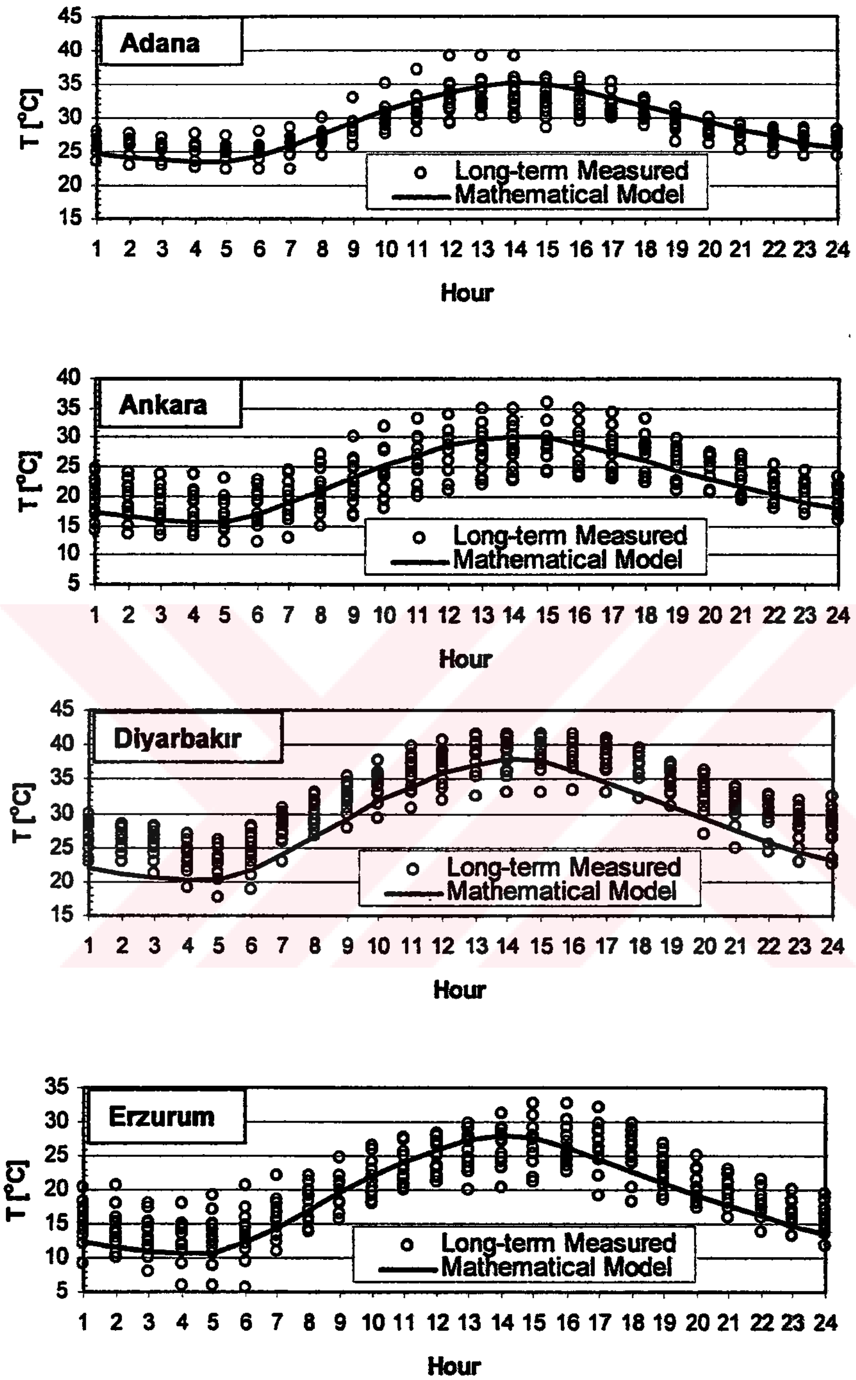


Figure 4.5.7. Hourly variation of outdoor dry-bulb temperature for main provinces on 23rd July (n=204).

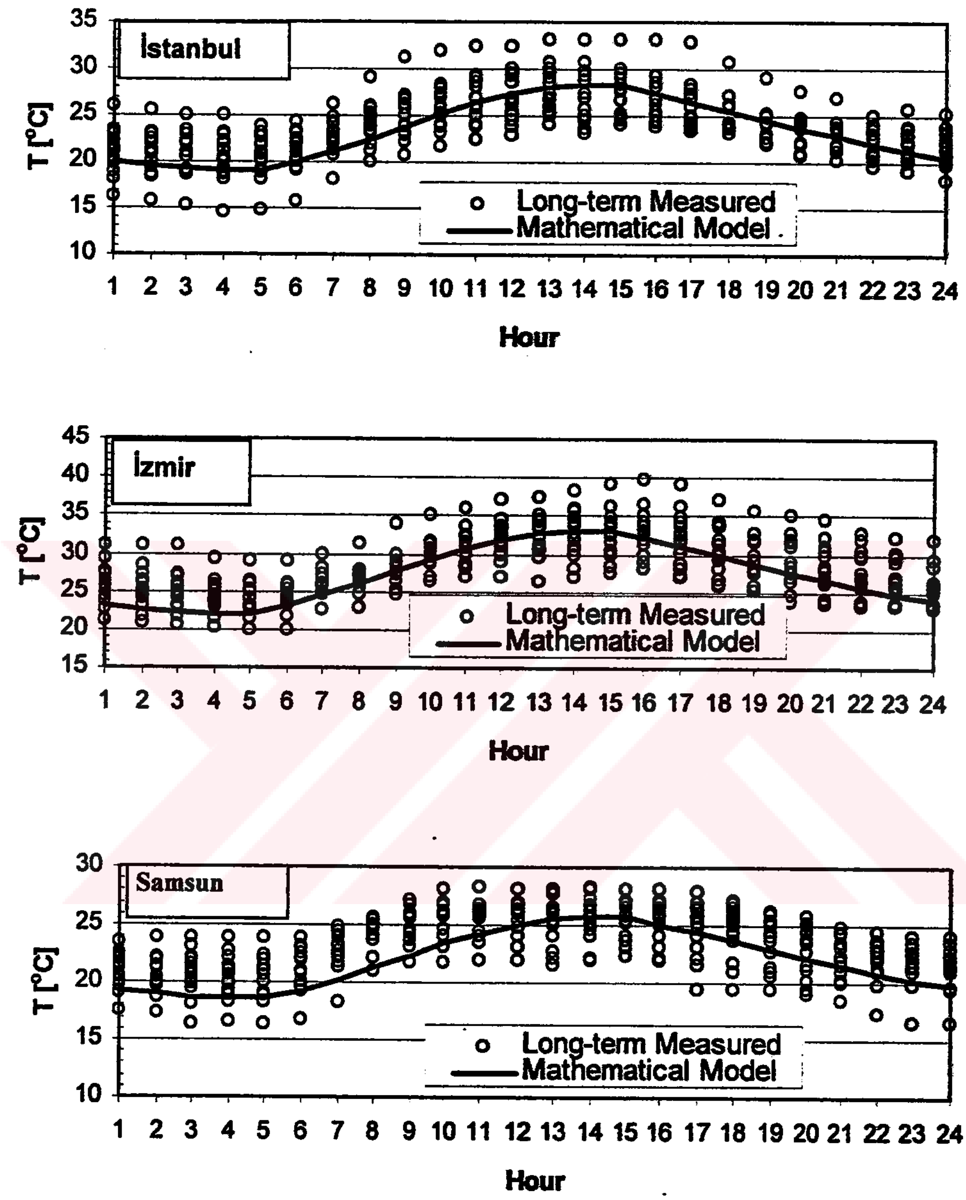


Figure 4.5.7. (Continued) Hourly variation of outdoor dry-bulb temperature for main provinces in 23rd July (n=204)

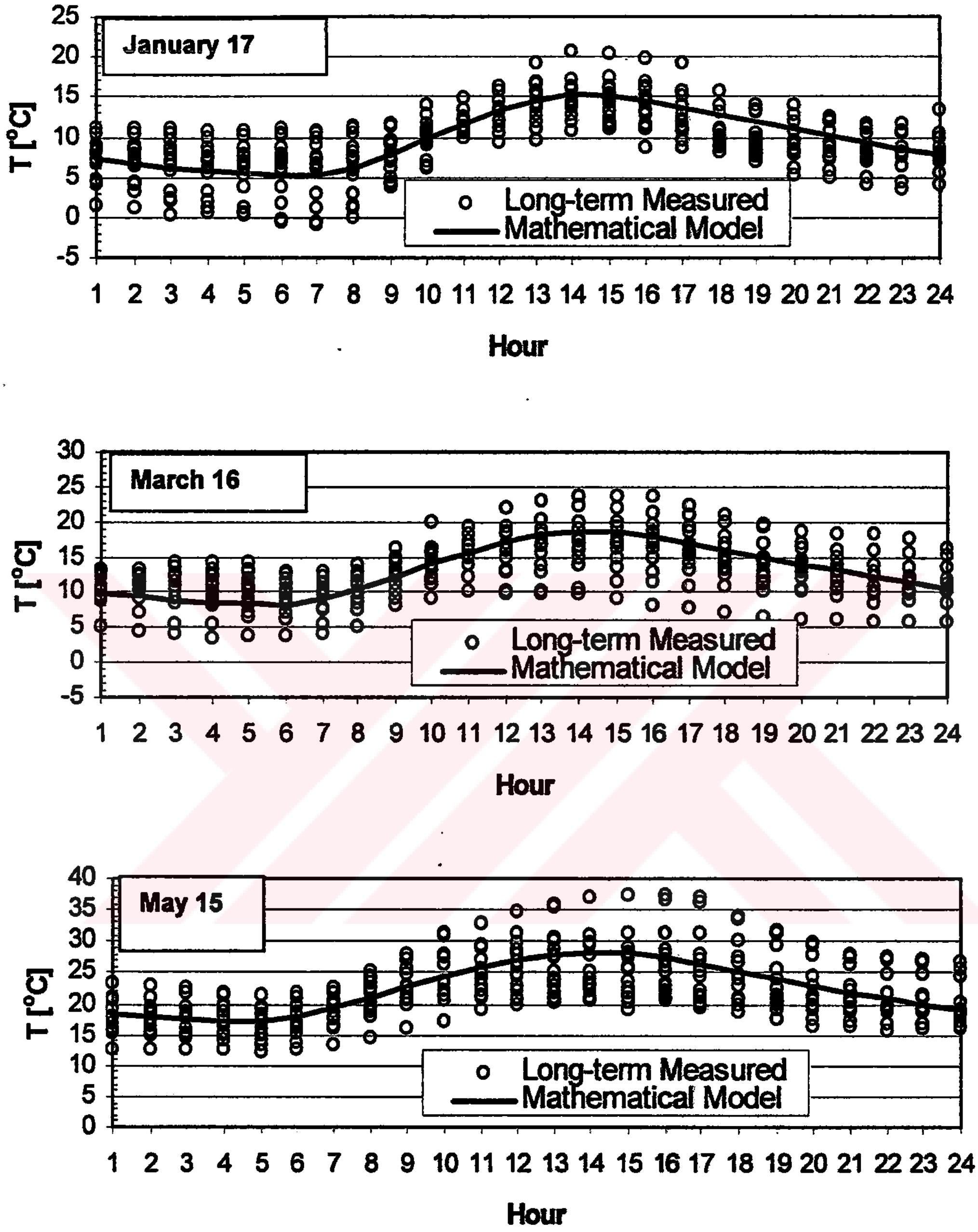


Figure 4.5.8. Hourly variation of outdoor dry-bulb temperature for Adana in various days of year

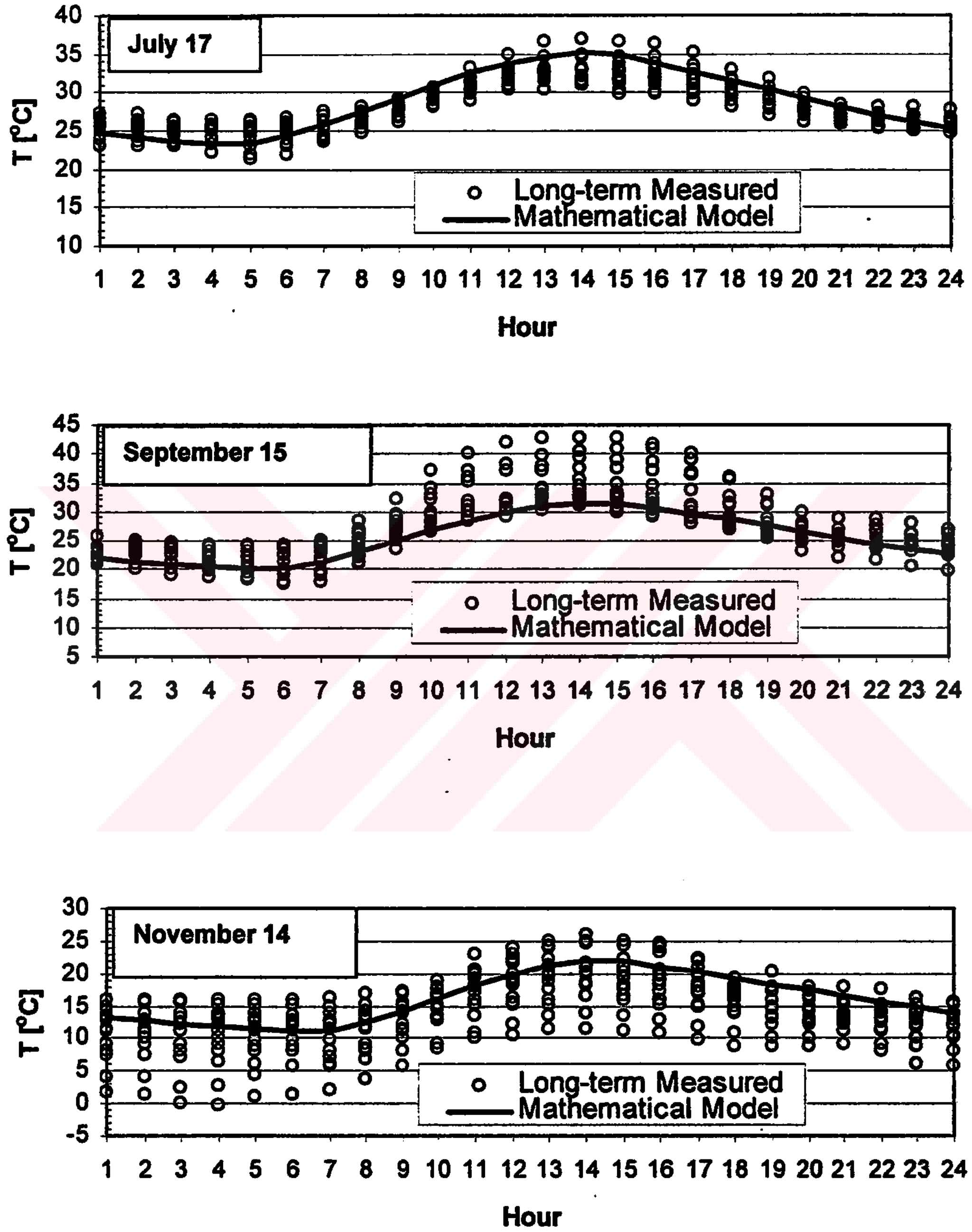


Figure 4.5.8. (Continued) Hourly variation of outdoor dry-bulb temperature for Adana in various days of year

4. 6. Analysis of Monthly Average Weather Elements for Turkey

Information on weather parameters such as temperature and humidity is essential for thermal energy analysis of buildings and any study with regard to heating and cooling load calculations. The ideal presentation of weather elements is hourly or daily bases. However the lack of weather elements and the difficulty of data storage are some obstacles in presentation of hourly or daily weather data. Sometimes monthly weather data are enough for energy analysis. In this study, monthly average values for dry-bulb temperature, wet-bulb temperature and humidity ratio for provinces of Turkey were calculated. Information on the meteorological database is given in Table 3.1.1. Monthly average dry-bulb temperatures were calculated by using hourly measurements. Humidity ratio was obtained from the measurements of relative humidity and dry-bulb temperature. Following procedure is given in Section 3.2.1. The monthly average wet-bulb temperatures were calculated from the measurements taken at 07:00, 14:00 and 21:00 o'clock. The daily average wet-bulb temperature were calculated using the following equation:

$$T_{wd} = \frac{T_{w7} + T_{w14} + 2T_{w21}}{4} \tag{4.6.1}$$

where T_{w7} is the wet-bulb temperature measured at 07:00 o'clock, T_{w14} is the wet-bulb temperature measured at 14:00 o'clock, T_{w21} is the wet-bulb temperature measured at 21:00 o'clock. In calculations of monthly average data, first the daily average data were obtained, then the monthly average data were determined by averaging daily data.

Table 4.6.1 shows monthly average dry-bulb temperature, monthly wet-bulb temperature and monthly average humidity ratio for 78 locations in Turkey. The minimum monthly average dry-bulb and wet-bulb temperatures appear in Ağrı, Ardahan, Kars, and Erzurum. These provinces are located in Eastern Turkey. Monthly average dry-bulb and wet-bulb temperatures are –11.1 °C and –11.6 °C, respectively in Ardahan in January. The maximum monthly average dry-bulb temperatures occur in July and August in Southeastern and Southern Turkey. Batman, Siirt, Adıyaman, Şanlıurfa, Diyarbakır, Gaziantep, Adana, Mersin, and Hatay have the maximum monthly average dry-bulb temperatures. The maximum monthly average dry-bulb temperature is 31.3 °C in August in Şanlıurfa. Provinces located in Southern Turkey have both maximum monthly average dry-bulb temperatures and maximum monthly average wet-bulb temperatures. The maximum monthly average wet-bulb temperature is 24.7 °C in August in Mersin. The provinces located in Southern Turkey have also maximum monthly average humidity ratio. This shows clearly that this region is humid and hot in summer. The monthly average humidity ratio for Mersin is 18.2 [gr/kg dry-air] in August. While the provinces located in Southeastern Turkey have maximum dry-bulb temperatures, their humidity ratio are relatively low. Therefore, this region can be characterized as arid. The provinces located in Western Turkey also have high monthly dry-bulb temperatures in summer relatively. The provinces located in Inner and Northern Turkey have moderate monthly average values.

Table 4.6.1. Monthly average dry-bulb (DB) temperature, wet-bulb (WB) temperature and humidity ratio (W) for 78 provinces of Turkey.

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Adana	1	9.6	6.3	4.8
	2	10.2	6.5	4.8
	3	13.1	9.6	5.9
	4	17.6	13.3	8.0
	5	21.7	17.1	10.3
	6	25.4	20.6	13.2
	7	28.2	23.5	16.1
	8	28.5	24.0	16.5
	9	26.3	20.9	13.1
	10	21.7	16.7	9.1
	11	15.3	10.9	6.5
	12	10.9	8.0	5.4
Adapazarı	1	5.9	4.0	4.3
	2	5.6	3.7	4.2
	3	7.6	5.4	4.7
	4	12.7	9.8	6.4
	5	17.0	13.9	8.7
	6	21.0	17.4	11.0
	7	22.7	19.4	12.7
	8	22.7	19.5	12.8
	9	19.4	16.3	10.2
	10	15.1	12.8	8.3
	11	10.5	8.4	6.1
	12	7.5	5.6	4.9
Adıyaman	1	4.5	2.3	3.6
	2	5.3	2.6	3.6
	3	9.2	5.7	4.4
	4	14.9	10.1	6.0
	5	20.3	13.7	7.3
	6	26.3	16.1	7.5
	7	30.7	18.3	8.5
	8	30.3	18.2	8.7
	9	25.8	15.3	7.1
	10	18.8	12.1	6.4
	11	11.1	7.7	5.4
	12	6.3	4.1	4.3

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Afyon	1	0.2	-1.1	3.4
	2	1.0	-0.7	3.4
	3	4.6	2.0	3.9
	4	10.2	6.3	5.1
	5	14.6	10.2	6.9
	6	18.7	13.2	8.3
	7	21.5	15.0	9.6
	8	21.5	14.9	9.2
	9	17.9	11.8	7.3
	10	12.1	8.2	6.1
	11	5.8	3.7	4.8
	12	2.2	0.8	4.0
Ağrı	1	-10.4	-10.7	1.9
	2	-10.1	-10.3	2.0
	3	-4.0	-4.6	2.9
	4	6.1	4.2	5.1
	5	11.7	8.8	6.8
	6	16.3	12.3	8.5
	7	21.1	15.5	10.3
	8	21.0	14.8	9.7
	9	16.3	10.8	7.2
	10	9.2	6.2	5.6
	11	1.0	-0.1	3.9
	12	-5.8	-6.3	2.6
Aksaray	1	0.5	-1.3	2.8
	2	1.2	-1.0	2.8
	3	5.5	2.4	3.4
	4	11.5	7.1	4.8
	5	15.9	10.9	6.3
	6	20.0	13.6	7.4
	7	23.1	15.5	8.3
	8	23.0	15.0	8.0
	9	18.9	11.8	6.3
	10	13.1	8.3	5.2
	11	6.4	3.6	4.0
	12	2.2	0.3	3.2

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Amasya	1	2.7	0.7	3.1
	2	3.5	0.8	3.0
	3	7.4	3.7	3.5
	4	13.3	8.6	5.1
	5	17.2	12.1	6.8
	6	20.8	14.9	8.1
	7	22.9	16.6	9.2
	8	23.1	16.7	9.3
	9	19.6	13.8	7.5
	10	14.2	9.9	5.9
	11	7.7	5.0	4.3
	12	4.3	2.3	3.6
Ankara	1	-0.1		3.0
	2	1.2		3.0
	3	5.7		3.6
	4	11.4		4.8
	5	15.4		6.1
	6	19.2		7.3
	7	22.4		7.8
	8	22.7		7.4
	9	18.9		6.1
	10	12.7		5.3
	11	5.9		4.1
	12	1.5		3.4
Antalya	1	9.4	5.8	5.0
	2	9.8	6.5	4.9
	3	11.8	8.9	5.9
	4	15.5	12.2	7.6
	5	19.9	16.2	9.6
	6	24.7	19.6	11.6
	7	28.0	21.8	13.0
	8	27.7	22.2	13.6
	9	24.5	19.0	11.5
	10	19.7	15.2	8.4
	11	14.2	9.6	6.4
	12	10.7	7.5	5.5

Table 4.6.1. (Continued) Monthly average dry-bulb (DB) temperature, wet-bulb (WB) temperature and humidity ratio (W) for 78 provinces of Turkey

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Ardahan	1	-11.1	-11.6	1.5
	2	-10.9	-11.3	1.5
	3	-4.7	-5.7	2.4
	4	4.1	1.7	4.0
	5	8.9	6.3	5.6
	6	12.5	9.7	7.3
	7	15.8	12.4	8.8
	8	15.9	11.9	8.2
	9	11.8	8.0	6.1
	10	6.2	3.6	4.5
	11	-0.7	-2.0	3.1
	12	-7.7	-8.3	2.0
Artvin	1	2.0	-0.2	2.8
	2	2.4	0.0	2.8
	3	6.1	2.9	3.4
	4	11.7	7.5	4.9
	5	15.4	11.2	6.7
	6	18.1	14.3	8.6
	7	20.0	16.6	10.5
	8	20.2	16.7	10.5
	9	17.7	13.8	8.3
	10	13.8	10.1	6.2
	11	8.2	5.2	4.3
	12	3.8	1.5	3.2
Aydın	1	8.0	5.6	4.6
	2	8.8	6.0	4.6
	3	11.2	7.8	5.2
	4	15.6	11.3	6.5
	5	20.6	15.0	8.3
	6	25.5	18.0	9.7
	7	28.0	20.3	11.7
	8	27.0	20.2	12.1
	9	23.3	17.0	9.5
	10	18.3	13.5	7.6
	11	12.7	9.5	6.1
	12	9.2	6.9	5.2

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Balıkesir	1	4.8	3.8	4.5
	2	5.2	3.9	4.5
	3	7.7	5.8	5.0
	4	13.0	10.1	6.5
	5	17.8	14.1	8.6
	6	22.2	17.2	10.2
	7	24.3	19.0	11.6
	8	24.2	19.1	11.8
	9	20.6	15.9	9.4
	10	15.4	12.3	7.7
	11	9.7	8.0	6.0
	12	6.2	5.1	5.0
Bartın	1	4.0	2.9	4.2
	2	3.9	2.5	4.0
	3	6.5	4.6	4.6
	4	11.1	8.8	6.1
	5	15.5	13.0	8.4
	6	19.4	16.5	10.5
	7	21.3	18.8	12.4
	8	21.3	18.7	12.4
	9	17.4	15.2	9.9
	10	13.6	11.7	7.9
	11	8.4	7.0	5.7
	12	5.7	4.5	4.8
Batman	1	2.9	1.6	3.7
	2	4.5	2.5	3.8
	3	9.0	6.0	4.7
	4	15.2	11.0	6.6
	5	20.2	14.6	8.2
	6	26.4	17.2	8.9
	7	31.0	19.4	9.8
	8	30.2	18.8	9.4
	9	25.0	15.8	7.8
	10	17.9	12.6	7.1
	11	10.3	7.9	5.6
	12	5.0	3.7	4.3

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Bayburt	1	-6.4	-7.4	2.0
	2	-6.2	-7.3	2.1
	3	-0.7	-2.6	2.9
	4	6.9	3.6	4.2
	5	11.3	7.5	5.7
	6	14.7	10.3	6.9
	7	18.3	12.7	8.1
	8	18.1	12.3	7.7
	9	14.4	8.8	5.9
	10	9.1	5.4	4.8
	11	2.0	0.0	3.5
	12	-3.4	-4.6	2.6
Bilecik	1	2.3	1.1	3.6
	2	3.1	1.5	3.6
	3	5.9	3.5	4.0
	4	11.3	8.0	5.4
	5	15.6	12.0	7.5
	6	19.6	15.3	9.1
	7	21.5	17.1	10.5
	8	21.5	17.0	10.4
	9	18.3	14.0	8.3
	10	13.7	10.7	6.8
	11	7.7	5.6	4.9
	12	4.3	2.8	4.0
Bingöl	1	-2.4	-3.8	2.7
	2	-1.9	-3.6	2.6
	3	3.2	0.7	3.5
	4	10.8	6.7	5.2
	5	16.0	10.6	6.7
	6	21.6	13.5	7.7
	7	26.4	15.6	8.5
	8	26.0	15.2	8.0
	9	21.1	12.2	6.7
	10	13.9	8.9	6.2
	11	6.2	3.6	4.5
	12	0.5	-1.0	3.3

Table 4.6.1. (Continued) Monthly average dry-bulb (DB) temperature, wet-bulb (WB) temperature and humidity ratio (W) for 78 provinces of Turkey

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Bitlis	1	-2.9	-4.0	2.7
	2	-2.6	-3.9	2.7
	3	1.2	-0.6	3.4
	4	7.7	4.8	4.9
	5	13.0	9.1	6.6
	6	18.3	12.2	7.7
	7	22.9	15.0	9.4
	8	22.5	14.7	9.3
	9	18.2	11.3	7.2
	10	11.6	7.6	6.0
	11	4.4	2.4	4.3
	12	-0.8	-2.0	3.2
Bolu	1	0.6	-0.4	3.2
	2	1.2	-0.2	3.1
	3	4.3	2.2	3.7
	4	9.7	6.7	5.0
	5	13.7	10.8	6.9
	6	17.0	13.8	8.5
	7	19.2	15.8	9.8
	8	19.3	15.8	9.7
	9	15.9	12.6	7.8
	10	11.5	9.1	6.3
	11	5.8	4.2	4.5
	12	2.6	1.5	3.7
Burdur	1	2.5	0.8	3.4
	2	3.1	0.9	3.3
	3	6.2	3.2	3.7
	4	11.3	7.1	4.8
	5	16.1	11.1	6.4
	6	20.8	14.1	7.5
	7	24.0	15.6	8.0
	8	24.0	15.4	7.8
	9	20.0	12.6	6.5
	10	14.2	9.2	5.6
	11	7.7	5.1	4.6
	12	3.9	2.3	3.9

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Bursa	1	5.3	3.3	4.0
	2	5.5	3.2	3.9
	3	7.7	5.0	4.4
	4	12.8	9.3	5.9
	5	17.3	13.4	7.9
	6	21.7	16.6	9.6
	7	24.0	18.4	10.8
	8	23.9	18.4	11.0
	9	20.1	15.5	9.0
	10	15.2	12.0	7.5
	11	10.1	7.7	5.6
	12	6.8	4.8	4.5
Çanakkale	1	6.4	5.2	5.1
	2	6.1	4.7	4.8
	3	7.7	6.2	5.3
	4	12.3	10.5	7.1
	5	17.0	14.8	9.5
	6	22.1	19.0	12.4
	7	24.6	20.6	13.5
	8	24.6	20.8	13.8
	9	21.0	17.8	11.5
	10	16.1	13.8	9.1
	11	11.0	9.3	6.9
	12	8.0	6.8	5.8
Çankırı	1	-1.1	-2.0	2.9
	2	0.3	-1.1	2.9
	3	5.5	2.9	3.8
	4	11.1	7.6	5.2
	5	14.9	11.2	6.9
	6	19.0	14.4	8.4
	7	21.7	16.1	9.2
	8	22.0	15.8	8.9
	9	17.9	12.4	7.2
	10	11.8	8.1	5.5
	11	4.6	2.9	4.1
	12	0.9	-0.1	3.3

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Çorum	1	-0.2	-1.3	3.0
	2	0.4	-1.1	2.9
	3	4.3	1.9	3.5
	4	10.3	7.0	4.9
	5	14.2	10.8	6.7
	6	17.7	13.6	8.0
	7	20.2	15.3	8.8
	8	20.3	15.2	8.6
	9	16.8	12.1	7.0
	10	11.5	8.1	5.5
	11	5.1	3.2	4.1
	12	1.7	0.5	3.5
Denizli	1	5.7	3.7	4.2
	2	6.6	4.2	4.2
	3	9.4	6.3	4.8
	4	14.6	10.3	6.2
	5	19.5	14.1	7.9
	6	24.3	16.9	9.1
	7	27.0	18.8	10.5
	8	26.6	18.8	10.6
	9	22.6	15.8	8.8
	10	16.8	12.2	7.3
	11	10.8	8.1	5.7
	12	7.1	5.2	4.8
Diyarbakır	1	1.5	-0.2	3.3
	2	2.9	0.5	3.4
	3	7.6	5.0	4.5
	4	13.5	9.4	6.3
	5	18.9	13.1	7.8
	6	25.6	16.2	8.4
	7	30.5	18.8	9.0
	8	29.6	17.9	8.3
	9	24.4	14.4	6.9
	10	16.8	10.7	6.2
	11	9.0	5.6	4.9
	12	3.7	1.7	3.8

Table 4.6.1. (Continued) Monthly average dry-bulb (DB) temperature, wet-bulb (WB) temperature and humidity ratio (W) for 78 provinces of Turkey

Province	Month	DB [°C]	[°C]	[gr/kg]
Edirne	1	2.7	1.8	3.9
	2	3.8	2.3	3.9
	3	6.8	4.7	4.5
	4	12.7	9.6	6.1
	5	17.6	13.7	8.1
	6	21.8	16.9	9.9
	7	24.1	18.1	10.4
	8	23.7	17.8	10.3
	9	19.7	14.9	8.6
	10	13.7	10.9	7.0
	11	7.8	6.4	5.5
	12	3.7	2.8	4.3
Elazığ	1	-0.7	-2.1	3.1
	2	0.1	-1.6	3.1
	3	5.0	2.1	3.9
	4	11.8	7.4	5.4
	5	16.6	11.2	7.1
	6	22.1	13.8	7.7
	7	26.7	15.9	8.5
	8	26.2	15.4	8.0
	9	21.5	12.3	6.5
	10	14.4	9.3	6.3
	11	6.7	4.3	5.0
	12	1.9	0.4	3.8
Erzincan	1	-2.8	-4.1	2.6
	2	-1.9	-3.5	2.7
	3	3.7	0.9	3.6
	4	10.7	6.5	5.1
	5	15.1	10.3	6.8
	6	19.3	13.3	8.2
	7	23.3	15.8	9.7
	8	23.0	15.5	9.4
	9	18.5	12.1	7.4
	10	12.0	8.2	6.2
	11	4.8	2.7	4.4
	12	-0.2	-1.5	3.3

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Erzurum	1	-9.3	-10.0	1.8
	2	-9.7	-10.4	1.8
	3	-3.5	-4.7	2.6
	4	5.4	2.6	4.1
	5	10.4	6.9	5.6
	6	14.4	10.0	6.9
	7	18.7	12.8	8.2
	8	18.8	12.2	7.5
	9	13.8	8.3	5.7
	10	7.4	4.2	4.6
	11	0.1	-1.6	3.3
	12	-6.6	-7.8	2.2
Eskişehir	1	-0.1	-1.5	3.0
	2	0.8	-1.3	2.9
	3	4.1	1.4	3.4
	4	10.1	6.0	4.7
	5	14.7	11.0	6.9
	6	18.4	14.1	8.3
	7	21.0	15.7	9.0
	8	21.0	15.6	8.8
	9	17.2	11.7	6.6
	10	11.4	8.4	5.5
	11	5.3	3.1	4.1
	12	1.4	0.5	3.5
Gaziantep	1	3.3	1.7	3.6
	2	4.1	2.0	3.6
	3	7.8	5.6	4.4
	4	13.3	9.8	5.9
	5	18.7	13.6	7.2
	6	23.9	16.7	8.5
	7	27.8	19.8	10.1
	8	27.6	19.7	10.0
	9	23.4	16.1	8.2
	10	16.4	12.2	6.6
	11	9.4	6.6	5.0
	12	4.8	3.5	4.0

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Giresun	1	7.2	4.9	4.4
	2	6.2	4.1	4.2
	3	7.6	5.6	4.8
	4	11.3	9.3	6.4
	5	15.2	13.3	8.7
	6	19.8	17.5	11.5
	7	22.6	20.0	13.6
	8	23.1	20.2	13.8
	9	20.0	17.4	11.4
	10	16.1	13.7	8.8
	11	11.8	9.2	6.2
	12	9.1	6.6	5.0
Gümüşhane	1	-2.0	-3.5	2.6
	2	-1.9	-3.6	2.5
	3	2.7	0.1	3.3
	4	9.4	5.6	4.8
	5	13.3	9.3	6.5
	6	16.7	12.1	7.9
	7	19.5	14.7	9.6
	8	19.5	14.5	9.3
	9	16.1	11.3	7.2
	10	11.1	7.5	5.7
	11	4.4	2.1	4.0
	12	0.2	-1.5	3.1
Hakkari	1	-5.0	-6.2	2.1
	2	-4.1	-5.4	2.3
	3	0.9	-1.3	3.1
	4	7.9	4.3	4.4
	5	13.6	8.6	5.9
	6	19.7	12.1	7.1
	7	24.5	14.9	8.3
	8	24.0	14.3	7.9
	9	19.8	11.0	6.0
	10	12.3	7.3	5.2
	11	4.4	1.7	3.8
	12	-2.4	-3.8	2.6

Table 4.6.1. (Continued) Monthly average dry-bulb (DB) temperature, wet-bulb (WB) temperature and humidity ratio (W) for 78 provinces of Turkey

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Hatay	1	8.1	5.9	5.0
	2	9.3	6.6	5.1
	3	12.6	9.9	6.3
	4	17.2	13.5	8.2
	5	21.1	17.1	10.6
	6	24.5	20.6	13.5
	7	27.0	23.2	16.3
	8	27.7	24.0	16.8
	9	25.6	21.0	14.1
	10	20.6	16.5	9.5
	11	13.9	10.4	6.7
	12	9.3	7.4	5.5
Iğdır	1	-3.1	-4.8	2.0
	2	-0.9	-3.3	2.1
	3	6.0	1.8	2.8
	4	13.2	7.5	4.3
	5	17.2	11.1	5.9
	6	21.7	14.3	7.3
	7	25.7	17.1	9.1
	8	24.9	16.5	8.7
	9	19.7	12.8	6.8
	10	12.6	8.2	5.1
	11	5.5	2.7	3.6
	12	-0.4	-2.2	2.5
Isparta	1	1.6	-0.2	3.1
	2	2.2	0.0	3.0
	3	5.3	2.4	3.5
	4	10.3	6.5	4.6
	5	14.9	10.3	6.0
	6	19.4	13.5	7.3
	7	22.7	15.5	8.3
	8	22.5	15.3	8.3
	9	18.5	12.2	6.7
	10	12.8	8.3	5.3
	11	6.6	3.9	4.1
	12	3.0	1.3	3.5

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
İskenderun	1	11.7	8.3	5.4
	2	12.0	8.5	5.5
	3	14.4	11.0	6.8
	4	18.1	14.8	9.1
	5	21.4	18.4	12.0
	6	24.7	21.6	14.9
	7	27.3	24.1	17.5
	8	28.2	24.7	18.1
	9	26.4	22.2	15.2
	10	22.5	17.8	11.0
	11	16.9	12.7	7.6
	12	13.2	9.7	6.1
İstanbul	1	6.2	4.2	4.6
	2	5.6	3.8	4.3
	3	7.2	5.4	4.7
	4	12.0	9.6	6.3
	5	16.6	13.9	8.7
	6	21.1	17.8	11.0
	7	23.4	20.0	12.9
	8	23.5	20.5	13.1
	9	20.0	17.1	10.8
	10	15.5	14.1	8.7
	11	10.9	9.1	6.3
	12	7.6	6.1	5.3
İzmir	1	8.8	5.9	5.1
	2	8.9	6.4	5.0
	3	11.1	8.4	5.7
	4	15.8	11.7	7.1
	5	20.6	15.3	9.0
	6	25.3	18.6	10.9
	7	27.7	20.2	11.9
	8	27.3	20.5	12.2
	9	23.6	17.8	10.5
	10	18.7	15.1	8.7
	11	13.5	10.3	6.6
	12	10.0	7.8	5.8

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
kahramanmaraş	1	5.0	2.9	3.7
	2	5.9	3.1	3.7
	3	9.7	6.2	4.5
	4	15.2	10.4	6.0
	5	20.0	14.1	7.8
	6	24.7	17.8	9.9
	7	28.1	20.7	12.3
	8	28.7	21.0	12.8
	9	25.0	17.7	9.7
	10	18.6	13.0	7.2
	11	10.8	7.9	5.5
	12	6.2	4.2	4.3
Karaman	1	0.2	-1.2	3.4
	2	0.8	-1.0	3.3
	3	5.1	2.3	4.0
	4	11.5	7.0	5.3
	5	15.8	10.9	7.0
	6	20.1	13.6	8.1
	7	22.9	15.1	8.8
	8	22.7	14.6	8.4
	9	18.8	12.0	7.1
	10	12.9	8.2	5.8
	11	6.3	3.7	4.7
	12	2.3	0.7	3.9
Kars	1	-9.8	-10.0	1.8
	2	-9.5	-9.8	1.9
	3	-3.3	-4.1	2.8
	4	5.7	3.5	4.7
	5	9.9	7.5	6.3
	6	13.8	11.0	8.2
	7	17.4	14.2	10.2
	8	17.6	13.7	9.6
	9	13.4	9.6	7.1
	10	7.1	4.7	5.2
	11	0.0	-1.1	3.6
	12	-6.4	-7.0	2.4

Table 4.6.1. (Continued) Monthly average dry-bulb (DB) temperature, wet-bulb (WB) temperature and humidity ratio (W) for 78 provinces of Turkey

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Kastamonu	1	-0.7	-1.9	2.8
	2	0.1	-1.6	2.7
	3	3.8	1.3	3.2
	4	9.3	6.0	4.6
	5	13.5	10.0	6.2
	6	16.9	12.9	7.7
	7	19.4	14.6	8.4
	8	19.3	14.3	8.2
	9	15.6	11.2	6.7
	10	10.5	7.6	5.4
	11	4.2	2.5	3.9
	12	0.8	-0.4	3.2
Kayseri	1	-2.1	-3.6	2.9
	2	-0.7	-2.6	3.1
	3	4.0	2.0	3.9
	4	10.4	6.5	5.4
	5	14.6	10.4	7.1
	6	18.2	13.0	8.4
	7	21.4	15.1	9.5
	8	21.2	14.4	9.0
	9	17.0	11.1	7.0
	10	11.3	7.7	5.7
	11	4.7	2.1	4.3
	12	0.0	-1.1	3.4
Kırıkkale	1	0.3	-0.8	3.1
	2	1.4	-0.1	3.1
	3	6.1	3.4	3.8
	4	12.1	8.2	5.2
	5	16.0	11.5	6.7
	6	20.2	14.5	8.1
	7	23.0	16.3	9.0
	8	23.2	15.9	8.6
	9	19.5	12.9	6.9
	10	13.2	9.0	5.6
	11	5.8	3.8	4.2
	12	2.0	0.7	3.4

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Kırklareli	1	3.0	1.8	3.9
	2	3.4	1.9	3.8
	3	6.3	4.2	4.4
	4	11.8	8.8	5.9
	5	16.7	13.1	7.9
	6	21.3	16.8	10.1
	7	23.5	18.1	10.8
	8	23.1	17.9	10.7
	9	19.3	15.0	8.8
	10	13.9	11.0	7.1
	11	8.0	6.3	5.4
	12	4.6	3.4	4.5
Kırşehir	1	-0.5	-1.6	3.0
	2	0.1	-1.3	2.9
	3	4.9	2.3	3.6
	4	10.8	7.2	5.0
	5	14.6	10.6	6.5
	6	19.0	13.7	7.8
	7	22.0	15.7	8.8
	8	22.4	15.6	8.7
	9	18.8	12.6	7.0
	10	12.6	8.7	5.7
	11	5.2	3.3	4.2
	12	1.2	0.0	3.4
Kilis	1	5.8	3.4	3.9
	2	6.6	3.5	3.8
	3	10.0	6.2	4.5
	4	15.4	10.1	5.7
	5	20.5	13.3	6.8
	6	24.9	16.3	8.3
	7	27.7	19.2	10.5
	8	27.8	19.3	10.6
	9	25.2	16.3	8.2
	10	19.8	12.2	6.1
	11	12.1	8.1	5.3
	12	7.4	4.9	4.4

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Kocaeli	1	6.1	4.5	4.5
	2	5.8	4.0	4.3
	3	7.8	5.7	4.9
	4	12.9	9.8	6.3
	5	17.1	13.8	8.6
	6	21.6	17.4	10.8
	7	23.2	19.3	12.4
	8	23.4	19.7	12.8
	9	20.2	16.8	10.6
	10	15.8	13.4	8.7
	11	10.8	8.8	6.3
	12	8.0	6.1	5.1
Konya	1	-0.7	-2.9	3.3
	2	0.3	-2.3	3.2
	3	4.5	1.8	3.8
	4	10.7	5.9	5.1
	5	15.3	10.1	6.7
	6	19.7	12.5	7.8
	7	22.9	14.1	8.6
	8	22.7	14.0	8.4
	9	18.7	11.0	6.8
	10	12.3	7.7	5.7
	11	5.3	2.3	4.4
	12	1.0	-0.4	3.7
Kütahya	1	0.4	-1.2	2.8
	2	0.8	-1.2	2.7
	3	4.4	1.4	3.1
	4	10.0	5.7	4.1
	5	14.0	9.3	5.6
	6	18.0	12.5	6.9
	7	20.1	14.2	7.8
	8	20.3	14.2	7.8
	9	16.7	11.1	6.2
	10	11.5	7.5	5.0
	11	5.5	3.0	3.8
	12	1.9	0.2	3.2

Table 4.6.1. (Continued) Monthly average dry-bulb (DB) temperature, wet-bulb (WB) temperature and humidity ratio (W) for 78 provinces of Turkey

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Malatya	1	0.2	-1.4	2.8
	2	1.2	-0.8	2.9
	3	6.1	3.0	3.6
	4	12.9	7.9	4.8
	5	17.6	11.7	6.4
	6	22.5	14.3	7.1
	7	26.8	16.6	8.0
	8	26.5	16.0	7.6
	9	22.1	13.2	6.4
	10	14.9	9.8	5.7
	11	7.1	4.7	4.5
	12	2.1	0.5	3.3
Manisa	1	6.3	4.6	4.5
	2	7.3	5.0	4.5
	3	9.8	6.9	5.0
	4	15.0	10.9	6.4
	5	20.2	14.7	8.2
	6	25.2	17.6	9.4
	7	27.9	19.2	10.4
	8	27.5	19.3	10.6
	9	23.3	16.4	8.8
	10	17.5	13.1	7.6
	11	11.3	8.9	6.1
	12	7.6	6.1	5.2
Mardin	1	2.9	0.7	3.5
	2	3.5	0.9	3.5
	3	7.3	4.0	4.4
	4	13.6	8.6	5.8
	5	19.5	12.1	6.9
	6	25.3	14.8	7.5
	7	29.7	16.9	8.4
	8	29.3	16.5	8.1
	9	25.2	14.3	6.9
	10	18.2	11.3	6.6
	11	10.6	6.8	5.3
	12	4.9	2.6	4.1
Mersin	1	10.5	7.7	5.4
	2	11.0	8.4	5.6
	3	13.5	10.4	6.7
	4	17.6	14.5	9.1
	5	21.2	18.4	12.1
	6	24.7	22.0	15.4
	7	27.4	24.5	18.1
	8	28.0	24.7	18.2
	9	25.8	21.5	14.5
	10	21.6	16.9	10.3
	11	16.0	12.4	7.6
	12	11.9	9.0	6.0
Muğla	1	5.2	3.2	4.2
	2	5.5	3.6	4.1
	3	7.9	5.7	4.7
	4	12.4	8.9	5.8
	5	17.4	13.1	7.4
	6	22.7	16.3	8.7
	7	26.2	18.3	9.8
	8	25.9	18.2	9.8
	9	21.8	15.2	8.4
	10	15.9	12.2	6.8
	11	9.8	7.4	5.5
	12	6.3	5.0	4.8
Muş	1	-7.3	-7.9	2.2
	2	-7.0	-7.6	2.2
	3	-0.5	-1.7	3.3
	4	8.8	6.0	5.4
	5	14.4	10.4	7.1
	6	19.5	13.3	8.2
	7	24.6	15.6	9.0
	8	24.4	14.9	8.2
	9	19.6	11.8	6.6
	10	12.2	8.2	6.0
	11	3.8	2.2	4.4
	12	-2.9	-3.7	3.0
Nevşehir	1	-0.4	-2.3	2.9
	2	-0.1	-2.1	2.9
	3	3.8	0.9	3.5
	4	9.9	5.6	4.7
	5	14.0	9.3	6.4
	6	17.8	12.2	7.6
	7	20.4	13.9	8.5
	8	20.5	13.4	8.0
	9	17.1	10.4	6.4
	10	11.6	6.9	5.3
	11	5.4	2.6	4.2
	12	1.5	-0.5	3.4
Niğde	1	-0.6	-2.1	3.0
	2	0.0	-1.9	3.1
	3	4.3	1.5	3.7
	4	10.5	6.3	5.0
	5	14.7	10.1	6.7
	6	18.7	12.9	8.0
	7	21.8	14.6	8.7
	8	21.7	14.3	8.5
	9	17.9	11.3	6.8
	10	12.2	7.7	5.7
	11	5.8	3.1	4.4
	12	1.4	-0.3	3.5
Ordu	1	6.9	4.4	4.2
	2	6.1	3.7	4.0
	3	7.5	5.3	4.6
	4	11.3	9.1	6.3
	5	15.3	13.1	8.5
	6	20.0	17.1	11.1
	7	22.7	19.5	13.0
	8	23.2	19.7	13.1
	9	20.0	16.7	10.7
	10	15.9	13.1	8.4
	11	11.3	8.5	5.9
	12	8.6	5.9	4.7

Table 4.6.1. (Continued) Monthly average dry-bulb (DB) temperature, wet-bulb (WB) temperature and humidity ratio (W) for 78 provinces of Turkey

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Rize	1	6.3	4.1	4.3
	2	5.8	3.6	4.1
	3	7.5	5.6	4.7
	4	11.7	9.2	6.2
	5	15.7	13.3	8.5
	6	20.0	17.5	11.1
	7	22.5	20.2	13.3
	8	22.9	20.4	13.5
	9	19.8	17.6	11.4
	10	15.9	14.2	8.9
	11	11.4	8.9	6.2
	12	8.0	6.1	4.9
Samsun	1	7.0	4.0	4.2
	2	6.2	3.6	4.1
	3	7.5	5.6	4.8
	4	11.2	9.2	6.5
	5	15.1	13.3	8.7
	6	19.7	17.4	11.4
	7	22.7	19.9	13.2
	8	23.1	20.3	13.4
	9	19.7	17.1	11.0
	10	15.8	13.6	8.6
	11	11.8	8.6	5.9
	12	8.5	6.0	4.7
Siirt	1	2.5	0.7	3.3
	2	3.5	1.0	3.2
	3	7.7	4.4	4.0
	4	14.0	9.2	5.5
	5	19.0	12.7	6.9
	6	25.5	15.4	7.3
	7	30.2	17.2	7.8
	8	29.8	16.6	7.2
	9	25.3	14.0	6.1
	10	17.7	11.1	5.9
	11	9.9	6.7	4.9
	12	4.5	2.6	3.8

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Sinop	1	6.8	4.6	4.3
	2	5.8	3.6	4.0
	3	7.0	4.9	4.5
	4	10.5	8.3	5.9
	5	14.6	12.3	8.0
	6	19.5	16.7	10.7
	7	22.4	19.4	12.9
	8	22.8	19.5	12.9
	9	19.7	16.6	10.5
	10	16.0	13.2	8.3
	11	11.6	9.0	6.1
	12	8.7	6.2	4.9
Sivas	1	-3.6	-4.6	2.6
	2	-2.9	-4.2	2.6
	3	2.1	-0.1	3.4
	4	9.1	5.4	4.8
	5	13.3	9.3	6.5
	6	16.8	12.0	7.8
	7	19.6	14.0	8.9
	8	19.8	13.8	8.6
	9	16.1	10.7	6.9
	10	10.6	6.9	5.5
	11	3.8	2.0	4.2
	12	-1.0	-2.2	3.2
Şanlıurfa	1	5.6		3.8
	2	6.6		3.9
	3	10.4		4.8
	4	16.3		6.3
	5	22.3		7.3
	6	27.8		7.7
	7	31.7		8.9
	8	31.3		9.0
	9	27.1		7.5
	10	20.2		6.6
	11	12.6		5.6
	12	7.2		4.6

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Tekirdağ	1	5.1	3.9	4.5
	2	4.8	3.3	4.3
	3	6.6	5.0	4.8
	4	11.6	9.6	6.7
	5	16.3	14.0	9.1
	6	20.7	17.9	11.8
	7	23.2	19.6	12.9
	8	23.3	19.7	13.1
	9	19.9	16.7	10.8
	10	15.2	12.8	8.5
	11	10.0	8.4	6.4
	12	6.6	5.3	5.1
Tokat	1	2.1	0.1	3.0
	2	2.7	0.1	2.9
	3	6.5	3.1	3.4
	4	12.4	8.1	5.1
	5	16.0	11.5	6.7
	6	19.1	14.1	8.0
	7	21.5	15.8	9.0
	8	21.6	15.8	9.0
	9	18.6	13.2	7.4
	10	13.3	9.5	6.0
	11	7.2	4.6	4.3
	12	3.7	1.7	3.4
Trabzon	1	7.0	4.4	4.1
	2	6.4	3.7	3.9
	3	8.0	6.0	4.6
	4	11.9	9.4	6.3
	5	15.6	13.4	8.4
	6	20.0	17.6	11.0
	7	22.8	20.3	13.1
	8	23.1	20.5	13.1
	9	20.0	17.5	10.9
	10	16.3	14.0	8.4
	11	12.1	9.0	5.9
	12	8.9	6.3	4.6

Table 4.6.1. (Continued) Monthly average dry-bulb (DB) temperature, wet-bulb (WB) temperature and humidity ratio (W) for 78 provinces of Turkey

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Tunceli	1	-1.9	-2.9	2.6
	2	-0.8	-2.3	2.6
	3	4.7	2.0	3.4
	4	11.8	7.7	5.0
	5	16.6	11.6	6.6
	6	22.1	14.7	7.7
	7	26.9	17.2	8.8
	8	26.6	16.5	8.2
	9	21.6	13.1	6.5
	10	14.5	9.9	6.0
	11	6.5	4.4	4.4
	12	1.2	-0.2	3.2
Uşak	1	2.6	0.8	3.4
	2	2.7	0.7	3.3
	3	5.9	3.2	3.8
	4	10.8	7.3	5.1
	5	15.4	11.3	6.8
	6	20.0	14.4	8.1
	7	23.0	16.5	9.3
	8	23.2	16.4	9.0
	9	19.4	13.3	7.3
	10	13.7	9.4	5.9
	11	7.4	4.8	4.5
	12	4.0	2.5	4.0
Van	1	-3.6	-5.5	2.1
	2	-3.0	-4.8	2.2
	3	1.2	-1.3	3.0
	4	8.0	3.7	4.1
	5	12.9	7.4	5.3
	6	18.0	10.7	6.5
	7	22.1	13.5	7.8
	8	21.7	12.7	7.2
	9	17.6	9.6	5.5
	10	11.1	6.1	4.7
	11	5.0	1.3	3.6
	12	-0.4	-3.4	2.6

Province	Month	DB [°C]	WB [°C]	W [gr/kg]
Yalova	1	6.6	4.5	4.4
	2	6.1	4.0	4.2
	3	7.8	5.6	4.8
	4	12.2	9.7	6.5
	5	16.5	14.0	8.9
	6	21.1	17.9	11.5
	7	23.0	19.7	13.1
	8	23.1	19.9	13.3
	9	19.9	16.7	10.8
	10	15.8	13.2	8.6
	11	11.1	8.7	6.1
	12	8.4	6.2	5.0
Yozgat	1	-2.0	-3.1	3.0
	2	-1.5	-2.8	3.0
	3	2.3	0.3	3.7
	4	8.5	5.5	5.3
	5	12.8	9.6	7.2
	6	16.3	12.4	8.6
	7	18.9	14.1	9.5
	8	19.3	13.9	9.1
	9	15.9	10.7	7.3
	10	10.4	6.9	5.9
	11	4.2	2.3	4.5
	12	0.0	-1.1	3.6
Zonguldak	1	6.1	3.5	3.8
	2	5.3	2.7	3.6
	3	6.9	4.1	4.0
	4	11.2	8.0	5.4
	5	15.1	12.1	7.5
	6	19.3	15.9	9.8
	7	21.2	18.0	11.6
	8	21.3	18.1	11.6
	9	18.5	15.0	9.3
	10	15.0	11.9	7.5
	11	10.8	7.6	5.3
	12	8.0	5.2	4.4

Figure 4.6.1. depicts the variation of monthly average dry bulb temperature for selected provinces. As seen from the Figure each location indicates the main characteristic of its own region. Monthly average dry-bulb temperatures for Diyarbakır, Adana, and Izmir are at high levels in summer. While Erzurum located in eastern Turkey has low dry-bulb temperature throughout the year, İstanbul, Samsun and Ankara have relatively moderate temperatures. The variation of monthly average wet bulb temperature for selected provinces are shown in Figure 4.6.2. The highest monthly average wet-bulb temperature appears in Adana and the lowest monthly average wet-bulb temperature is in Erzurum throughout the year. Monthly average wet-bulb temperatures for İstanbul, İzmir, and Samsun take place between Adana and Erzurum. Figure 4.6.3 shows the variation of monthly average humidity ratio for selected provinces. While the maximum monthly average humidity ratio is observed in Adana, the values for İstanbul, Izmir, and Samsun are higher compared with the values for Diyarbakır, Erzurum, and Ankara. As seen from the Figure, the humidity ratio in the provinces located in coastal region (such as Samsun, Istanbul, İzmir and even Adana) exhibits a rapid change in summer months.

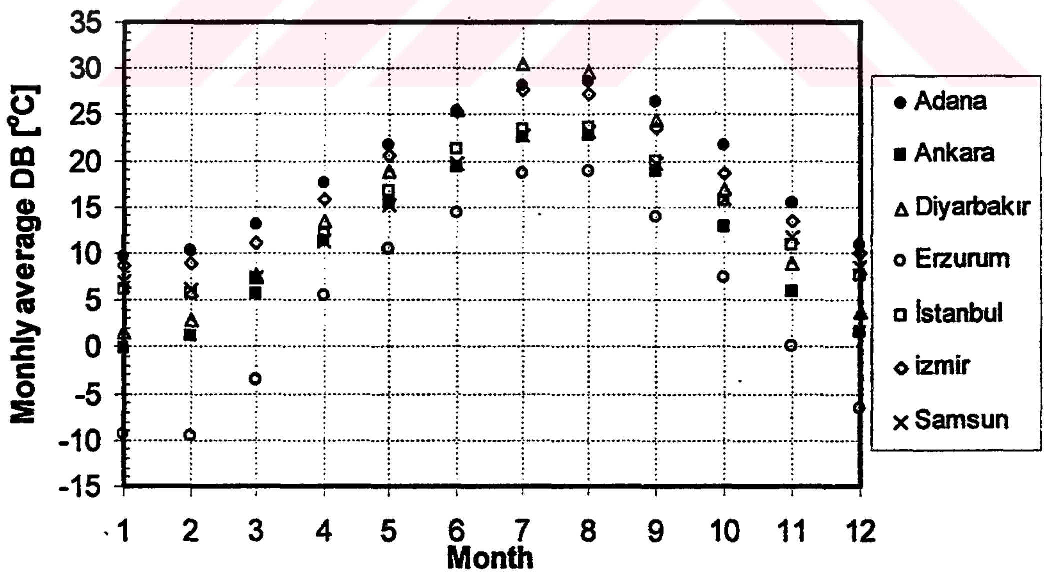


Figure 4.6.1. Variation of monthly average dry-bulb temperatures for selected provinces

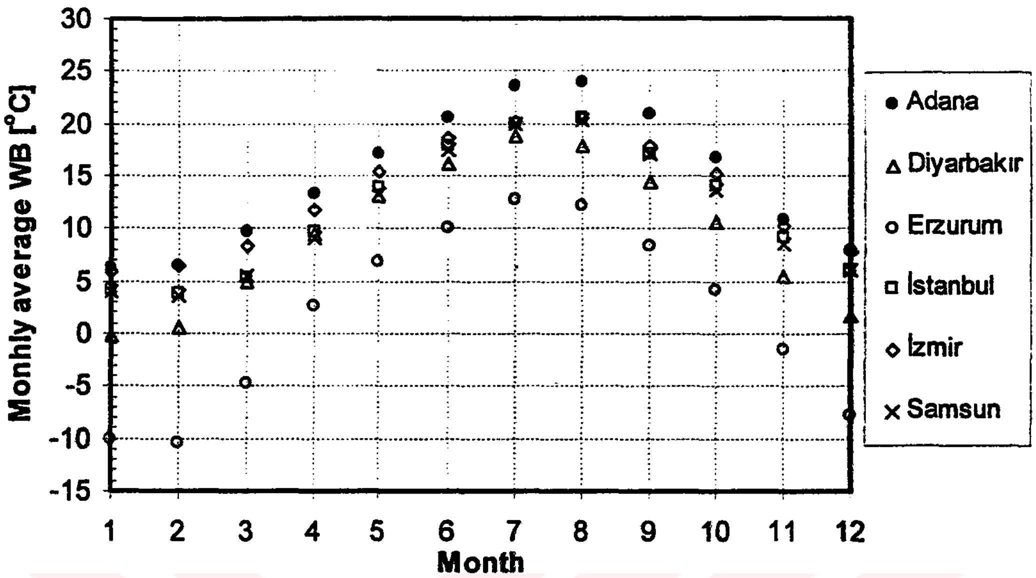


Figure 4.6.2. Variation of monthly average wet-bulb temperatures for selected provinces

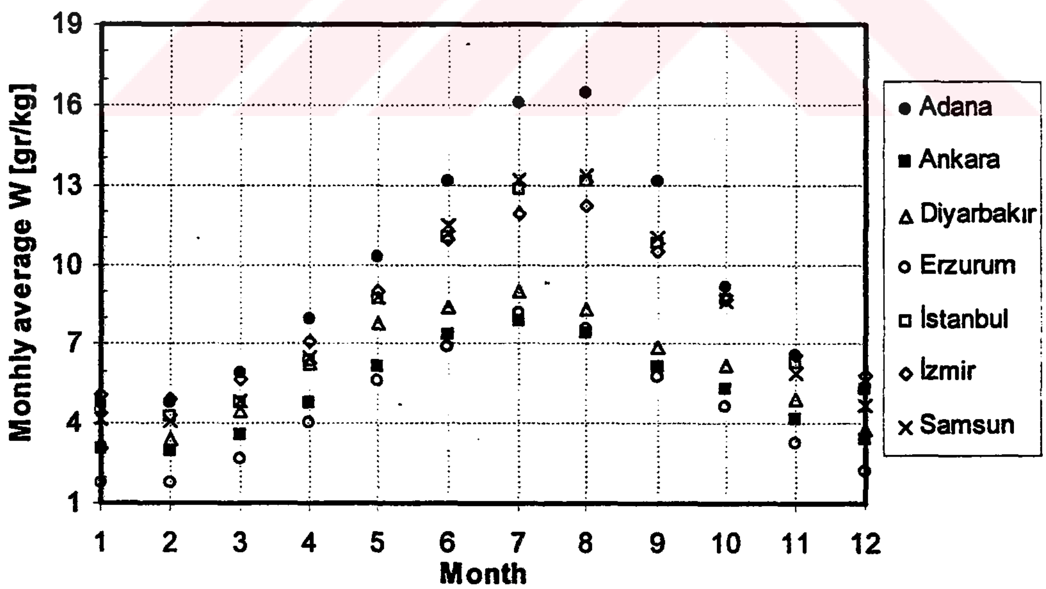


Figure 4.6.3. Variation of monthly average humidity ratio for selected provinces.

Latent cooling loads for buildings can be estimated on a monthly basis by the following equation (Al-Homoud, 2001 and Kredier and Rabl, 1994):

$$Q_{latent} = 0.3010\dot{V}(W_{o,m} - W_{i,m}) \qquad (4.6.1)$$

where Q_{latent}[W] is the monthly mean latent cooling load, $\dot{V}$ [m^3/s] is the monthly mean infiltration, $W_{o,m}$ [kg/kg$_{dry\text{-}air}$] is monthly average outdoor humidity ratio and $W_{i,m}$ [kg/kg$_{dry\text{-}air}$] is the monthly average indoor humidity ratio. Table 4.6.1 contains monthly average outdoor humidity ratios for 78 weather stations of Turkey.

4. 6. 1. Analysis of Monthly Average Outdoor Dry-bulb Temperature Used in Calculation of Thermal Insulation in Buildings

Energy savings in buildings must be taken into account in design stage. For this purpose, the Turkish Standard TS825, compulsory standard for thermal insulation in buildings, has been in force since 14 June 2000 (TS825, 1999). TS825 deals with calculation of heating energy requirement in buildings and brings restriction to the heating energy requirement. Heat gains are taken into account in calculation of monthly conductive heat losses of a building. Annual heating energy requirement of a building is calculated from monthly heating energy requirements. TS825 brings limitation to the annual heating requirement according to total useful area or volume of the building.

The monthly total heating energy requirements in buildings due to conduction are given as:

$$Q_m = (\sum UA)(T_{i,m} - T_{o,m})\, t_m \qquad (4.6.2)$$

where Q_m [J] is the monthly heating energy requirements due to conduction, A [m^2] is total area of building where heat losses occur, U [W/m^2K] is heat transmission coefficient of building envelope, $T_{i,m}$ is monthly average indoor air dry-bulb temperature and it is usually taken as 19 °C in residential buildings, and t_m [s] is the total time in the month of the test. $T_{o,m}$ is monthly average outdoor dry-bulb temperature.

Monthly average outdoor temperatures are given for 4 different degree-day regions in Turkey in TS825 for calculation of heating energy requirement of buildings (Table 4.6.2). The monthly average outdoor temperatures presented in TS825 (T_{TS825}) were compared with the monthly average outdoor temperatures ($T_{m,m}$) obtained from the long-term measured data. The long-term measured monthly average dry-bulb temperatures ($T_{m,m}$) data are given in Table 4.6.1. For comparison, the differences (MTD) between the measured and the data given in the standard were calculated for each weather station. However the monthly temperature differences

(MTD) were calculated only for the temperatures below 19 °C, since the indoor temperature is usually taken as 19 °C in residential buildings.

Table 4.6.2. Monthly average outdoor dry-bulb temperatures given in TS825

Month	T_{TS825} [°C]			
	1st Region	2nd Region	3rd Region	4th Region
January	8.0	3.3	1.3	-5.2
February	9.3	4.5	2.0	-4.1
March	11.5	7.2	5.0	-1.3
April	15.7	12.6	9.8	5.1
May	20.6	17.8	14.1	10.1
June	25.4	21.9	18.1	13.5
July	28.0	24.4	21.1	17.2
August	27.2	23.8	20.6	17.2
September	23.3	19.6	16.5	13.2
October	18.1	14.1	11.3	6.9
November	13.3	9.1	6.5	1.3
December	9.4	4.9	2.6	-3.0

MTD is expressed as:

$$MTD = (T_{m,m} - T_{TS825}) \qquad (4.6.3)$$

Although MTD values were calculated for 78 weather stations, due to space limitations, they are given in Tables 4.6.3., 4.6.4, 4.6.5, and 4.6.6 for only 4 selected weather stations from each degree-day region.

MTD values for Adana, Antalya, İzmir and Hatay that are located in the 1st degree-day region are given in table 4.6.3. The last row shown in the Table presents the yearly total MTD values. Figure 4.6.4.a shows variation of monthly average dry-bulb temperature for selected weather stations from the 1st region. Analysis of the Figure and the Table 4.6.3 reveals that the monthly mean dry-bulb temperatures given in T_{TS825} are generally less than the values obtained in this study, $T_{m,m}$. MTD values are usually positive. While the maximum yearly total MTD is 13.1 °C in Adana, the yearly total MTD in İzmir (1.5 °C) is insignificant.

İstanbul, Diyarbakır, Samsun and Denizli were chosen as representative provinces for the 2nd region. MTD values for these locations were given in table

4.6.4. Variation of monthly average dry-bulb temperature throughout the year is depicted in figure 4.6.4.b. MTD values are again positive for all representative locations. While yearly total MTD for Diyarbakır is 0.4 °C, it is 17 °C for Denizli.

MTD values for Ankara, Elazığ, Isparta and Tokat that are located in the 3rd region are given in Table 4.6.5. Figure 4.6.4.c shows variation of monthly average dry-bulb temperature throughout the year. As seen from the Figure and the Table, T_{TS825} values are generally less than $T_{m,m}$.

Erzurum, Kayseri, Van and Sivas were chosen from the 4th degree-day region. MTD values for these weather stations are given in Table 4.6.6. Variation of monhtly average dry-bulb temperature is demonstrated in Figure 4.6.1.d. The temperatures given in T_{TS825} for Erzurum is generally higher than $T_{m,m}$. MTD values for the other 3 locations are positive. Yearly total MTD values for 4th region are very high compared with the other regions.

Yearly total MTD values for 78 weather stations of Turkey are given in Table 4.6.7. T_{TS825} values for 5 weather stations located in the 1st region are less than $T_{m,m}$. Only in Aydın, monthly mean temperature obtained from the measured data is less than the value given in TS825. Three weather stations out of 30 provinces located in the 2nd region have negative yearly total MTD values. Yearly total MTD values are positive in the remaining 27 provinces. The maximum yearly total MTDin the 2nd region is 27.7 °C in Şanlıurfa. In the 3rd region, yearly total MTD is positive in 18 locations and negative in 9 locations. Yearly total MTD values in the 4th region where winter season is severe are higher than the values for the other regions. The monthly mean dry-bulb temperatures obtained in this study for Ardahan, Erzurum, and Kars are significantly higher than the values given in TS825. 54.6 °C for Erzincan is the maximum MTD value in all weather stations considered. Ardahan has the minimum yearly total MTD value (-30.8 °C) as negative value in all regions.

It seen that there are significant differences between the data recommended in TS825 and the long-term measured. In general, the data given in TS825 are less than the long-term measured data. It is also observed that there are big differences in monthly average outdoor temperatures even for the provinces located in the same degree-day region. Therefore monthly mean dry-bulb temperatures should be given on a location bases not on a region bases. The actual monthly average outdoor dry-bulb temperature for each location should be used in the calculation of heating energy requirements.

Table 4.6.3. MTD values for representative weather stations selected from the 1st degree-day region

Month	MTD [°C]			
	Adana	Antalya	İzmir	Hatay
January	1.6	1.4	0.8	0.1
February	0.9	0.5	-0.4	0.0
March	1.6	0.3	-0.4	1.1
April	1.9	-0.2	0.1	1.5
May	-	-	-	-
June	-	-	-	-
July	-	-	-	-
August	-	-	-	-
September	-	-	-	-
October	3.6	1.6	0.6	2.5
November	2.0	0.9	0.2	0.6
December	1.5	1.3	0.6	-0.1
Yearly Total	13.1	5.8	1.5	5.7

Table 4.6.4. MTD values for representative weather stations selected from the 2nd degree-day region

Month	MTD [°C]			
	İstanbul	Diyarbakır	Samsun	Denizli
January	2.9	-1.8	3.7	2.4
February	1.1	-1.6	1.7	2.1
March	0.0	0.4	0.3	2.2
April	-0.6	0.9	-1.4	2.0
May	-1.2	1.1	-2.7	1.7
June	-	-	-	-
July	-	-	-	-
August	-	-	-	-
September	-	-	-	-
October	1.4	2.7	1.7	2.7
November	1.8	-0.1	2.7	1.7
December	2.7	-1.2	3.6	2.2
Yearly Total	8.1	0.4	9.6	17.0

Table 4.6.5. MTD values for representative weather stations selected from the 3rd degree-day region

Month	MTD [°C]			
	Ankara	Elazığ	Isparta	Tokat
January	-1.4	-2.0	0.3	0.8
February	-0.8	-1.9	0.2	0.7
March	0.7	0.0	0.3	1.5
April	1.6	2.0	0.5	2.6
May	1.3	2.5	0.8	1.9
June	1.1	4.0	1.3	1.0
July	-	-	-	-
August	-	-	-	-
September	2.4	5.0	2.0	2.1
October	1.4	3.1	1.5	2.0
November	-0.6	0.2	0.1	0.7
December	-1.1	-0.7	0.4	1.1
Yearly Total	4.6	12.2	7.4	14.4

Table 4.6.6. MTD values for representative weather stations selected from the 4th degree-day region

Month	MTD [°C]			
	Erzurum	Kayseri	Van	Sivas
January	-4.1	3.1	1.6	1.6
February	-5.6	3.4	1.1	1.2
March	-2.2	5.3	2.5	3.4
April	0.3	5.3	2.9	4.0
May	0.3	4.5	2.8	3.2
June	0.9	4.7	4.5	3.3
July	1.5	4.2	4.9	2.4
August	1.6	4.0	4.5	2.6
September	0.6	3.8	4.4	2.9
October	0.5	4.4	4.2	3.7
November	-1.2	3.4	3.7	2.5
December	-3.6	3.0	2.6	2.0
Yearly Total	-11.0	49.1	39.7	32.8

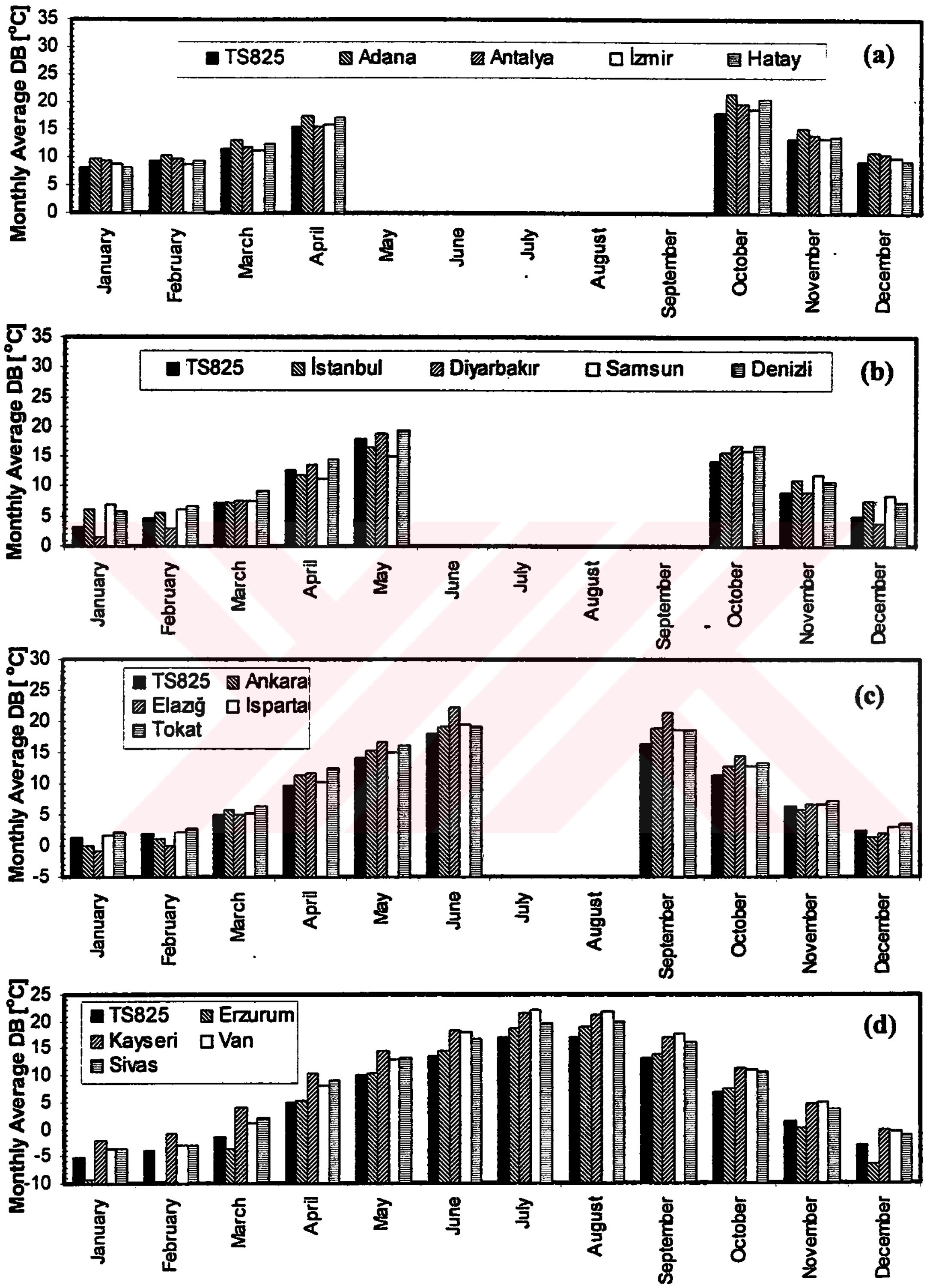


Figure 4.6.4. Variation of monthly average dry-bulb temperature for selected weather stations from different degree-day regions

Table 4.6.7. Yearly total MTD values for all provinces located in different degree-day regions

	Province	Yearly Total MTD
1st Region	Adana	13.1
	Antalya	5.8
	Aydın	-1.5
	Hatay	5.7
	İçel	16.8
	İzmir	1.5
2nd Region	Adapazarı	8.4
	Adıyaman	16.9
	Amasya	-3.2
	Balıkesir	6.3
	Bartın	-4.8
	Batman	11.5
	Bursa	7.2
	Çanakkale	11.1
	Denizli	17.0
	Diyarbakır	0.4
	Edirne	-4.7
	Gaziantep	4.3
	Giresun	11.0
	İstanbul	8.1
	K.Maraş	17.9
	Kilis	24.1
	Kocaeli	10.8
	Manisa	21.5
	Mardin	7.0
	Muğla	6.9
	Ordu	9.4
	Rize	8.8
	Samsun	9.6
	Siirt	5.3
	Sinop	7.5
	Şanlıurfa	27.7
	Tekirdağ	2.7
	Trabzon	12.7
	Yalova	11.0
	Zonguldak	4.9

	Province	Yearly Total MTD
3rd Region	Afyon	0.1
	Aksaray	8.0
	Ankara	4.6
	Artvin	12.0
	Bilecik	14.6
	Bingöl	1.8
	Bolu	-4.9
	Burdur	18.6
	Çankırı	-2.3
	Çorum	-5.4
	Elazığ	12.2
	Eskişehir	-3.9
	Iğdır	4.3
	Isparta	7.4
	Karabük	20.3
	Karaman	6.6
	Kırıkkale	9.4
	Kırklareli	21.1
	Kırşehir	-0.5
	Konya	-0.1
	Kütahya	-4.0
	Malatya	19.5
	Nevşehir	-6.6
	Niğde	-2.3
	Tokat	14.4
	Tunceli	9.1
	Uşak	14.7
4th Region	Ağrı	1.5
	Ardahan	-30.8
	Bayburt	7.2
	Bitlis	42.6
	Erzincan	54.6
	Erzurum	-11.0
	Gümüşhane	38.1
	Hakkari	44.7
	Kars	-15.0
	Kastamonu	41.8
	Kayseri	49.1
	Muş	38.7
	Sivas	32.8
	Van	39.7
	Yozgat	34.2

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Weather data are required for load calculations and detailed energy analysis in buildings. Accurate, attainable, and reliable weather data information is crucial for energy simulation and analysis in HVAC systems due to the accuracy and the characteristics of the results. In this study, detailed weather data for energy analysis and load calculations were determined and analyzed for Turkey.

Degree-Days:

The heating and cooling degree-days with variable base temperatures for Turkey were determined by using long-term measured data. Base temperatures 14, 16, 18, 20, and 22 °C were chosen in the calculation of heating degree-days. 18, 20, 22, 24, 26 and 28 °C base temperatures were used in the determination of cooling degree-days. Yearly heating and cooling degree-days are given in tabular forms for all provinces of Turkey. The cooling and the heating degree-days are also presented on the counter maps. The values of both heating and cooling degree-days exhibit variations throughout Turkey. While the Northeastern and the Inner regions of Turkey require comparatively more heating energy, they need less or no cooling.

Bin Weather Data:

The bin data for dry-bulb temperature from -36 °C to 45 °C with 3 °C increments were calculated in six daily 4-h shifts for 78 provinces of Turkey. The heating and 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 were 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 periods of the day (for Adana, Ankara, Diyarbakır, Erzurum, İstanbul, İzmir, and Samsun) were 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 were analyzed in detail. The influences of elevation, latitude and longitude on bin data were demonstrated. It is found that the low temperature bins appear in eastern and northeastern Turkey that have high elevations relatively. The high temperature bins are 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.

New Outdoor Design Conditions:

New outdoor design conditions were developed both for cooling and heating systems for all provinces of Turkey according to the format recommended by ASHRAE. Dry-bulb temperatures corresponding to 99.6% and 99% annual cumulative frequency of occurrence and the mean, median and standard deviation of the annual minimum (Min) dry-bulb temperatures were determined as heating design conditions for 78 weather stations of Turkey. It was found that while Ağrı, Erzurum, Ardahan and Kars have the minimum design temperatures, İskenderun, Mersin, Adana and Antalya have the maximum design temperatures. As cooling design conditions, dry-bulb temperatures corresponding to 0.4 %, 1% and 2% annual cumulative frequency of occurrence and the mean coincident wet-bulb temperature, the mean, median and standard deviation of the annual maximum dry-bulb temperatures, and the mean daily ranges were obtained for Turkey. It was found that the minimum design temperatures are in Ardahan, Sinop, and Rize, whilst the maximum design temperatures are in Batman, Şanlıurfa, and Diyarbakır. The cooling design conditions of the weather stations considered scatter on psychrometric diagram.

Current Outdoor Design Conditions:

The current outdoor heating and cooling design conditions were analyzed according to their frequency level based on the database available. It was seen that cooling design data for 10 provinces are not available in the literature. The analysis of climatic data for Turkey reveals that existing weather data for HVAC applications are inadequate and limited.

The frequency levels of the current cooling design conditions are between 0.0% and 3.09%. The current design conditions usually overestimate the cooling dry-bulb temperature. For 69 of 78 provinces, the frequency level of the current dry-bulb temperature is smaller than the minimum risk level (0.4%) proposed by ASHRAE (1997). The frequency level of the current dry-bulb temperature is between the levels (between 0.4% and 2%) proposed by ASHRAE (1997) in 4 provinces (Erzurum, Artvin, Kahramanmaraş, and Adıyaman), whilst frequency level is higher than the maximum frequency level of 2% in ASHRAE (1997) in 5 provinces (Muş, Amasya, Nevşehir, Bingöl and Tokat). It can be concluded that both dry-bulb and wet-bulb temperatures used currently as cooling design data are generally very high.

The annual cumulative frequencies for heating design conditions are in the range of 97.61% and 100%. The frequency levels of current heating design temperatures are between the levels recommended by ASHRAE (1997) for only 11 provinces. Only 8 locations have frequency levels lower than the recommended level. For the remaining locations (59 provinces), the frequency levels are higher than the maximum level (99.6%) recommended by ASHRAE (1997). Some locations such as Adıyaman, Hakkari, Kahramanmaraş, and Kilis have zero risk factor, because very low values were chosen for the current heating design temperatures for these locations.

Modeling Weather Variables:

Four typical weather variables: daily maximum dry-bulb temperature, daily minimum dry-bulb temperature, daily humidity ratio, and hourly dry-bulb temperatures were modeled with trigonometric equations using the long-term meteorological data.

It was found that the equation obtained for daily maximum dry-bulb temperature has good correlation with the measured data. The correlation coefficients are in the range of 0.81 and 0.95, the mean absolute errors are between 2.03 and 4.13, and root-mean-square-errors are in range of 2.64 and 5.12.

The correlation coefficients are in the range of 0.81 and 0.94, the mean absolute errors are between 1.96 and 4.51, and root-mean-square-errors are in the range of 2.51 and 5.08 for the equation obtained for daily minimum temperature.

For the equation for daily mean humidity ratio, correlation coefficients are in the range of 0.68 and 0.93, the mean absolute errors are between 0.85 and 1.70, and root-mean-square-errors are in range of 1.10 and 2.17.

It was seen that the accuracy of the equations obtained for daily maximum and minimum dry-bulb temperatures and daily mean humidity ratio is good on monthly bases.

Hourly variation of outdoor dry-bulb temperature was expressed with mathematical equations using daily minimum and maximum temperatures. The root mean square error of the mathematical model for hourly outdoor dry-bulb temperature is in the range from 2.40 to 4.42. The outdoor dry-bulb temperature vary approximately in the band of ±10 °C during the day for all weather stations. The mathematical model always is in the range of this band.

Monthly Average Weather Elements:

Monthly average dry-bulb temperature, wet-bulb temperature and humidity ratio for provinces of Turkey were presented and analyzed. The minimum monthly average dry-bulb and wet-bulb temperatures appear in Ağrı, Ardahan, Kars, and Erzurum. The maximum monthly average dry-bulb temperatures occur in July and August in Southeastern and Southern Turkey. Batman, Siirt, Adıyaman, Şanlıurfa, Diyarbakır, Gaziantep, Adana, Mersin, and Hatay have the maximum monthly average dry-bulb temperatures. Provinces located in Southern Turkey have both maximum monthly average dry-bulb temperatures and maximum monthly average wet-bulb temperatures. The provinces located in Southern Turkey have also maximum monthly average humidity ratio.

Monthly Average Outdoor Dry-bulb Temperature Used in Calculation of Thermal Insulation in Buildings:

Monthly average outdoor temperature presented in TS825 were compared with the temperature data obtained from the long-term measurements. It was found that there are significant differences between the recommended data in TS825 and the long-term measured data. In general, the data given in TS825 are less than the long-term measured data. It was also observed that there are big differences in monthly average outdoor temperatures even for the provinces located in the same degree-day region. Therefore the monthly average dry-bulb temperature should be given on a location bases not on a regional bases. The actual monthly average outdoor dry-bulb temperature for each location should be used in calculation of heating energy requirements.

5.2. Recommendations for Future Work

In this study, climatic data were presented for HVAC applications and building energy analysis. Solar data were not included in these analyses. Since the solar component is one of the most important parameters in the weather data, accurate and reliable solar data should be developed for Turkey. The new solar data for Turkey should be based on recent measurements and long-term data.

In this study, 78 weather stations located in 78 different provinces were considered. The weather database and climatic analysis of the other locations were not handled. However there could be big variations even in short distances due to geographical changes. Therefore, weather data should be obtained for location which measurements are available.

Using the weather data presented in this study, a detailed study for the energy analysis of various buildings in Turkey can be carried out for different locations.

The technical and economical suitability, and applicability of various HVAC systems such as evaporative cooling and desiccant cooling can be investigated for Turkey by using the weather data. Different HVAC Systems for different locations or regions can be suggested as a result.

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