INVESTIGATION OF TURKEY'S CARBON DIOXIDE PROBLEM BY NUMERICAL MODELING

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INVESTIGATION OF TURKEY'S CARBON DIOXIDE PROBLEM BY NUMERICAL MODELING

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Approval of the Graduate School of Natural and Applied Sciences

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ABSTRACT

INVESTIGATION OF TURKEY'S CARBON DIOXIDE PROBLEM BY NUMERICAL MODELING

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CO_2 emission is very important, because it is responsible for about 60% of the "Greenhouse Effect". The major objectives of this study were to prepare a CO_2 emission inventory of Turkey based on districts and provinces by using the fuel consumption data with respect to its sources, to find the CO_2 uptake rate of forests in Turkey based on provinces and districts, and to estimate the ground level concentrations of CO_2 across Turkey using U.S. EPA's ISCLT3 model for the preparation of ground level concentration maps. The basic sources of the CO_2 emission were taken as households, manufacturing industries, thermal power plants and road vehicles. The sinks of the CO_2 were forests. The CO_2 uptake by forests was calculated using the annual increment of forest biomass.

The results of the CO_2 emission inventory conducted in this study between the years 1990 and 2003 showed that the CO_2 emission in 1990 was 142.45 million tones/year and the highest emission was calculated in 2000 with a value of 207.97 million tones/year.

The regional distribution of CO_2 emissions showed that the Marmara Region emits the highest regional CO_2 emission throughout the years with an average value of 54.76 million tones/year. It was also concluded that Marmara and Aegean Regions are responsible for half of the CO_2 emission of Turkey.

The results of the CO_2 uptake calculations showed that the CO_2 uptake of forests in the coastal zone was higher than that in the inland zone. The CO_2 uptake in the Central Anatolia, Eastern Anatolia and South-Eastern Anatolia regions were 2.6, 1.9 and 1.1 million tons/year, respectively. The maximum CO_2 uptake is in the Black Sea region with a value of 16.4 million tons/year.

The highest ground level CO_2 concentrations without any sink effect were always obtained in the Marmara Region. However, the forest areas in this region decrease the concentrations considerably.

The dispersion model performance is determined highly without the result of the year 2002.

Keywords: Emission Inventory, Sink, Source, ISCLT3 Dispersion Model, IPCC Methods, CO_2 Emission, CO_2 Uptake

ÖZ

TURKİYE'DEKİ KARBON DIOKSIT PROBLEMİNİN SAYISAL MODELLEME İLE İNCELENMESİ

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CO_2 emisyonu, Sera Gazı Etkisinin yaklaşık %60'ına sebep olmasından dolayı oldukça önemlidir. Bu çalışmanın en önemli hedefi ise, emisyon kaynaklarına göre yakıt tüketimlerini kullanarak il ve ilçe düzeyinde Türkiye CO_2 emisyon envanterini hazırlamak, il ve ilçe düzeyinde Türkiye ormanlarının CO_2 soğurmasını bulmak ve U.S. EPA ISCLT3 modeli kullanarak Türkiye'deki yer seviyesi CO_2 konsantrasyonu, konsantrasyon haritaları hazırlayabilmek için tahmin etmektir. CO_2'in en önemli kaynakları, haneler, imalat sanayii, termik santraller ve ulaşım araçları olarak ele alınmıştır. CO_2'i soğurma mekanizmaları ise ormanlardır. Ormanlardaki CO_2 soğurması yıllık biokütle artışları kullanılarak hesaplanmıştır.

Bu çalışmadaki, 1990 ve 2003 yılları arasına ait CO_2 emisyon envanter sonuçları, en düşük CO_2 emisyon değerinin 1990 yılında 142.45 milyon ton ve en yüksek değerin ise 2000 yılında 207.97 milyon ton olarak hesaplandığını göstermiştir.

Yıllar itibariyle en yüksek bölgesel CO_2 emisyonu, Marmara Bölgesinden ortalama 54.76 milyon ton/yıl olarak yayılmıştır. Ayrıca, Marmara ve Ege Bölgelerinde, Türkiye CO_2 emisyonunun yarısının atıldığı da tespit edilmiştir.

CO_2 soğurma hesaplarından elde edilen sonuçlara göre, kıyı bölgelerde ormanlar tarafından soğurulan CO_2 , iç bölgelere göre daha yüksektir. İç Anadolu, Doğu Anadolu ve Güneydoğu Anadolu Bölgelerinde, CO_2 sırasıyla 2.6, 1.9 ve 1.1 milyon ton/yıl olarak soğurulmuştur. Karadeniz Bölgesinde CO_2 soğurması 16.4 milyon ton/yıl olarak maksimumdur.

Yer seviyesindeki soğurma olmaksızın, en yüksek CO_2 konsantrasyonu Marmara Bölgesinde elde edilmiştir. Ormanlar konsantrasyonu önemli ölçüde düşürmüştür.

Model dağılım performasının 2002 yılı verisi olmaksızın daha yüksek olduğu tespit edilmiştir.

Anahtar Kelimeler: Emisyon Envanteri, Soğurma, Kaynak, ISCLT3 Dağılım Modeli, IPCC Metodu, CO_2 Emisyonu, CO_2 Konsantrasyonu

To My Parents

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TABLE OF CONTENTS

LIST OF TABLES

Table

LIST OF FIGURES

LIST OF ABBREVIATIONS

α	Cronbach Alfa value
^{o}C	Degrees Celsius
Δh	Plume rise
$\Delta x, \Delta y, \Delta z$	Dimensions of a unit cube
μm	Micrometer
$\mu g/m^3$	Micrograms per meter cube
η_s	Total number of industries according to its size
η_d	Number of the industries in districts according to its size
η_p	Total number of industries in provinces according to its size
%	Percent
σ^{xy}	Correlation Coefficient
$\sigma_y;\sigma_z$	Standard Deviations
ψ_d	Number of households in district d
ψ_p	Number of households in province p
C(x,y,z)	Concentration of pollutant at location x,y,z
B	Volume of biomass
Ca_p	Number of car in province p
Ca_t	Total number of cars
cov (x,y)	Covariance between x and y
CFCs	Chlorofluorocarbons
CH_4	Methane
CS	Carbon Storage
CO_2	Carbon dioxide
CO	Carbon monoxide
D	Dry biomass density
df	Degrees of freedom
d_{ij}	Distance coefficient between two cases

E(t)	Distribution mean of Mann-Kendall Rank Correlation Test
ef	Energy consumption factor of the industries according to its size
ef_p	Energy consumption factor of the industries in provinces according to its size
ef_{pn}	Normalized energy consumption factor of the industries in provinces according to its size
EPA	Environmental Protection Agency
fc_p	Total fuel consumption in provinces
fc^t_d	Fuel consumption in the industries in districts according to its size
f_{di}	Fuel consumption in district d according to fuel type i
f_d	Fuel consumption of households in district d
f_i	Fuel consumption by car according to fuel type *i*
f_r	Fuel consumption factor of region r per households
GAW	Global Atmosphere Watch
GCP	Global Carbon Projects
GHG	Greenhouse Gases
GIS	Geographic Information Systems
h	Physical height of stack
H	Effective stack height
HFCs	Hydrofluorocarbons
I	Annual biomass increment
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ISCLT3	Industrial Source Complex Long-Term Model, version 3
k	Total number of items
K; K_x; K_y; K_z	Turbulent Diffusion Coefficients
Kcal	Kilocalorie
kg	Kilogram
m^3	Metercube
m/s	Meter per second (speed)
MOE	Ministry of Energy

MOEF*(1)	Ministry of Environment and Forestry
MOF*(1)	Ministry of Forestry
MW	Megawatts
N	Sample size
NMVOC	Non-methane Volatile Organic Carbon
N_2O	Nitrous oxide
NO_x	Nitrogen oxides
PFCs	Perfluorocarbons
ppm	Parts per million
ppmv	Parts per million by volume
r	Average correlation between pairs of items
RF	Root Factor
SIS*(2)	State Institute of Statistics
Q	Pollutant Emission Rate
SEM	Standard Error of Mean
S_y; S_x	Standard Deviation of Series
SF_6	Sulfurhexafluoride
SO_2	Sulfur dioxide
TB	Total biomass including roots
tC	Tones carbon
TEGTC	Turkish Electricity Generation Transmission Corporation
$t_{\alpha,df}$	Student t-table value
TJ	Tetajoule
TOE	Tones of Oil Equivalent
ONC	Optimum number of cluster
u	Horizontal wind speed
u(t)	Mann-Kendall Rank Correlation value
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
Up	CO_2 uptake
VOC	Volatile Organic Carbon

WDCGG	World Data Center for Greenhouse Gases
W_{ijk}	Weight for the k^{th} variable between i and j cases
WMO	World Meteorological Organization
$\overline{X}$, $\overline{x}$	Mean value of X, x
X_i	Observed Value
X_{ik}	Value of variable k in case i
$\overline{Y}$, $\overline{y}$	Mean value of Y,y
Y_i	Predicted Value
$\overline{Z}$	Mean value of Z
Z_{AM}	Morning mixing height
Z_{PM}	Afternoon mixing height
W/m^2	Watt per metersquare

*(1) Ministry of Environment and Ministry of Forestry were combined in 2002 and became Ministry of Environment and Forestry

*(2) Turkish Statistical Institute (TURKSTAT)

CHAPTER 1

INTRODUCTION

1.1. General

Mankind's impact on the earth's climate should not be underestimated. By using different climate model calculations, scientist can state that the earth's climate is changing and the human beings have played an important role on this change.

The very rapid development of technology and multiplication of population has brought ecological crises to different regions of the earth. The destruction of forests is scarcely alone in its far-reaching effect. Automobile emissions reduce tree and crops production over large areas [49]. The increasing mean surface temperature reduce the snow cover and floating ice [6].

The temperature of the Earth's is strongly influenced by the, density and composition of the atmosphere [12]. The release of greenhouse gases has changed the radiative balance of the atmosphere and trapped some of the outgoing energy [29]. The earth's surface temperature would be on the average $-15\ ^{o}C$ without the natural greenhouse effect [39]. A schematic illustration of the greenhouse effect is given in Figure 1.1.

According to the IPCC [29], the most important greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluoro carbons (HFCs), perfluoro carbons (PFCs), and sulfurhexa fluoride (SF_6). Today's atmosphere contains only 0.038% CO_2 [39]. However, it is estimated that CO_2 is responsible for about 60% of the greenhouse effect attributed to the increased atmospheric concentrations of greenhouse gases [29], [99].

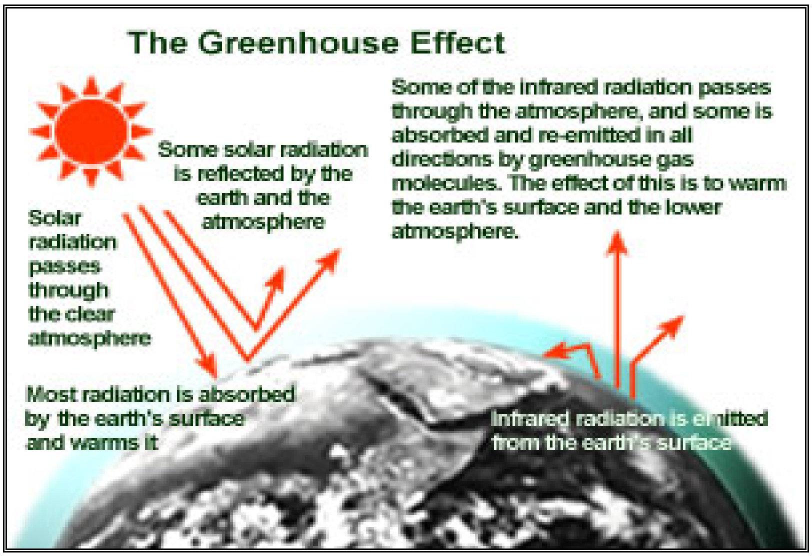


Figure 1.1 The Greenhouse Effect [6]

Table 1.1 shows the properties of the greenhouse gases that cause the greenhouse effect.

CO_2 has risen considerably after the industrial revolution. These gases are emitted into the atmosphere with an increasing quantity by years due to the combustion of coal, oil, natural gas and by the destruction of forests [1]. Combustion of fossil fuels is responsible for 75-90% of all anthropogenic emissions of CO_2 [28]. The atmospheric concentration of CO_2 as seen in Figure 1.2, has increased from a pre-industrial value of 280 ppmv to more than 370 ppmv today and is increasing at a rate of 0.5% /year [29]. The CO_2 growth rate has been about 1.5 ppmv (0.4%) per year over the past two decades. During the 1990s, the year-to-year increase varied from 0.9 ppmv (0.2%) to 2.8 ppmv (0.8%). The photochemical or chemical processes in the atmosphere could not destroy the inert gas CO_2 [5]. Therefore, this increase contributes to the enhancement of the greenhouse effect, which result in atmospheric global warming and climate change [32].

Table 1.1 Sources, Sinks and Characteristics of Greenhouse Gases [38]

	Properties	CO_2	CH_4	N_2O	CFCs and Halons
1	Residence time, years	2-4	10-12	150-200	75-110
2	Main IR Absorption Wavelengths, μm	4.3,15	3.3,7.6	4.5, 7.6, 8.6	8.68-11,22
3	IR Trapping, W/m^2 1985(2050)	50(33)	1.7(2.5)	1.3(1.5)	0.06(0.3)-0.12(0.6)
4	Estimated Temperature increase, °C	0.71	0.20	0.10	0.12-24
5	% Contribution to GHE	60 (1)	18	6	14
6	More effective than CO_2	1	21 times (2)	310 times (2)	140 - 23900 times (2)
7	Rate of increase in Concentration	25% Since industrial revolution in the mid 1800s	0.7 to 65 ppm in 400 years	50% since industrial revolution &5-10% in 200 years	Increasing rapidly ever since they were invented in 1930
8	% Increase/year	0.4 (1)	0.8 (1)	0.25 (1)	2.0-7.0 (1)
9	Atmospheric Concentration by Volume	358 ppm (3)	1.75 ppm (3)	0.31 ppm (3)	0.00028 – 0.00048 ppm (3)
10	Sources	Combustion of fossil fuels (industries thermal power plants, road vehicles, residential) and deforestration	Rice production animal husbandary land fills, marshy lands, coal seams, melting permafrost biomass burning, natural gas leaks	Nitrogen fertilizers, land clearance, biomass burning, fossil fuel combustion	Propellants and deodorants in aerosols, refrigerants, cleaning solvents, fire extinguishers, blowing agents for foamed or extruded polymers, sterilants for medical suppliers
11	Sinks	Oceans, forest and vegetation	Oxidation to CO, soils	Stratospheric photochemistry and aerobic and soils	Injection of alkenes, ethane or propane into the atmosphere can destroy /immobilize CFCs.

Source: (1) [29]; (2) [30]; (3) [39] (Protecting the earth atmosphere-1995)

1 μm = 1 micrometer (10^{-6} m)

1 W/m^2 = 1 Watt per meter square

The quantity of growth is determined by the global carbon cycle of carbon sources and sinks or reservoirs [99]. In another words, the increasing CO_2 concentration in the atmosphere means that a significant CO_2 cycle through the atmosphere, biosphere and ocean [19]. A schematic illustration is given in Figure 1.3 to show this balance. Rates of emissions of the sources of carbon, such as the combustion of fossil fuels and deforestration, and transfers of carbon between sinks or reservoirs determine the rate of accumulation of CO_2 in the atmosphere [99]. The main relationship between CO_2 emissions and atmospheric concentrations is mostly examined by carbon cycle models that consider all of the important sources and sinks [33]. The main sources of CO_2 are the burning of fossil fuels and land-use changes. The main sinks of CO_2 are the forests and oceans [29]. However, there are still large uncertainties as to whether the coastal zones act as sinks or sources [14].

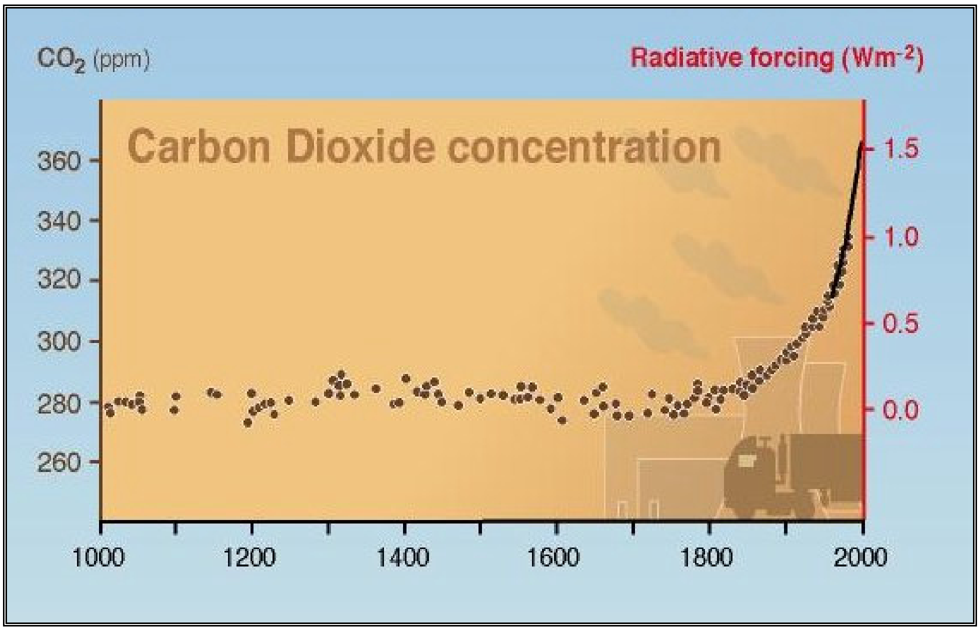


Figure 1.2 Atmospheric CO_2 Concentration [32]

CO_2 cycle is affected by the seasonal meteorological variations in the atmosphere [35]. The maximum CO_2 cycle is occurring from late winter to early spring and the minimum CO_2 cycle is occurring in late summer [18].

The most important atmospheric exchange of carbon is the one between the atmosphere and the biosphere. The biosphere removes carbon from the CO_2 of the atmosphere by photosynthesis. It again releases CO_2 into the atmosphere during the decay of plants [16]. The rate is equal to about 20-25 % of the total annual human-induced CO_2 emissions. Therefore, the significant proportion of global emissions coming from this source. The overall strategy to stabilize the atmospheric CO_2 concentration must include the forest protection as a key component [37].

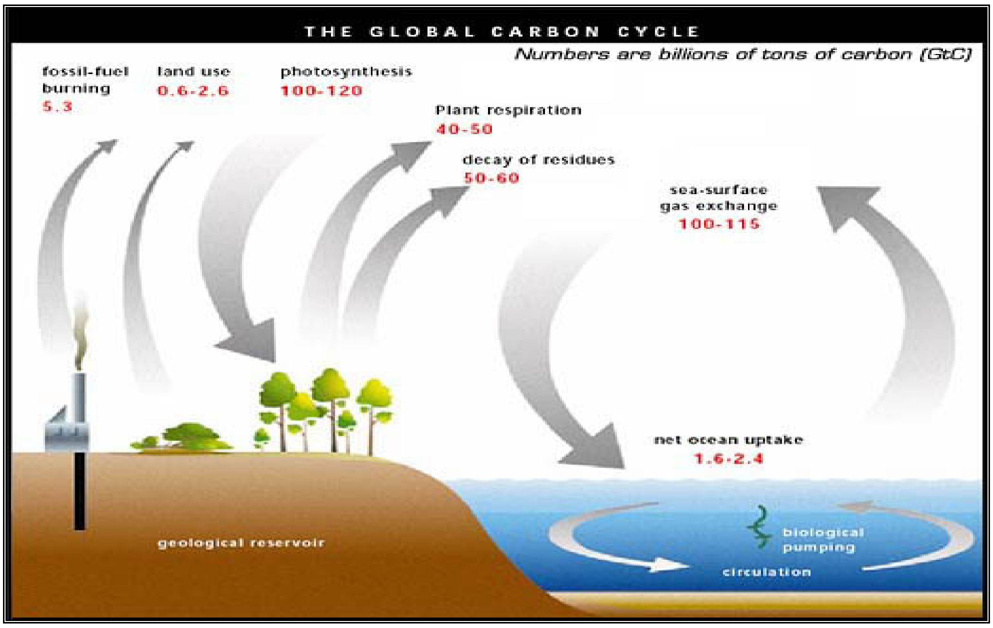


Figure 1.3 Schematic Diagram of the Carbon Cycle [95]

Atmospheric climate change is taking an increasingly important place in decision making process in both the public and private sectors and the policy programmes, countries have designed to meet their national goals, are extremely diverse [21]. The main international agreement (Rio de Janeiro in 1992) is the United Nations Framework Convention on Climate Change (FCCC) [93]. 189 Parties including Turkey have ratified the FCCC. Turkey is formally listed in Annex I of the Convention [43]. The main aim of the Convention is to stabilize GHG concentration in the atmosphere at a level that would prevent dangerous anthropogenic emissions [93].

In December 1997, the conference of parties to the UNFCCC held in Kyoto adapted the Kyoto Protocol. Kyoto conference has been accepted as a high profile event because for the first time industrialized countries adapted emission reduction targets that are legally binding [34]. The Protocol offers no guidelines for implementation at national level; rather, it offers freedom in respect of types of national legislation and policy. On the other hand, there are strict quantity norms in the Protocol. Improvement of energy efficiency, the storage of carbon in forests and the formation of sustainable agriculture are some of the important topics [98]. Turkey is not included in the list of countries under the Kyoto Protocol [43] because Turkey did not sign the protocol yet.

1.2. The Objectives of the Study

The major objectives of the study are;

- To prepare a CO_2 emission inventory of Turkey based on districts and provinces by using the fuel consumption data with respect to its sources,
- To find the CO_2 uptake rate of forests in Turkey based on provinces and districts,
- To estimate the ground level concentrations of CO_2 across Turkey using ISCLT3 model for the preparation of ground level concentration maps,
- To estimate the future CO_2 emission across Turkey based on different scenarios until year 2050.

1.2. The Scope of the Study

The main scope of the study is to assess the results of CO_2 inventories and dispersion modeling. Emission inventory of CO_2 in Turkey was done on the basis of districts and provinces in this study. The CO_2 inventory with this detail has not been done in Turkey previously. The inventory has been calculated between the years 1990 and 2003. Emissions in 1990 are important because the Kyoto Protocol accepts 1990 as the base year for CO_2 reduction.

For the CO_2 emissions, Households, Manufacturing Industries, Thermal Power Plants and Road Vehicles were considered as the main sources. All the major sources were included in the inventory. Emissions were estimated by using IPCC (Tier 1) method. The amount of fuel used was the basis for the estimation of emissions. This data was obtained mainly from the State Institute of Statistics. Additionally, CO_2 uptake by sink mechanism, especially by forests, was included in the study. The other sinks, like lakes, seas, soils, etc., are not included in the sink mechanisms, because according to the IPCC, the activities that are not anthropogenic in origin or do not result in a net source/sink of greenhouse gas emissions are intentionally excluded from the inventories. The forest areas have been accepted as the key sink for calculating the CO_2 removals in this study. Therefore, other sink mechanisms except forests have been excluded in the study, too, in order to make the results internationally comparable. The annual increment of the forest trees was the basis for the estimation of CO_2 uptake.

Following the emission inventory, the dispersion of CO_2 was studied by using the USEPA's Industrial Source Complex Long Term Model, Version 3 ISCLT3. Based on the results of modeling calculations, the ground level CO_2 concentration maps were prepared and superimposed on the geographical map of Turkey by using Geographic Information System (GIS) techniques. GIS techniques were used to map all the information.

The degree of accuracy for the results of the inventories and modeling were tested by the appropriate statistical methods.

At the end of the study some recommendations were done to help to determine the industrialization and the reforestation policies of Turkey until the year 2050.

CHAPTER 2

REVIEW OF LITERATURE

2.1. CO_2 Measurement Stations

In Turkey, there isn't any CO_2 measurement station. However, the CO_2 concentration is measured in most of the European countries and some Asian countries. A list of stations around Turkey is given in Table 2.1 and these stations are shown on a map in Figure 2.1. CO_2 concentration data obtained from these stations were used to estimate the upper atmospheric CO_2 concentration of Turkey. The data for these stations, nearest ones, were gathered from the internet site of the World Data Center for Greenhouse Gases (WDCGG). The WDCGG is established under the Global Atmosphere Watch (GAW) programme to collect, archive and provide data for greenhouse (CO_2, CH_4, N_2O, CFCs) and related (CO, NO_x, SO_2, VOC) gases in the atmosphere.

The total number of CO_2 measurement stations around Turkey is 12. However, some of the stations that make concentration observations were not included in the calculations for some years due to the missing data throughout the study period.

The CO_2 concentration maps over Turkey between 1995-2002 were obtained by using the Kriging Method [9] and an example was given in Figure 2.2. The results obtained by using the Kriging Method were used for the determination of the dispersion model performance.

Mauna Loa (Hawaii) station is the best station in the world in order to show the CO_2 concentration trends during the last quarter of century. The measurements were made in this station since 1974 [50], [100] and the results of the measurements between 1974 and 2003 are shown in Figure 2.3. As can be seen from the figure, the CO_2 concentration in the atmosphere has increased from 330 ppm to about 375 ppm in 29 years.

Table 2.1 CO_2 Measurement Stations around Turkey

COUNTRY	STATION	DATA (year)	LATITUDE	LONGITUDE	ALTITUDE (m)
HUNGARY	HEGYHAJSAL	1993-2002	46 57' N	16 39' E	344
HUNGARY	K-PUSZTA	1994-1995 1997-1998	46 58' N	19 33' E	125
ISRAEL	SEDE BOKER	1995-2002	31 8' N	34 53' E	400
ITALY	LAMPEDUSA	1992-2001	35 31' N	12 38' E	45
ITALY	MONTE CIMONE	1994-2001	44 11' N	10 42' E	2165
ITALY	PLATEAU ROSA	1993-1999	45 56' N	7 42' E	3480
KAZAKHSTAN	PLATEAU ASSY	1997-2002	43 15' N	77 53' E	2519
KAZAKHSTAN	SARRY TAUKUM	1997-2002	44 27' N	77 34' E	412
KIRGIZSTAN	ISSYK-KUL	1980-2000	42 37' N	76 59' E	1640
MALTA	DWESRA POINT	1993-1999	36 3' N	14 11' E	30
ROMANIA	BLACK SEA	1995-2002	44 10' N	28 41' E	3
ROMANIA	FUNDATA	2000-2001	45 28' N	25 18' E	1383,5

Figure 2.1 Map of CO_2 Measurement Stations around Turkey

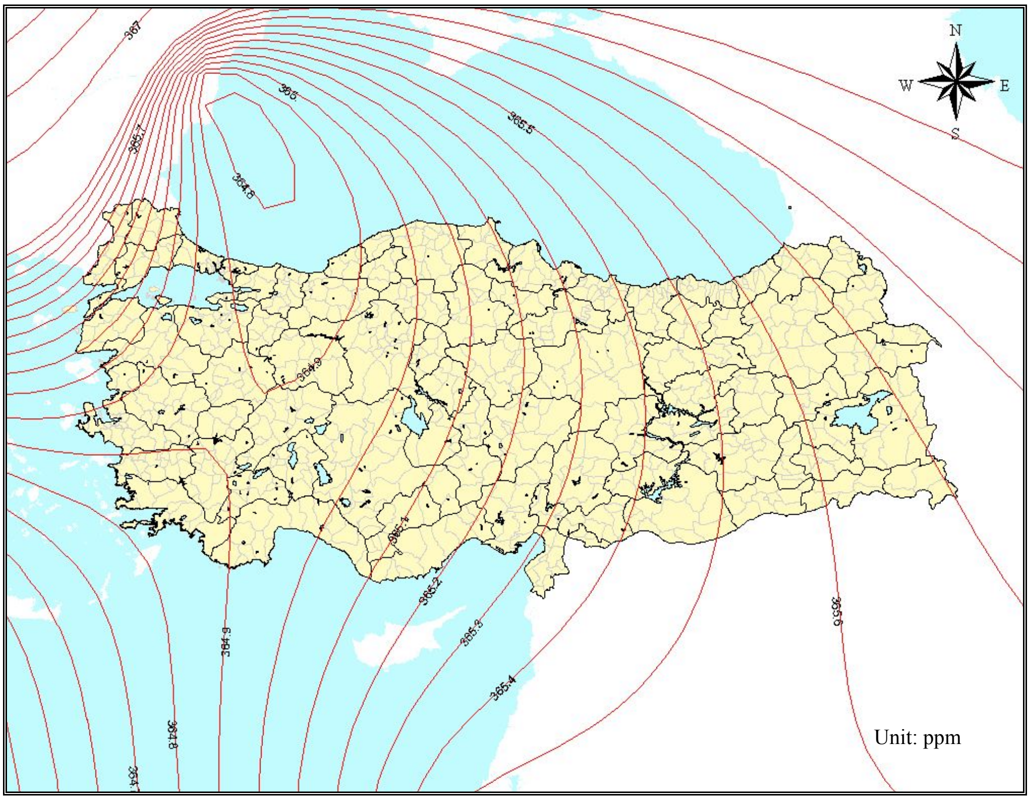


Figure 2.2 CO_2 Concentration Map by using the Kriging Method

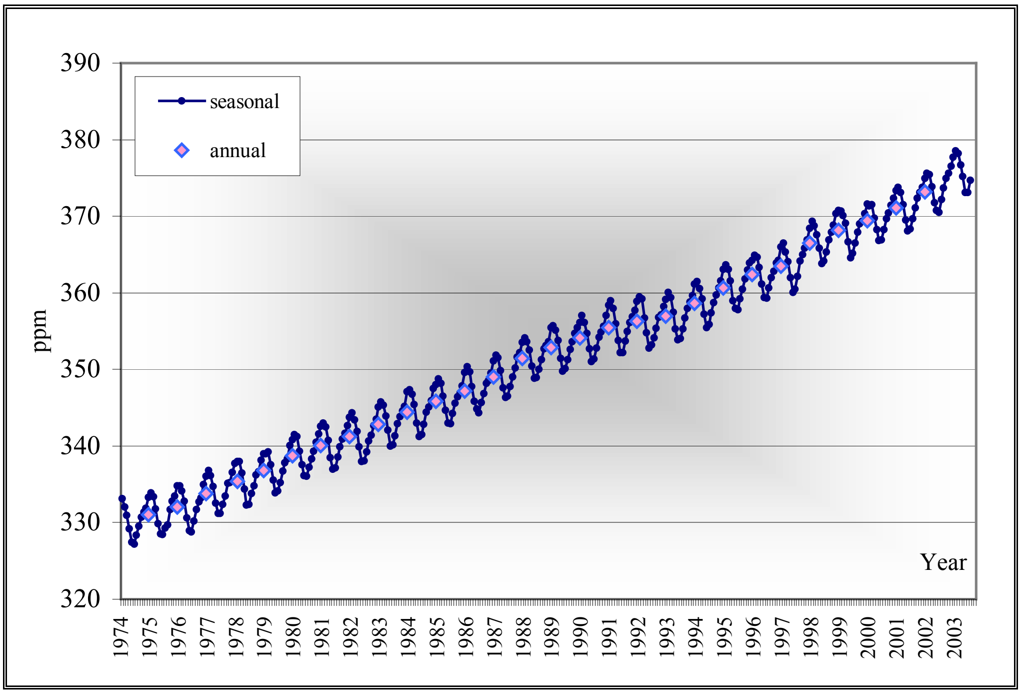
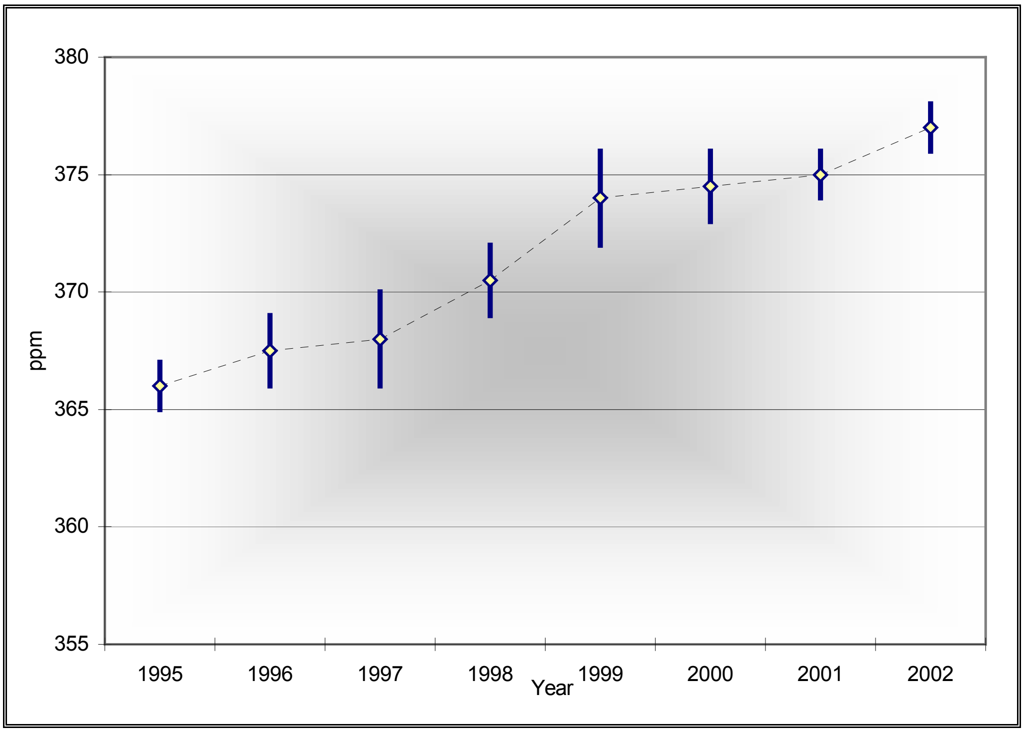


Figure 2.3. Yearly average CO_2 Concentrations measured at Mauna Loa, Hawaii [100]

WDCGG [100] states that the global CO_2 growth rate is 1.6 ppm/year on the average for the period of 1983-2001. However, IPCC [32] gives the CO_2 growth rate as 1.5 ppm per year over the past two decades.

Average CO_2 concentrations over Turkey were calculated by using the Kriging method based on the CO_2 data obtained in the countries around Turkey. The results are given in Figure 2.4.



Note: The figure is obtained by using the CO_2 Concentration Maps in Appendix A.

Figure 2.4 Average CO_2 concentrations over Turkey between 1995 and 2002

According to the results given in Figure 2.4, it can also be concluded that the average CO_2 concentration over Turkey has risen approximately 1.5 ppm /year between the years of 1995 and 2002. The highest CO_2 concentration interval that is the difference between the maximum and the minimum CO_2 concentration over Turkey was observed in year 1997 and 1999 with the value of 5 ppm.

2.2. Previous Studies on CO_2 Sources

The CO_2 emission inventory is one of the main tools used by the policy makers to set up their energy policies. Therefore, each country has to make their emission inventories for the control of man GHGs [21]. A well-constructed inventory should include enough documentation and data to allow readers to understand the underlying assumptions [96].

The estimates of CO_2 emissions from fuel combustions are calculated by using the IEA energy data supplied by national organization of countries. The default methods and the emissions factors are due to the Revised IPCC Guidelines for National Greenhouse Gas Inventories [30].

IEA published many books on CO_2 emissions from combustion of fuels. According to these books [22], [23], [24], [25], [26], [27], CO_2 emissions of several countries are given in Figure 2.5, 2.6 and 2.7.

In the studies carried out by IEA, the earth's fossil fuels CO_2 emission have indicated an increasing trend and reached approximately 24 billion tones of annual CO_2 emission in 2002 as can be seen in Figure 2.5.

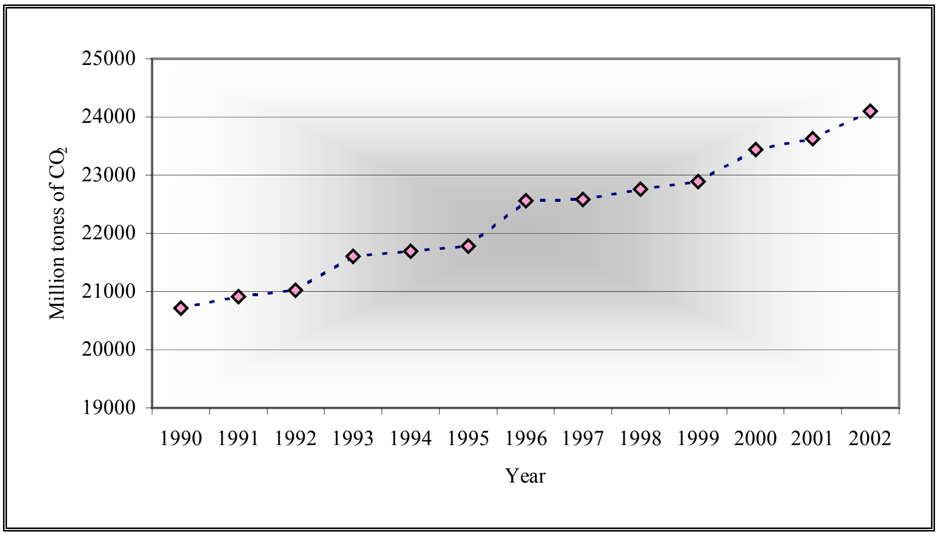


Figure 2.5 The Earth's CO_2 Emission

Contributions of USA, Russia, Japan and India to global CO_2 emission were exceed 10 billion tones per year. Figure 2.6 shows that annual CO_2 emission of USA was the highest with a value of 5.7 billion tones in 2002. It is approximately 24 percent of the total CO_2 emission in the world. The other highest CO_2 emitting countries are Russia, Japan and India with annual respective values of 1.5(%6), 1.2 (%5) and 1.0 (%4) billion tones in 2002.

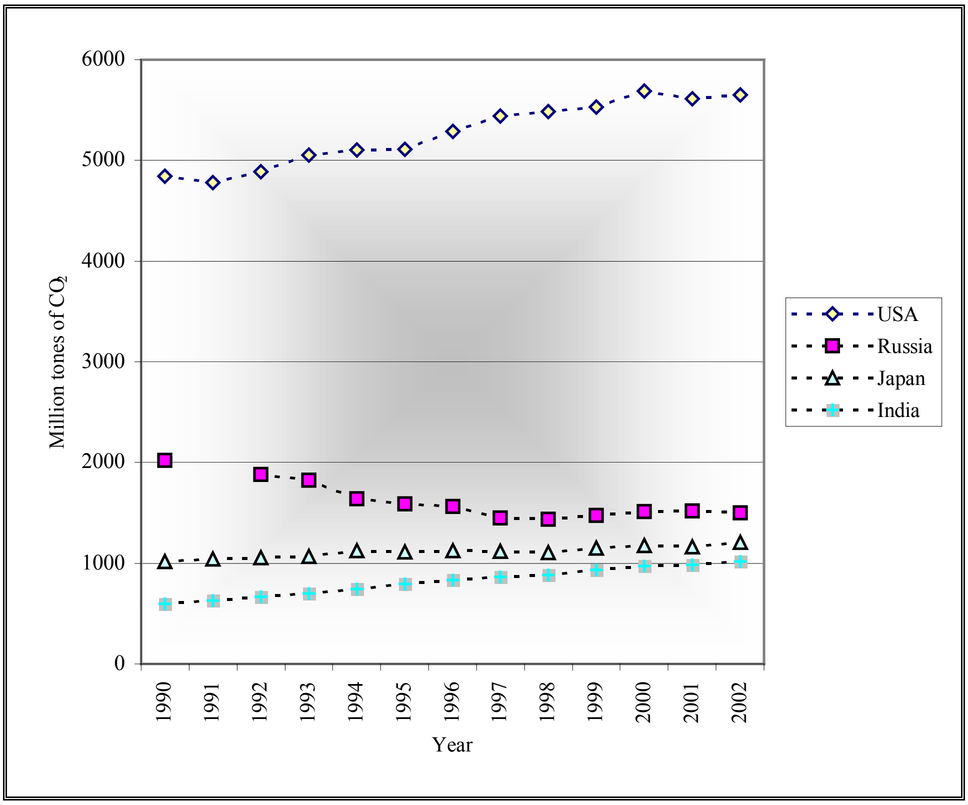


Figure 2.6 Countries emitting highest amount of CO_2

If we look at the CO_2 emissions of European Countries for the last 12 years as shown in Figure 2.7, the highest annual CO_2 emission was observed in Germany with 0.8 billion tones of CO_2. CO_2 emissions in Germany, England and Poland show a decreasing trend in the last 12 years. However, the trend is in the increasing direction for Spain, Greece and Italy. Following Germany, the highest

CO_2 emissions were observed in England, Italy, France and Poland with respective annual values of 0.53, 0.43, 0.38 and 0.34 billion tones in 2002.

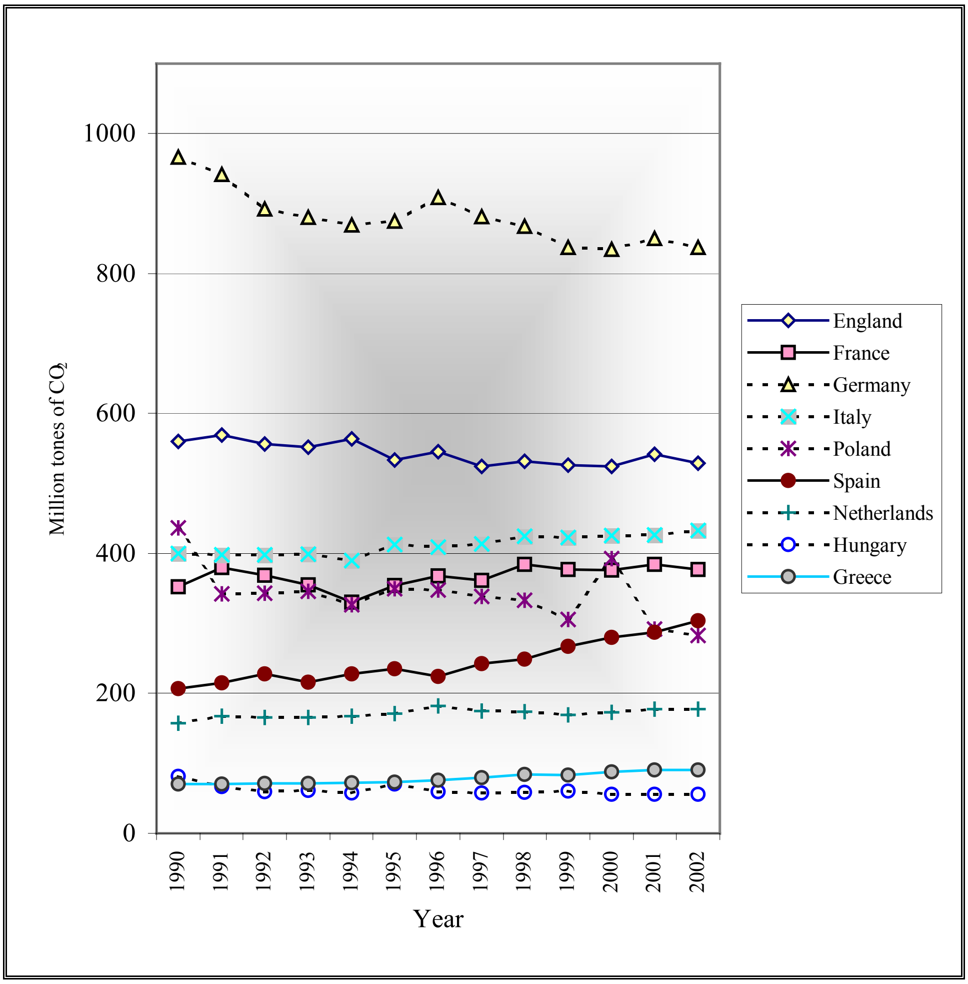


Figure 2.7 CO_2 Emission of European Countries

Studies related with the determination of CO_2 emission in Turkey are very few. Among those studies, the inventories of "International Energy Agency (IEA)" and "State Institute of Statistics (SIS)" are the important ones. However, both inventories are an accounting of total emissions of Turkey.

IEA emphasizes that the CO_2 emissions in Turkey have been increasing according to the base year 1990 as shown in Figure 2.8. The maximum CO_2

emission was observed in 2000 with an annual value of 203.7 million tones (0.2 billion tones). The annual emission is 0.19 billion tones in 2002. The emission increase is approximately 65 million tones between 1990 and 2002. The contribution of Turkey to global CO_2 emission is around 0.8% in 2002.

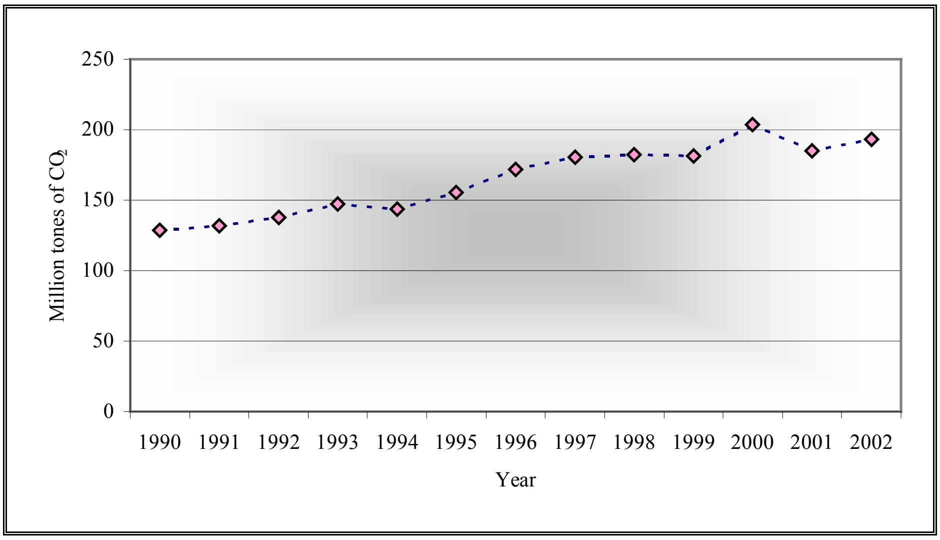


Figure 2.8. CO_2 Emission of Turkey

Another study carried out by SIS [57] covers the CO_2 emissions from sectors combusting fossil fuels (including electricity generation, industries, transportation and others) and fugitive leaks of industrial processes. The fugitive emissions from industrial processes are not directly related to energy activities. The source of emission chemically or physically transforms materials of production processes.

According to the SIS's results given in Figure 2.9, the trend for fugitive CO_2 emission was almost constant between 1990 and 2003 with a value of 15 million tones per year. However, the CO_2 emissions due to electricity generation, industries and transportation sectors have always shown an increasing trend on the average since 1995. Total CO_2 emission and CO_2 emissions due to fossil fuel combustion have shown an increasing trend over the last 14-year period.as seen in

Figure 2.10. The total CO_2 emission has reached to about 230 million tons in 2003.

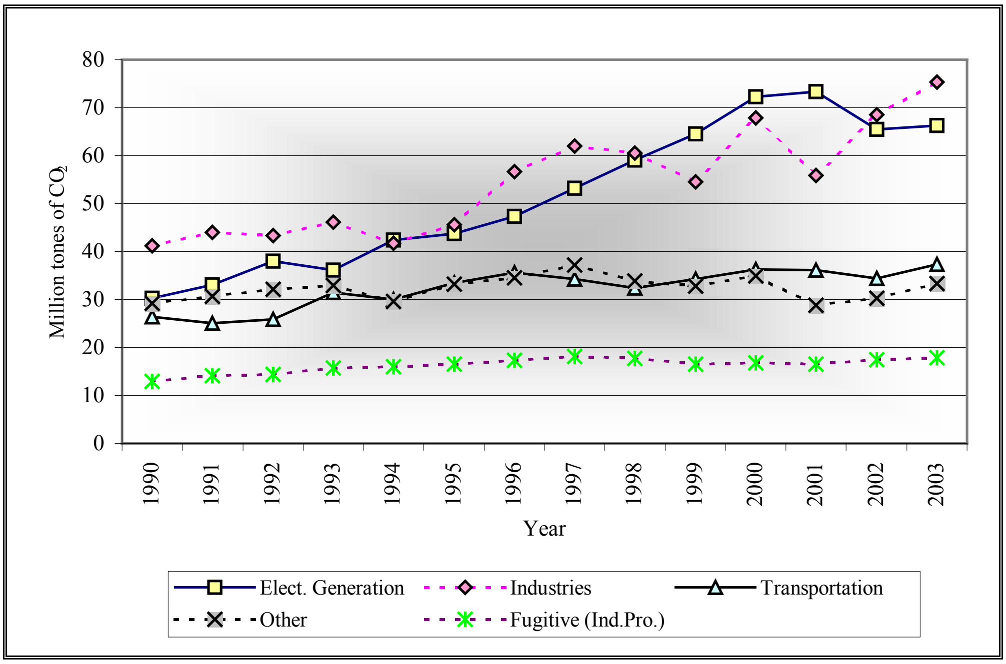


Figure 2.9 CO_2 Emission Sources for Turkey [55], [57]

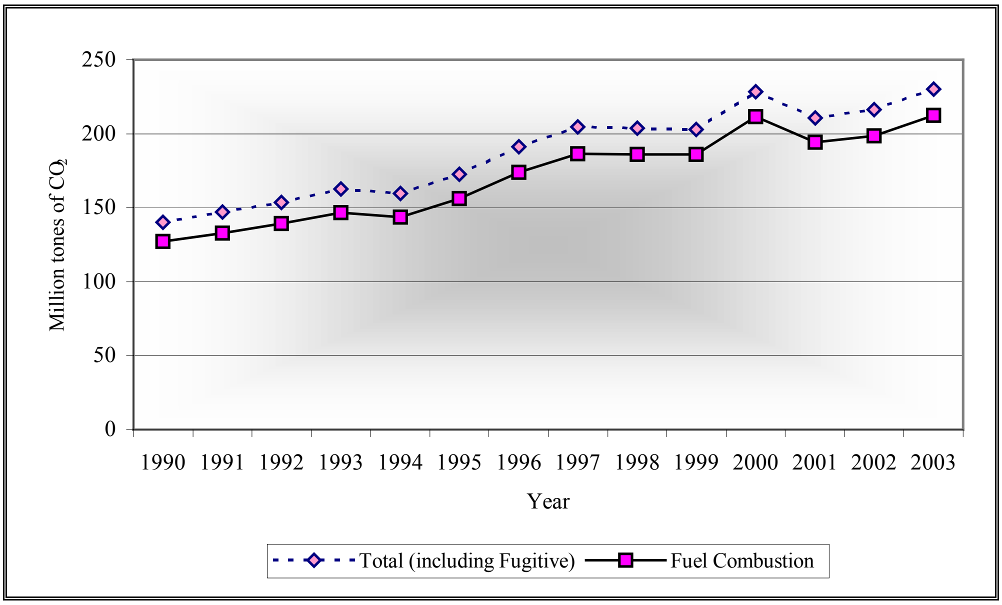


Figure 2.10 CO_2 Emission of Turkey [55], [57]

The sources for highest fossil fuels CO_2 emission in Turkey are industries and electricity generation with respective values of 75.3 and 66.3 million tones/year in 2003. The total amount of CO_2 emission from transportation and other sources together is around 70.7 million tones in 2003. The highest CO_2 emissions were observed in 2000 and 2003 with 211.4 and 212.3 million tones, respectively (Figure 2.10).

2.3. Previous Studies on CO_2 Sinks

Ministry of Forestry [44] has published the data on CO_2 uptake of forests between the years 1970 and 1997. In those years, the studies were mainly concerned with the extension of forest areas in Turkey. The increment of forest was the basis for the total CO_2 storage. According to the results of this study, it could be concluded that the annual carbon increments in forest was around 12 million tones. The total CO_2 storage of forest was the 49.7 million tones in 1997.

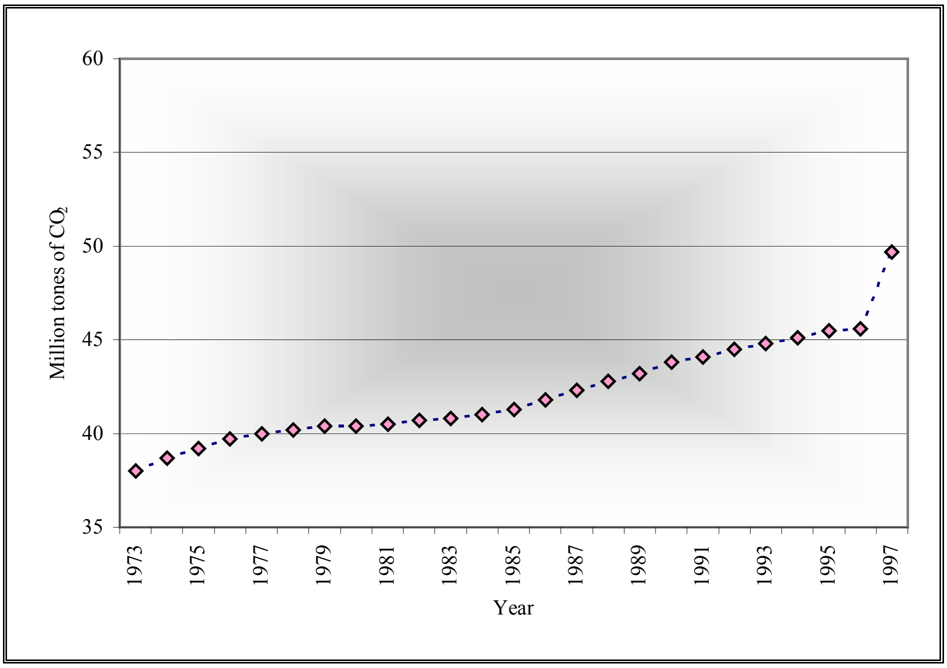


Figure 2.11 CO_2 Uptake of Forest in Turkey between 1973 and 1997 [44]

In a study, Asan [2] has examined the forest inventories in Turkey. He emphasized that the inventory has to be made every 5-year period. According to his results, it was concluded that 5 year trend has changed markedly in all years. Most importantly, he has found that the decreasing trend of CO_2 uptake of forest was observed during the years of 1960 and 1975. He explained that the main reason of this decreasing was due to the deforestration. The CO_2 uptake by forest has been increasing considerably since 1980. The highest CO_2 storage was seen in 1995 with a value of 80 million tones. According to the results of the study, 13 million tones of CO_2 in the atmosphere has been uptaken between 1990 and 1995.

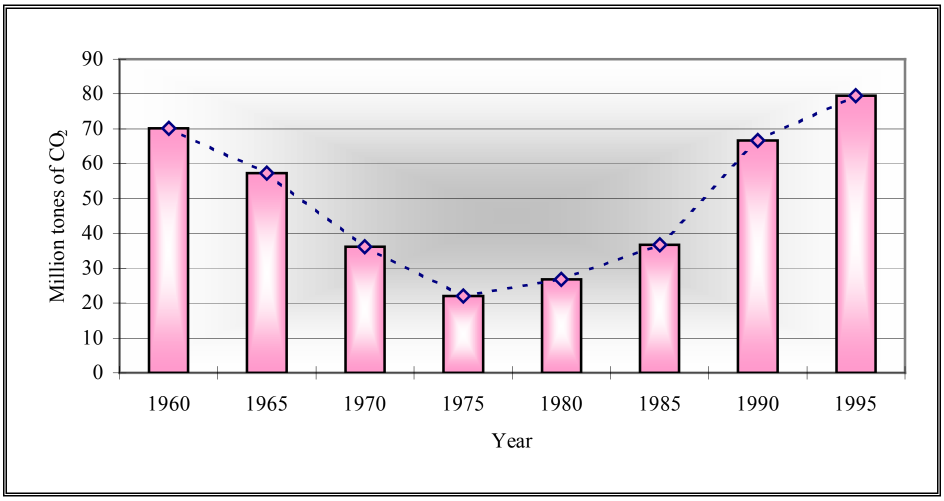
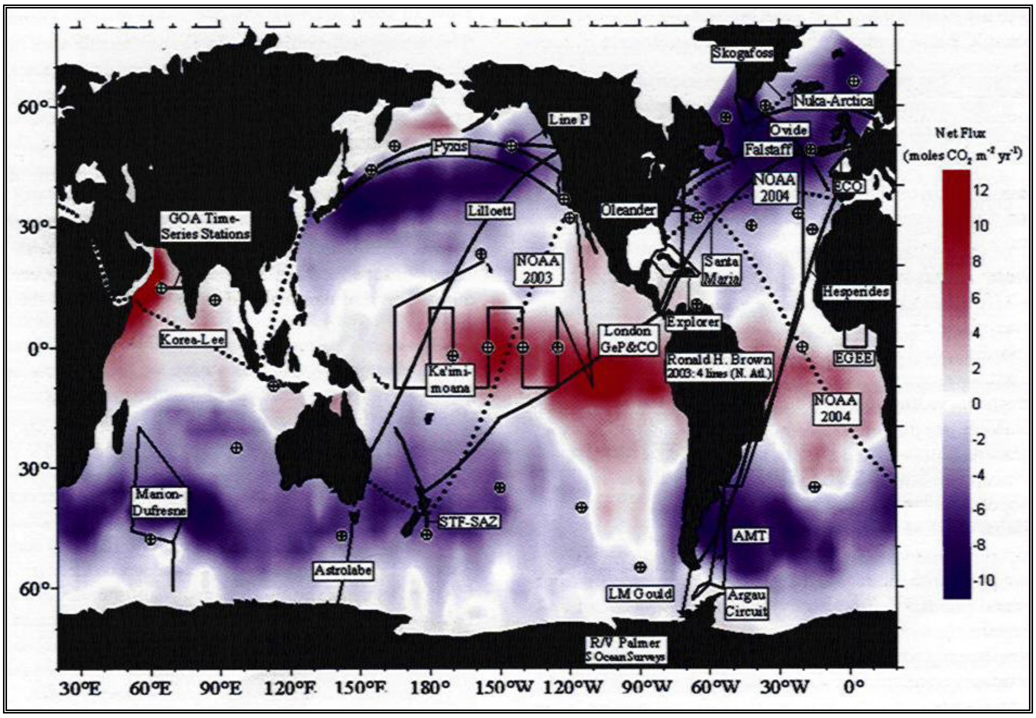


Figure 2.12 CO_2 Storage of Forest in Turkey [2]

Peng [48] said "The CO_2 taken up by the oceans is an important components of global budget of CO_2 released to the atmosphere by human activities". However, there are still large uncertainties as to whether coastal zones act as CO_2 sinks or sources [14]. The Global Carbon Projects (GCP) has continued to promote research activities to collect new data of carbon fluxes between air and water, and the sink strength of these water bodies. The map of net annual CO_2 fluxes of the water bodies given in Figure 2.12, reveals that freshwater bodies can be observed as carbon sources or sinks.



Labels: İndicate Ships name; Dashed Lines: Planned survey lines; Solid Lines: Funded survey lines

Figure 2.13 CO_2 Flux [14], [84]

According to the Figure 2.12, the net annual CO_2 flux on the Mediterranean and Black Sea Regions like the other inside water bodies' zones was observed as zero. It means, carbon dynamics in these regions shows no significant positive or negative CO_2 flux during a year. In the IPCC [30] Guidelines, the activities that do not result in a net source or sink of greenhouse gas are intentionally excluded from the inventories. The detailed explanation about sink and source activities are given in Chapter 3.

CHAPTER 3

MATERIALS AND METHODS

3.1. General

In the first part of this study, IPCC methods integrated with GIS techniques and statistical methods were used to estimate the emission and uptake inventories. The inventories were calculated for each district, province and region of Turkey. The following types of data were gathered as time series between years 1990 and 2010.

- The number of households and the population in districts
- Industries with respect to its size and its place
- Type of and amount of fuel used in each source
- Number of cars with respect to fuel type
- Forest areas and their increments

In the second part, dispersion model was used to estimate the ground level CO_2 concentrations.

The detailed information about each of the data set is given in the subsection of this chapter.

3.2. Emission Inventories

An emission inventory was prepared in this work by taking into account all possible emission sources. The basic source of CO_2 is the combustion of fossil fuels in households, manufacturing industries, thermal power plants and road vehicles. The carbon content and emission factors of the fuels used were the starting point for the estimation of CO_2 emissions.

Basically the study was divided into three main parts:

1st- Database construction and calculations

2nd-Transfer of the database to the Geographic Information System (GIS)

3rd-Statistical evaluations

3.2.1. Construction of the Database

The data for the annual fuel use in various sources between 1990-2003 was basically obtained from the State Institute of Statistics (SIS) and Ministry of Energy (MOE). The data was entered into the computer.

Thermal Power Plants:

The amount of fuel consumed and other related data of each power plants was gathered from the annual reports of the Turkish Electricity Generation-Transmission Corporation [85], [86], [87], [88], [89]. The missing and the predicted data especially for the years 2004-2010 were obtained from the internet site of the Turkish Electricity Transmission Corporation [90].

Road Vehicles:

The transport sector is distinguished from the other main energy sectors where multiple fuels are used. For that reason, the calculation of the CO_2 emission is simple for road vehicles.

According to the IEA [20], more than ¼th of the total CO_2 emission comes from transportation and transport sector is the core sector of many environmental problems. Although, the technological improvements reduce the growth of emission from transport, the rising in the number of road vehicles is the growing area of concern.

The amount of fuel consumed on the roads of each district of Turkey was calculated by using the following formula.

$$f_{di} = \frac{\psi_d}{\psi_p} \times \frac{Ca_p}{Ca_t} \times f_i$$

where,

ψ_d : Number of households in district d of province p

ψ_p : Number of households in province p

Ca_p: Number of car in province p

Ca_t: Total number of cars

f_{di} : Fuel consumption in district d according to fuel type *i* (tones)

f_i : Fuel consumption by car according to fuel type *i* (tones)

i : Gasoline or diesel

The number of cars according to fuel type and the number of households were obtained from the SIS [58], [59], [60], [61], [62], [63], [64], [65], [66]. A top-down approach was used for the estimation of CO_2 emission from each district. The properties of each road vehicles registered to the tax offices of the Ministry of Interior are sent to the SIS annually and the SIS publishes an annual book called “Transportation by Road Vehicles”. However, the amount of fuel consumption data by road vehicles was taken from the Ministry of Energy.

Households:

According to the SIS population census in 2000, approximately 67 million people live in Turkey. The main source of CO_2 emission from households is considered as the fuel consumption for heating purposes. SIS made a research about energy consumption in residences. Approximately 24.400 households in 9 selected provinces (İstanbul, Kocaeli, İzmir, Antalya, Ankara, Konya, Samsun, Erzurum, Gaziantep) according to the 7 geographic regions were asked to determine annual provincial and regional fuel consumption. According to the survey results of SIS [54], the amount of fuel used in 11.549.759 residences in Turkey was approximately 21 million tons of oil equivalent (TOE). The regional households’ fuel used factors were used to estimate the total number of households’ fuel consumption in districts, provinces and regions for the years 1990-2010.

$$f_d = \psi_d \times f_r$$

where,

ψ_d : The number of households in district d

f_r : Fuel consumption factor of region r per households

f_d : Fuel consumption of households in district d

The details of the calculations for Çankaya district are given in Appendix B as an example.

The total number of households and the population in the districts between 1990-2010 were taken from the Demographic Statistics Division in SIS. SIS made the latest population censuses in 1990 and 2000. The mid-year population between 1990-2000 and the population for the following 10 years after 2000 were calculated by means of demographic and historical literature [53].

Manufacturing Industries:

SIS has published annual books on energy consumption in the manufacturing industries. Energy consumption is one of the basic indicators of economical development. Because of the economical importance, industries in most of the countries were not subjected to any energy saving policies. However, environmental issues in the last 10 years have focused on decreasing CO_2 emissions from burning of fossil fuels.

In this study, different types of data were obtained from the SIS and MOE. These data are:

- The number of manufacturing industries according to size of establishments between 1990 and 2003 in each district [79].
- The total energy consumption (TOE) of the manufacturing industries in Turkey according to size of establishments [71], [72], [73], [74], [75], [76], [77].
- The fuel consumption of the manufacturing industries in each province [56].
- The total fuel consumption of the manufacturing industries in Turkey [42].

The annual fuel consumption of the manufacturing industries in districts were estimated by using the following formula:

$$ef_p = \frac{ef}{\eta_s} \times \eta_p \qquad fc_d^t = \frac{fc_p}{\eta_p} \times ef_{pn} \times \eta_d$$

where,

η_d :Number of manufacturing industries in district according to its size

η_s :Total number of manufacturing industries according to its size

η_p :Total number of manufacturing industries in provinces according to its size

ef :Energy consumption factor of the manufacturing industries according to its size (TOE)

ef_p :Energy consumption factor of the manufacturing industries in provinces according to its size (TOE)

ef_{pn}:Normalized energy consumption factor of the manufacturing industries in provinces according to its size

fc_p :Total fuel consumption in provinces (tones)

fc^t_d :Fuel consumption in manufacturing industries in districts according to its size

t :year (1990 – 2010)

Example calculations for industries are given in Appendix B.

3.2.2. GIS Techniques

The main purposes of using Geographic Information Systems (GIS) in this study are:

- to show the variations and changes in the districts and provinces for the emission and uptake inventories.
- to determine the forest area of districts and provinces with respect to forest type

In this study scaled maps were prepared by using GIS software Arc-View. Then the inventories were linked to the GIS maps of the districts and provinces [40], [101].

The following scaled maps given in Table 3.1 were digitized. The projection of the maps was Lambert Conformal Conic [81].

Table 3.1 Digitized scaled maps

Maps	Scale	Description
Provinces	1/1 000 000	80 provinces (Düzce taken as Bolu)
Districts	1/1 000 000	911 districts
Lakes*1	1/1 000 000	All lakes and Dams
Forest*2	1/1 000 000	According to 4 classes: Empty Land, Poor Forest, Intermediate Forest, Good Forest
Roads*3	1/100 000	According to 3 classes: Railway, Highway, Others
Thermal Power Plants*4	-	According to X and Y coordinate

Sources: 1 Water Hydraulic Works; 2 Ministry of Environment and Forestry; 3 General Directorate of Highways; 4 Turkish Electricity Generation -Transmission Corporation

The GIS maps are given in Appendix B.

3.2.3. Statistical Methods

In this study, some statistical methods were used to estimate the uncertainties and the accuracy of the inventories. The process is based on certain characteristics of the variables of data sets. The ideal methods take the following concepts into account:

- The arithmetic mean of the data set
- The standard deviation of the data set
- Covariance of the input quantity with other input quantities

Uncertainty Analysis:

In order to study the total uncertainties in the emissions, the statistical methods can be applied. This type of analysis yields internal errors. It means that the uncertainties are only determined from the emission data. In these analyses, the important variables for the sample data are the mean, the standard deviation and the standard error of the mean [94].

When a particular measurement is repeated several times and random differences occur for each measurement, the probabilistic methods can be applied to analyze the uncertainties. Moreover, it is common to assume that the distribution of the emissions follow a normal distribution [41].

In this study, the probability density function of the annual emission is assumed as normally distributed and the range of uncertainty is expressed within 95% confidence intervals according to the IPCC Good Practice Guidance [31].

The probability density function of the differences of the mean values for the emissions in years t_x and t_y is also normal with the following equations. Here, t_y is the base year.

$$\text{mean} = \overline{x} - \overline{y};$$

where

$$\overline{x} = \frac{1}{N}\sum_{i=1}^{N} X_i \quad ; \quad \overline{y} = \frac{1}{N}\sum_{i=1}^{N} Y_i$$

and

$$\text{standard deviation} = (S_x^2 + S_y^2)^{1/2};$$

where

$$S_x^2 = \frac{1}{N}\sum_{i=1}^{N}(X_i - \overline{X}) \quad ; \quad S_y^2 = \frac{1}{N}\sum_{i=1}^{N}(Y_i - \overline{Y})$$

then, the standard error of the mean (SEM) is given as:

$$\text{SEM} = \frac{\text{s tan dard deviation}}{\sqrt{N}}$$

finally, the uncertainty interval from the set of data is estimated using classical method [31], [51].

$$\text{mean} \pm \text{SEM} \times t_{0.05,df}$$

where,

N : Sample Size

df : Degrees of freedom

$t_{0.05,df}$: Student t-table value obtained from the Appendix J for (N-1) degrees of freedom and 0.05 (95% of confidence interval) probability of a absolute value [83].

3.2.4. IPCC Methods

The Intergovernmental Panel on Climate Change (IPCC) was established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) in 1998 preceding the creation of the United Nations Framework Convention on Climate Change (UNFCCC). Approximately 140 scientist and national experts from more than thirty countries collaborated for the creation of the Revised 1996 IPCC Guidelines [30].

The IPCC Methods are designed to estimate and report on national inventories of anthropogenic greenhouse gas emissions and removals. The methods are the primary technical guidelines for the national inventories. The IPCC provides a common structure to categorize sources and sinks. This common structure is essential to compare the inventories and to avoid double counting problems.

The activities that are not anthropogenic in origin or do not result in a net source/sink of greenhouse gas emissions are intentionally excluded from the inventories. Volcanic eruptions, carbon dioxide uptake or release by oceans, natural forest fires and human induced land use changes are the activities that are not anthropogenic. The main reasons for excluding such kind of activities from inventories are the insufficient scientific understandings and the data were not adequately available to make calculations [30], [96].

In this study, thermal power plants, road vehicles, households and manufacturing industries were considered as CO_2 emission sources. The detailed example calculations for each source are given in Appendix B. The fuel consumption data was the basis for the estimation of emissions. According to the IPCC [30], CO_2 emission from fuel combustion could be calculated accurately unlike other direct (CH_4, N_2O) and indirect (NO_x, CO, NMVOC) gases. CO_2

emissions are primarily dependent on the carbon content of the fuel with the adjustments as carbon non-oxidized. The methods for estimating the CO_2 emissions are divided into "Tiers" including different levels of activity and technology in detail.

Tier 1 method was used in this study to estimate the CO_2 emissions. The estimation process is generally very simple and requiring less data. On the other hand, Tier 2 and 3 is not simple and requiring source specific data. The fuel consumption data and average emission factors are the starting point of this method. The emission inventory in this study was developed for the inputs of air dispersion model.

The general formula according to the IPCC [30] for the CO_2 emission is given as:

CO_2 emissions =Σ Fuel consumption in energy units (TJ) for each sector * Carbon Emission Factor * Fraction Oxidized * Convert Carbon Emission to CO_2.

The main steps for the emission estimation process of the IPCC (Tier 1) methods are:

- Estimating the fuel consumption according to fuel/product type
- Converting the fuel data to a common energy unit (TetaJoule) by using Table 3.2
- Selecting "carbon emission factors" for each fuel/product type as given in Table 3.3 and estimating the total carbon content of the fuels
- Accounting for carbon not oxidized during combustion according to Table 3.4
- Converting emissions of carbon to full molecular weight of CO_2

$$2C + 2O_2 \xrightarrow{process} 2CO_2$$

Table 3.2 TOE Factors and Calorific Values of Fuels [30]

Fuels (1 tone)	TOE Factor	Calorific Value (Kcal/kg)	Fuels (1 tone)	TOE Factor	Calorific Value (Kcal/kg)
Hard coal	0.610	6100	LPG	1.090	10900
Lignite Heating &Industrial	0.300	3000	Gasoline	1.040	10400
Lignite - Santral	0.200	2000	Jet Keresone	1.070	10700
Lignite Power plant	0.110	1100	Diesel Oil	1.200	10200
Coke	0.720	7200	Naphtha	1.040	10400
Crude petroleum	1.050	10500	Natural Gas $1000^3 m^3$	0.825	8250
Fuel-oil	0.960	9600	Wood	0.300	3000
Gasoline	1.025	10250	Peat	0.230	2300
Keresone	0.829	8290			

Table 3.3 Carbon Emission Factor [30]

Fuel	Carbon Emission Factor (tC/TJ)	Fuel	Carbon Emission Factor (tC/TJ)	Fuel	Carbon Emission Factor (tC/TJ)
Crude Oil	20.0	Residual Fuel Oil	21.1	Other oil	20.0
Orimulsion	22.0	LPG	17.2	Anthracite	26.8
N. Gas Liquids	17.2	Ethane	16.8	Cooking Coal	25.8
Gasoline	18.9	Naphtha	20.0	Other Bit. Coal	25.8
Jet Keresone	19.5	Bitumen	22.0	Sub-bit Coal	26.2
Other Kerosene	19.6	Lubricants	20.0	Lignite	27.6
Shale Oil	20.0	Petroleum Coke	27.5	Oil Shale	29.1
Gas/Diesel Oil	20.2	Refinery Feedstock	20.0	Peat	28.9

The “Fugitive CO_2 emissions” were not considered in this study due to the inadequate data and the low CO_2 emission rate. The main fugitive CO_2 emissions are from the chemicals, oils and various types of fuels production, processing and distributions.

Table 3.4 Fraction of Carbon Oxidized [30]

Coal [a]	0.98
Oil and Oil Products	0.99
Gas	0.995
Peat for electricity Generations [b]	0.99

[a] This Figure is a global average but varies for different types of coal, and can be as low as 0.91.
[b] The Fraction for peat used in households may be much lower.

3.3. Uptake Inventories

The most important CO_2 uptake activity is the one by biosphere. The biosphere removes CO_2 from the atmosphere during photosynthesis. The CO_2 uptake is usually proportional to forest area. According to the Banan and Shugart [3], the forest area is about 11% of the earth's total land area. From the inventory of Ministry of Forestry, the good and intermediate forest area was determined as around 5.37% and 4.29% of the total land area of Turkey, respectively [44].

The net uptake of CO_2 by forests is usually calculated by estimating total forest area and the annual increment of biomass in the forest area [30].
The IPCC method for CO_2 uptake is defined as:

$$B = I \times D$$
$$TB = B \times (1 + RF)$$
$$CS = TB \times 0.45 \text{ (tones C/ton dry biomass)}$$
$$Up = CS \times 44/12$$

where;

B : Volume of biomass (tones/year)

I : Annual increment (m^3/year)

D : Dry biomass density (tones/m^3)

TB: Total biomass including roots

RF: Root Factor (%)

CS: Carbon Storage (tones)

Up: CO_2 uptake (tones)

The above formula summarizes how CO_2 uptake calculations are done. According to IPCC [30], national factors are advised, because using default factors usually result in highly uncertain estimates. The national factors determined by the MOF are given in Table 3.5. The CO_2 uptake calculations are shown in Appendix B.

Table 3.5 The factors for the estimation of biomass

Type	Dry Biomass Density		ROOT Factor (1) %
	gr/cm3	tones/m3	
Broadleaf	0.636	0.636	20
Coniferous	0.497	0.497	15

Source: [44]

The annual increments of provincial aboveground forest biomass are obtained from the inventories of MOEF. The inventory started in 1980s and finished in 1999 [44]. The entire forest area in Turkey was covered. The total annual increments of broadleaf and coniferous forests were considered separately. In Turkey, there are basically 4 types of forest area. These are high forest, low forest, standard coppice and bad coppice. However, the forest areas in topograpical map are categorized into three groups by MOEF. Therefore, the forest areas in the inventory were linked to the forest map as follows:

- Good Forest Area: High Forest
- Intermediate Forest Area: Low Forest and Standard Coppice
- Bad Forest Area: Bad Coppice

The forest inventory and the output of provincial CO_2 uptake calculations according to the forest categorization were connected to the provincial forest maps. Then this map was intersected with district map on the GIS in order to estimate CO_2 uptake in forest area of the districts [4].

3.4. Dispersion Model

Air dispersion models are important tools for making decisions concerning air pollution. The fundamental parameters for calculating the pollutant concentrations in the ambient air are the emissions from the sources into the atmosphere, the meteorological variables, topography and the parameters describing removal and transformation processes. The system, which relates the ambient air pollutant concentrations to the depending parameters, is defined as modeling [45]. The models can be categorized as numerical, statistical (empirical) and physical models. The Gaussian Model, that is widely applied, is one of the numerical models dominating the field [17].

Most of the models are simple material balances. De Nevers [8] has shown the general balance equation by using the following formula:

Accumulation Rate = Inflow Rates + Outflow Rates + Creation Rate – Destruction Rate

3.4.1. ISCLT3 Model

Industrial Source Complex-Long Term Dispersion Model (ISCLT) was developed by the Environmental Protection Agency (EPA) of the USA. It was used to model the air pollution for a specific area. The ISCLT provides options to model emissions from a wide range of sources that might be present at a typical industry. The basis of the model is the steady state Gaussian Plume Equation (See Appendix D). Emission Sources are categorized into four basic types: point sources, area sources, volume sources and open pit sources. The area sources option may also be used to simulate line sources [13].

The ISCLT3 model is widely used in the world and accepted by the regulatory authorities, researchers and decision-makers for estimating concentrations of non-reacting pollutants. It is the updated version of ISCLT2, which enables users to define area and open-pit sources with new algorithm and to specify the receptor elevations.

In our study, manufacturing industries and thermal power plants were considered as point sources. On the other hand, transportation (line sources) and households were considered as area sources.

The basic assumptions for the model (Gaussian Dispersion Model) are the following:

- The pollutant is traveling in the x direction and spreading in the y and z directions. The plume has a Gaussian distribution in both horizontal and vertical planes with σ_y and σ_z as the standard deviations of the concentrations of the plume in horizontal crosswind and vertical directions, respectively.
- The mean speed affecting the plume is the wind speed at the level where dispersion starts.
- Uniform and continuous emission of pollutant takes place.
- Diffusion of pollutants in "x" direction is negligible as compared to diffusion in crosswind direction (it is exactly true while emission is continuous and wind speed is more than 1 m/s). Advection is dominant in the x direction.
- There is no adsorption, deposition or reaction of pollutants at the ground surface. Also the pollutants are inert. No atmospheric chemical reactions between the pollutants and between the pollutants and the atmosphere. There is no gravity fallout.
- Parameters concerning the diffusion of the pollutant do not change in space and time.
- Elastic Buoyancy of the pollutants on the ground surface and the inversion layer takes place.

3.4.2. Inputs to ISCLT3 Model

Basically, the ISCLT3 model inputs have been divided into two parts: "Runstream File" and "Meteorological Input File (STARDATA)".

A) Runstream File

Modeling Options: Time periods, type of pollutants, rural/urban specifications, units and other controlling options may be entered and defined in this section.

Source Locations: Multiple sources including point, area, volume, line and open pit source may be handled and modeled. Sources may be grouped and the contributions of each group may be found separately. Emission rate, release height, gas temperature, gas exit velocity, internal diameter of stack, source locations may be specified.

Receptor Information: The multiple receptors (mix Cartesian grid receptor networks and polar grid receptor networks) may be modeled. Concentration of the pollutant for each receptor above ground elevation can be calculated. The receptor map of the study area in this study given in Figure 3.1 was used to define the receptor coordinates and elevations.

Meteorological Properties: The model estimates the concentration for each source and receptor combination of input meteorological data. Air temperature, mixing height, anemometer height and meteorological station information may also be specified in this part.

Output Options: The format of the output files may be defined in this section.

B) Meteorological Input File (STARDATA)

The ISCLT3 model accepts frequency distributions of wind speed according to the wind directions and stability classes. The meteorological parameters (wind speed, wind direction, sunbathing and cloudiness data) are very important. Model uses this separate file "STARDATA (STability ARray DATA)" for transport and dispersion of pollutants.

The stability classes are determined by using Pasquill Stability Classes as shown in Table 3.6.

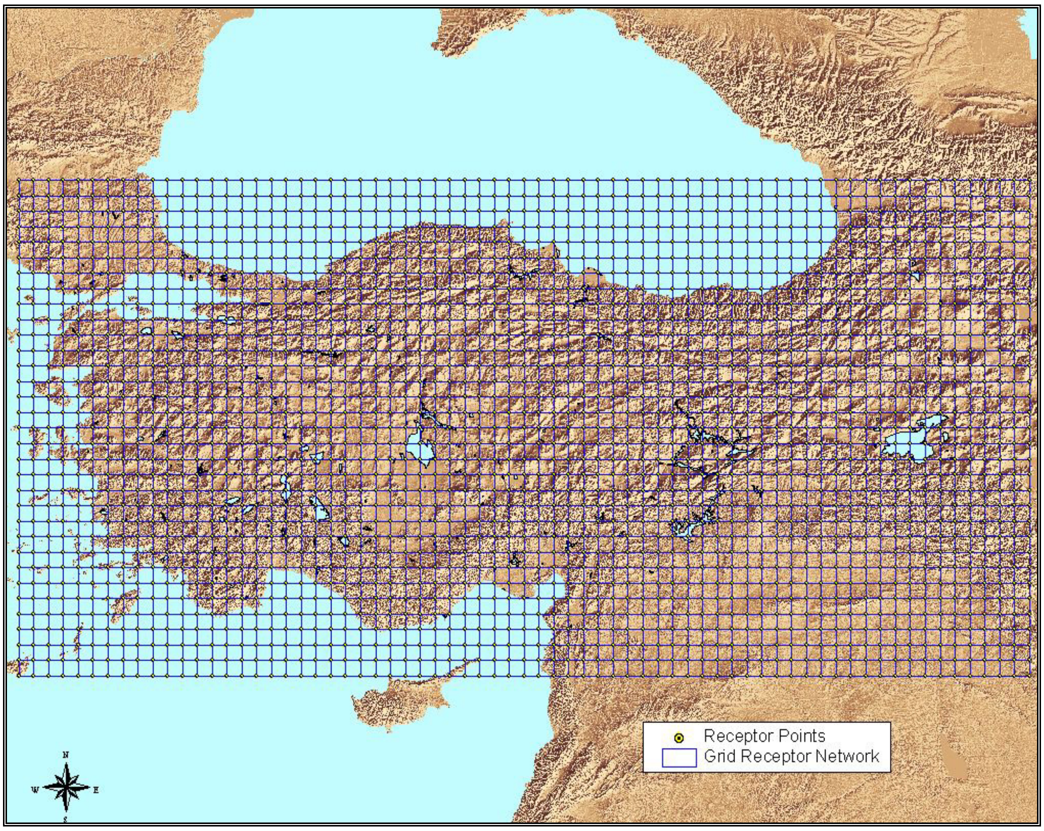


Figure 3.1 Receptor map

Table 3.6 Pasquill Stability Classes [82]

Surface wind speed (m/s)	insolation			Night	
	Strong (>6)	Moderate (=<6 or >3)	Slight (<3)	>=.5 low cloud	<0.5 cloud
<2	A	B	B	-	-
2-3	A	B	C	E	F
3-5	B	C	C	D	E
5-6	C	D	D	D	D
>6	C	D	D	D	D

A-Extremely Unstable, B-Moderately Unstable, C-Slightly Unstable, D-Neutral, E-Slightly Stable, F-Moderately Stable

* Surface wind speed is measured at 10 m above ground.

A computer program given in Appendix E was written for obtaining the Stardata. The programming language is QBASIC. Examples for Runstream and Stardata files of this study are given in Appendix F.

3.4.3. ISCLT3 Special Features

The following features in ISCLT3 are not available in ordinary Gaussian dispersion model.

- Effects of stack-tip downwash are considered.
- Direction specific building downwash for point sources can be estimated.
- The process of predicting concentrations from continuous releases of several types of source groups in simple, intermediate and complex terrain is simplified.
- Dry and wet removal of gaseous mass from the plume as it is deposited on the surface can also be simulated.

3.4.4. Methodology Followed in Calculating the Concentrations at Receptor Points

One of the basic advantages of ISCLT3 model is that the options can be controlled according to the needs of users. For this study, large number of receptors was involved. Therefore, the limits of the programs were increased beyond the 640K of DOS system. Special requirements was planned to eliminate the continuity problem of model runs over Turkey. Although the concentration of non-reacting CO_2 was not transported more than 100 km away from sources, the receptors were defined all over Turkey. A Cartesian type receptor grid network was defined. The number of receptors for this study was 2277 as seen in Figure 3.1. The distance between two receptors was 25 km. The distance in west to east direction over Turkey was 1725 km and the distance in south to north direction over Turkey was 825 km. The emission sources in this study were categorized into two groups:

- Point sources : Thermal power plants and industries
- Area sources : Households and
- Line sources : Roads (treated as narrow area sources)

The output file of ISCLT3 model contains the CO_2 concentration at each receptor point in units of $\mu g/m^3$. After running the dispersion model separately for all sources at district level, the CO_2 concentration at each receptor point was calculated by superimposing all outputs for industries, households, thermal power plants and road vehicles. The superposition of all outputs at the receptors resulted as the total CO_2 concentration at each point. Then by using these concentrations at the receptors, the ground level CO_2 contour maps of Turkey were obtained by using the methodology called the Kriging method [9]. The annual average CO_2 concentrations at ground level were determined by using these maps. Then the results were used for model evaluations.

As a basic assumption the ISCLT3 model accepts the pollutants as non-reactive chemicals. Therefore, the CO_2 uptake of the forest areas in each district was calculated and subtracted proportionally from the emissions at district level. Then, the model was run again with reduced CO_2 emissions and the concentrations were calculated for each receptor point as before.

3.4.5. ISCLT3 Model Evaluations

The output file of the ISCLT3 model was obtained separately for each source in district level. Basically, the file contains the ground level CO_2 concentration at the receptor points in unit $\mu g/m^3$. The total CO_2 concentration at the receptor points from each sources were obtained by superimposing. Additionally, the continuity of the each model run was maintained by defining the receptors all across the country as seen in Figure 4.1. The model results were, then, used for model evaluations.

The model performance evaluation was determined by using statistical methods composed of deterministic forms (i.e., measuring relationships and deviations between variables) and trends analysis [11].

In order to compare the data sets formed by ISCLT3 model predicted values and upper atmospheric observed values, standardization (i.e., normalization according to the distribution characterized by mean and standard deviation of the values) is expected. Such expectation is calculated by the following equation;

$$\tau_i = \frac{(X_i - \mu_i)}{\sigma_i}$$

where;

X_i : Data sets

μ_i : Aritmetic mean of the distribution

σ_i : Standard deviation of the distribution

The correlation coefficient between the predicted and the observed values is given as;

$$\sigma^{xy} = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{(\sum_{i=1}^{n}(X_i - \overline{X})^2)^{1/2}(\sum_{i=1}^{n}(Y_i - \overline{Y})^2)^{1/2}}$$

where;

$$\overline{Y} = \frac{\sum_{i=1}^{n} Y_i}{n} \quad ; \quad \overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} \quad , \quad i=1,2,3,\ldots\ldots,n$$

Nonzero correlation coefficient implies that there is an association between two data sets and $\sigma^{xy} = 1$ means a high correlation.

The deviation between two variables is given by covariance;

$$\operatorname{cov}(X,Y) = \frac{1}{n}\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})$$

In this study, some other statistical methods were also used. These methods are:

K-Mean Cluster Analysis: It attempts to identify homogenous groups of data sets. Each cluster center is determined iteratively [36].

Optimum number of cluster, $ONC = \frac{\sqrt{n}}{2}$

and

$$d_{ij}^{\ 2} = \frac{\sum_k \left(w_{ijk} (x_{ik} - x_{jk})^2 \right)}{\sum_k \left(w_{ijk} \right)}$$

where;

X_{ik} : Value of variable k in case i

X_{jk} : Value of variable k in case j

W_{ijk}: Weight of 1 or 0 depending upon whether or not the comparison is valid for the k^{th} variable.

d_{ij} : Distance coefficient between two cases

Distance coefficient measures the deviation between the variable and the cluster center, which are in the same group. Higher coefficient for a value shows the irrelevance of the value in the series.

Cronbach Alfa (α) Reliability Analysis: It determines the extent to which the series are related to each other. It is an internal consistency model based on the average correlation among items [7].

The relation between variables is given by;

$$\alpha = \frac{kr}{1 + (k - r)r}$$

where;

α : Cronbach alfa

k : Total number of items

r : Average correlation between pairs of items

Cronbach alfa varies between 0 and 1. As the alfa gets closer to 1, it shows the high internal consistency and relations between variables.

Mann-Kendal Rank Correlation: It is a non-parametric test used to detect any possible increasing or decreasing trend in the series [80].

In this test, for each element X_i or, for each element Y_i , for n_i number of elements, y_i preceding (i>j) is calculated such that $Y_i > Y_j$.

The null hypothesis must be rejected for high values of [u(t)] which is defined as follows:

$$u(t) = \frac{[t - E(t)]}{\sqrt{(\operatorname{var} t)}}$$

where,

$$t = \sum_{i=1}^{n} n_i \quad , \quad i=1,2,3,.........n.$$

and its distribution function, under the null hypothesis, is asymptotically Gaussian, with mean and variance as given by the following equations:

$$E(t) = \frac{n(n-1)}{4}$$

$$\operatorname{var} t = \frac{n(n-1)(2n+5)}{72}$$

By using the followings (Table 3.7. and Figure 3.2.)

Table 3.7 Critical z values

Significance level	0.1	0.05	0.01	0.005
Mann-Kendall	-1.645 and 1.645	-1.96 and 1.96	-2.58 and 2.58	-2.81 and 2.81

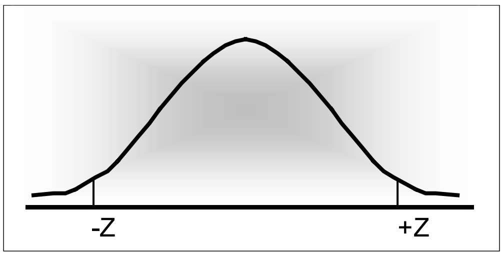


Figure 3.2 Normal distribution, for testing the randomness (two way test)

If $u(t)$ is between the region $-1,96 < u(t) < 1.96$ for significance level 0.05, then the data are random and there isn't any trend.

If $u(t)$ is $-1.96 > u(t)$, then (-) trend and negatively significant.

If $u(t)$ is $1.96 < u(t)$, then (+) trend and positively significant.

3.5. Meteorological Data of Turkey

The meteorological variables are very important parameters in air pollution modeling. Therefore, each meteorological variable should be studied carefully. The reliable model estimates can only be expected with good meteorological data, because air pollution is the result of stable meteorological conditions rather than excessive emissions from various sources [46].

The meteorological data obtained from various meteorological stations in Turkey were used for the model calculations in this study. The meteorological data obtained from the "State Meteorological Services" including 80 provincial stations were used in this study. Several meteorological parameters such as ambient air temperature, wind speed, wind direction, cloudiness, sunbathing etc. recorded on hourly basis were needed by the program. However, the upper air (synoptic) data are only measured in Samsun, İstanbul, Ankara, İzmir, Isparta, Diyarbakır and Adana stations. For that reason the upper air data from synoptic stations were used for all the neighboring stations around the synoptic one. This is acceptable because regional synoptic data do not change excessively. EPA [13] also recommends this approach. Upper air data are measured at 2:00 a.m. and 2:00 p.m. every day at synoptic stations.

The most important synoptic variable for the transport of pollutants is "Mixing Height (depth)". It is important to define the morning mixing height (Z_{AM}) and the afternoon mixing height (Z_{PM}). The mixing height is the average thickness of the layer within which pollutants are mixed for a particular geographic region over time [17].

By using the daily Z_{AM} and Z_{PM}, the annual average morning (Z_{AM}) and afternoon (Z_{PM}) mixing heights were formed for synoptic stations. Mixing heights are frequently called for in EPA dispersion models and they are defined according to the stability classes as given in Table 3.8.

Annual averages of some meteorological parameters are given as an example in Table 3.9 As can be seen from the table, the annual average temperature over Turkey ranges between minimum value of 4.3 ^{o}C and maximum value of 19.5 ^{o}C. The annual temperature variations for the year 1995 are shown in Figure 3.3.

Table 3.8 EPA standards for the mixing height

Stability Class	A	B	C	D	E	F
Mixing Heights	$1.5xZ_{PM}$	Z_{PM}	Z_{PM}	$(Z_{PM+ZAM})/2$	Z_{AM}	Z_{AM}

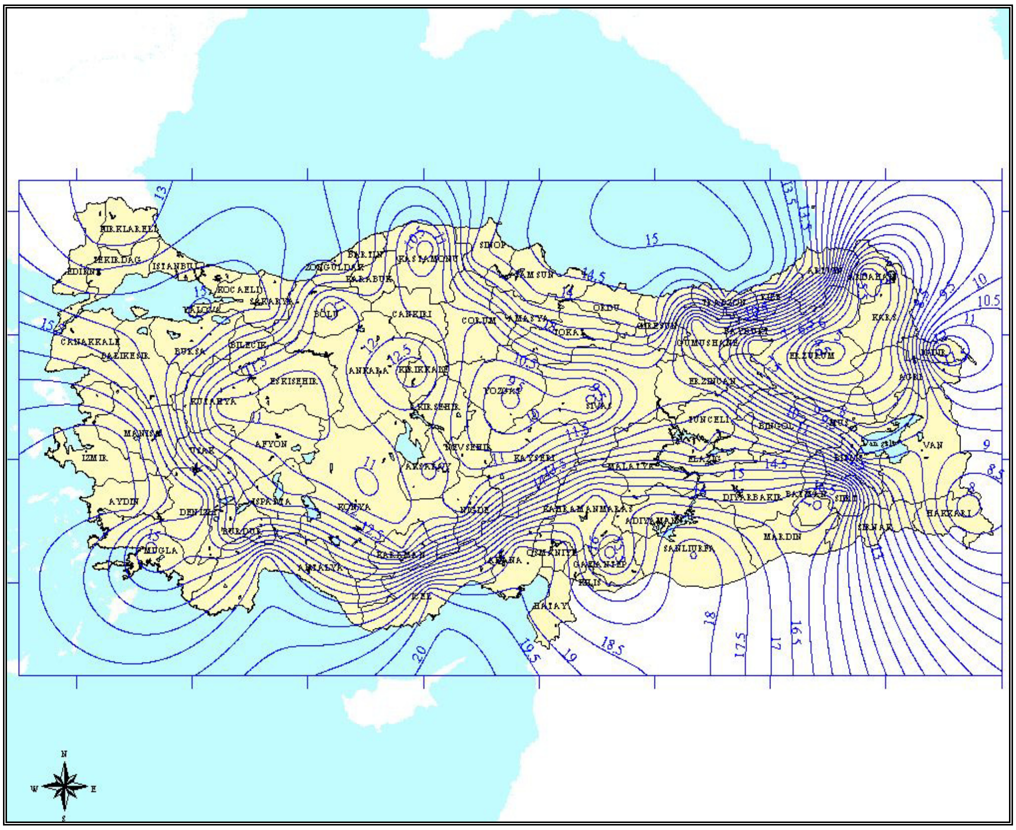


Figure 3.3 Annual temperature variations of Turkey for 1995

The morning mixing height of 7 synoptic stations in 1995 ranges between minimum value of 166.2 meter and maximum value of 784 meter. The afternoon mixing height of synoptic stations ranges between minimum value of 911 meter and maximum value of 2020 meter.

Table 3.9 Annual minimum and maximum averages of meteorological parameters over Turkey for 1995

	Temperature (^oC)		Mixing Height (m)				Wind Speed (m/s)	
			Z_{AM}		Z_{PM}			
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Value	4,3	19,5	166,2	784,1	911,0	2020,0	0	189
Province	Erzurum	Mersin	Diyarbakır	İstanbul	Samsun	Diyarbakır	Hakkari	Çanakkale

Wind roses were plotted in order to show the frequency distribution of wind directions for each province as seen in Appendix G. Figure 3.4 shows the frequency distributions of wind directions for Ankara, İzmir and İstanbul provinces on annual basis.

3.5.1. Meteorological Data Required by ISCLT3 Model

ISCLT3 model uses a frequency distribution (Stardata) file that contains records of meteorological variables for the period.investigated. Meteorological data file should contain wind speed classes according to the 16-wind directions and six stability classes.

The stability classes were determined by using cloudiness and sunbathing data. The wind speed classes are 0-3, 3-6, 6-10, 10-16, 16-21, and >21 m/s. Therefore, this file consists of 576 records. The first 96 records are for stability class 1, the next 96 are for stability class 2, and so forth as shown in Appendix F. Furthermore, additional parameters are required in meteorological part of the Runstream File. Meteorological part should contain ambient air temperature, anemometer height and urban mixing heights according to the stability classes. This is a minimum set of meteorological data required.

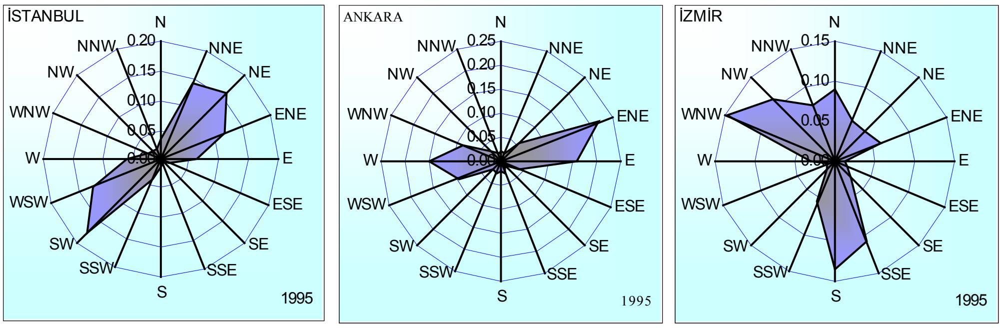


Figure 3.4 Wind roses of Ankara, İzmir and İstanbul provinces for 1995

3.5.2. Meteorological Data Processing

The raw data taken from the State Meteorological Services is not in the required format. For that reason, a computer program (Appendix E) was written as a meteorological pre-processor, which yields the annual input file of the model.

As an input for the computer program, three separate files are required:

- Hourly wind speed and wind directions
- Hourly cloudiness
- Hourly sunbathing data

The operation performed by the program is to calculate the annual frequency distributions of wind speeds according to the wind directions and stability classes. The output file generated by the program can directly be used as input meteorological data file (Stardata) in ISCLT3. Using this program, annual meteorological data files are prepared for the model runs.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Results of Emission Inventories

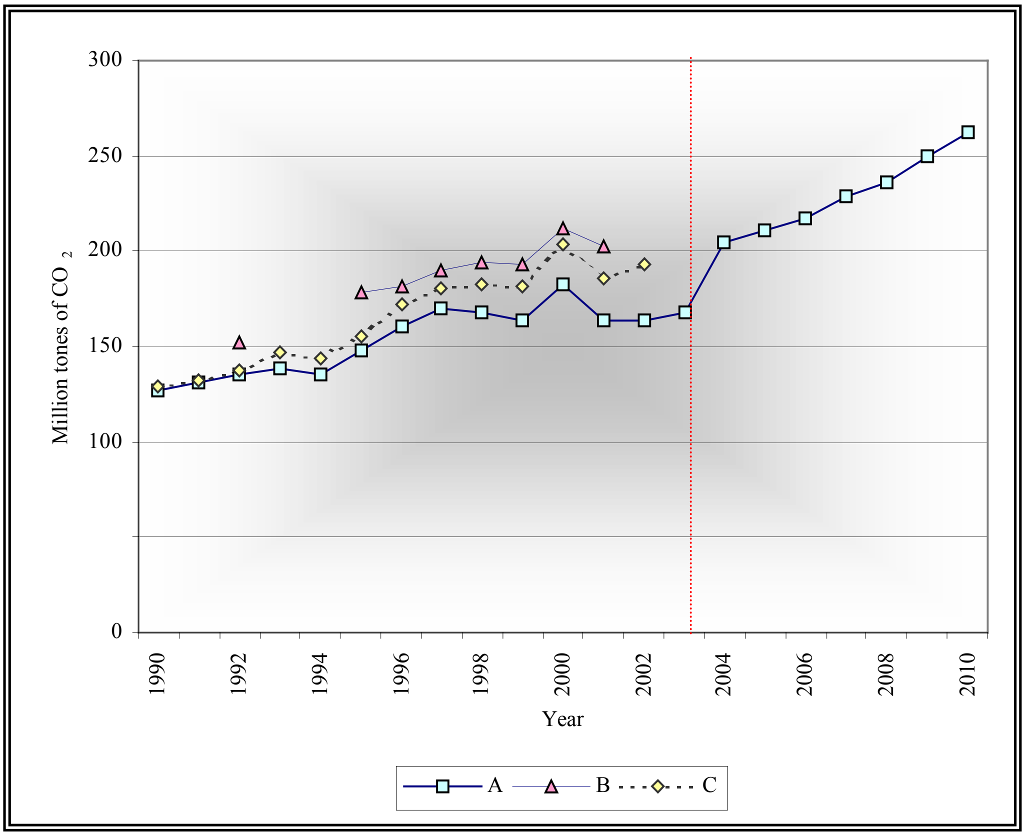
4.1.1. CO_2 Emission Inventories

The CO_2 emission inventory is the basic requirement of the ISCLT3 model. For that reason, the fuel consumption data at district, provincial and regional levels have been studied in detail in order to prepare the input data of the modeling program. The CO_2 emission inventory has been prepared for the years between 1990 and 2003 by using the real emission data. The CO_2 emissions for the years between 2004 and 2010 have been found by making projections. In order to make projections, the estimated fuel consumption data of MOE was used. The base year for emission is taken as 1990, in order to be in conformity with the Kyoto protocol.

This inventory covers four types of sources:

- Industrial sources
- Residential sources
- Traffic sources
- Thermal power plants

IPCC method was applied to the annual fuel consumption data in order to calculate the CO_2 emissions. The results of calculations are given in this section. In order to see the trend of CO_2 emissions throughout the years, amount of CO_2 emissions are plotted with respect to years as shown in Figure 4.1. It is clearly seen in Figure 4.1 that the CO_2 emission shows an increasing trend throughout the years. For the period between 1990 and 2003, the highest total CO_2 emission was observed in 2000 as 212 million tones. The main reason of this high amount of emission can be attributed to the increasing use of fuel consumption in power plants because of the increasing energy demand.



A: Inventory results-fuel consumption data source was MOE; B: Inventory results-fuel consumption data source was SIS; C: Source: IEA

Figure 4.1 Annual CO_2 emission trend

In order to see the distribution of total CO_2 emissions among the provinces and districts, the CO_2 emissions have been investigated on the provincial and district basis. For each province and district in Turkey, CO_2 emissions are calculated. The results of the calculations are mapped by using GIS techniques. The CO_2 emissions from provinces and districts for the year 2003 (as an Example) are shown in Figure 4.2 and 4.3, respectively.

In the provincial emissions, the maximum annual CO_2 emission was observed in İstanbul with an average value of 30 million tones per year between 1990-2003. The amount of increase in the CO_2 emission of İstanbul in 2003 as compared with 1990 (base year) was 47.3%. The future increase in the emission of İstanbul will obviously continue and will probably reach 41 million tones in 2010. The second highest CO_2 emissions were observed in Ankara, İzmir, Hatay and Manisa provinces with 12.3 (in 2001), 16.5 (in 1999), 12.1 (in 1997) and 8.3 (in 1994) million tones, respectively. The main reason for these high emissions is the high rate fuel consumption in thermal power plants and industries, because all of these cities are industrialized cities.

The regional distribution of CO_2 emissions is also investigated in this study. Turkey has been divided into 7 regions and each of these regions has quite different characteristics as far as the topography, climate and industrialization are concerned. CO_2 emission maps for province and districts for every 5-year between 1990 and 2010 are given in Appendix H. Also, the general distribution for 2003 is shown in Figure 4.4.

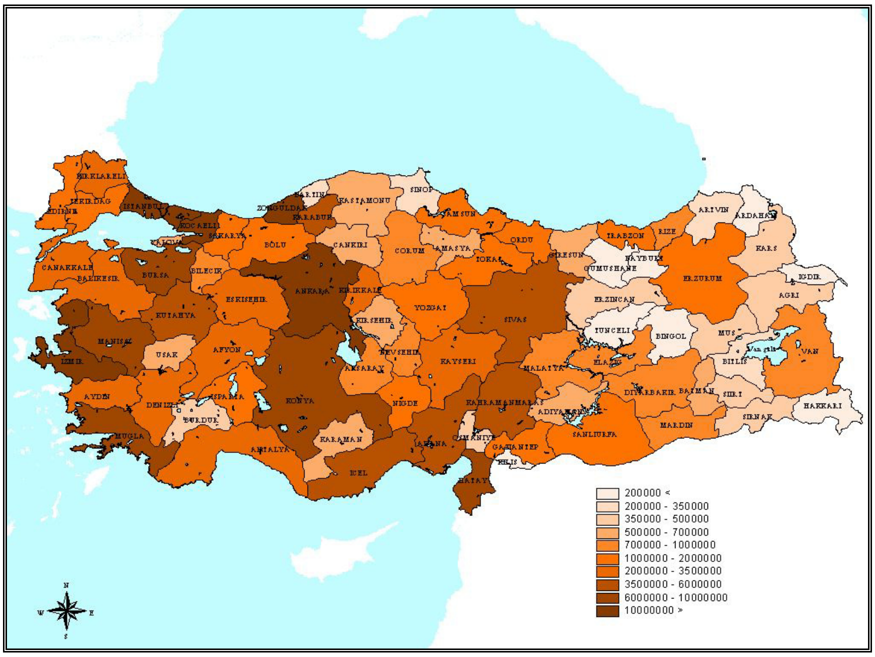


Figure 4.2 CO_2 emissions from provinces for 2003 in tones

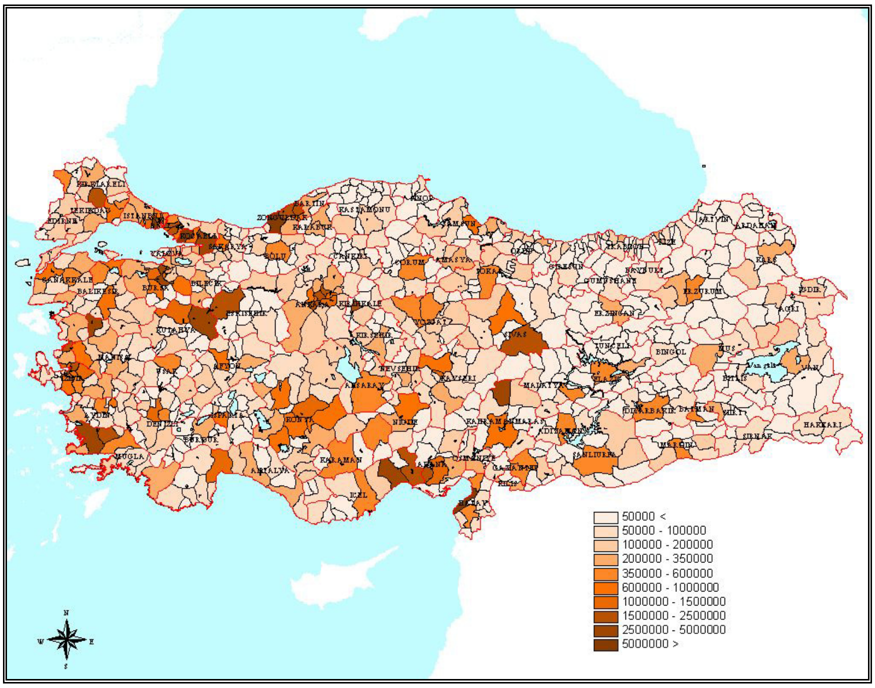


Figure 4.3 CO_2 emissions from districts for 2003 in tones

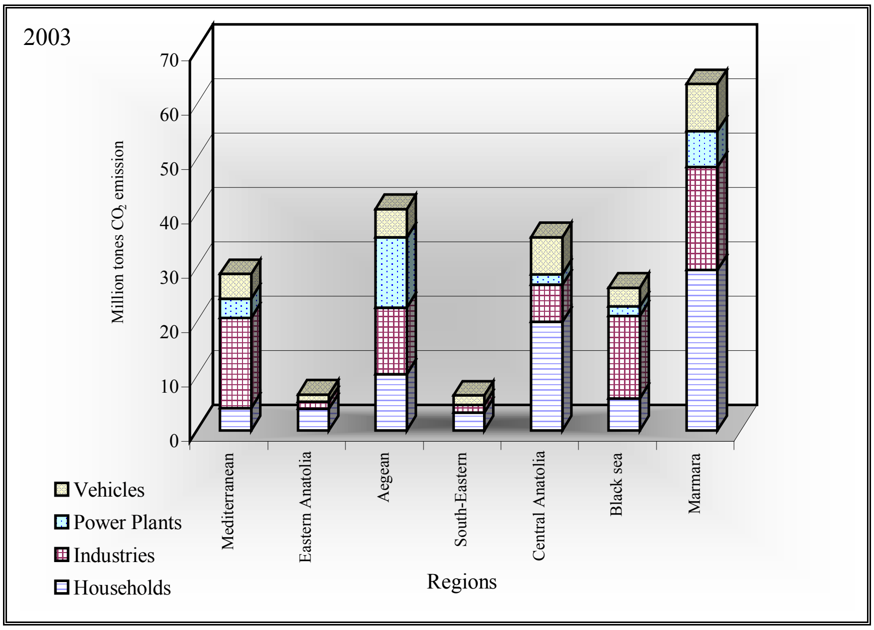


Figure 4.4 Regional CO_2 emissions from the sources for 2003

Analysis of the regional results, as shown in Figure 4.5, in the **Marmara Region** shows that the highest CO_2 emission was 65.8 million tones in 2002. The percentage emission increase as compared to the base year was found as 54.4%. The contribution of households, industries, power plants and road vehicles in this region to the annual total CO_2 emission of Turkey are 13.9%, 7.8%, 6.3% and 4.1%, respectively.

In the **Aegean Region**, the annual average CO_2 load from all the sources is around 40 million tones. The highest emission is due to the thermal power plants. The CO_2 emissions from thermal power plants range from minimum emission value of 11.9 million tones in 1990 to the maximum value of 21.8 million tones in 1999. The maximum emission increase as compared to base year is observed to be 77.0% in 2000. The contribution to the annual CO_2 emissions was 4.7 % for households, 6.3% for industries, 10.8% for power plants and 2.3% for road vehicles in that year.

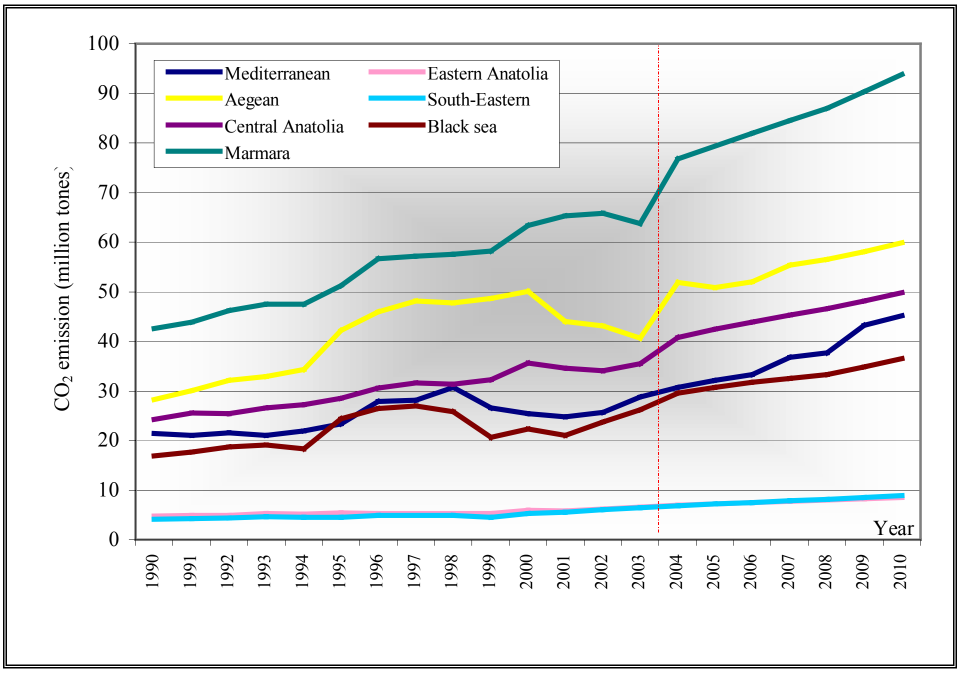


Figure 4.5 Regional CO_2 emission trend

In the **Central Anatolia Region**, the emission trend is increasing until 2000. The total annual emission is around 30 million tones. The highest total emission is observed in 2000 with a value of 35.6 million tones and the lowest emission value is observed as 24.3 million tones in 1990. The maximum emission increase as compared to base year is 46.5%. According to the inventory results between 1990-2003, the annual CO_2 loads of households, industries, power plants and road vehicles are 18.6, 4.9, 3.3 and 6.3 million tones, respectively. As can be seen from the annual averages, the highest emission comes from households. The annual contribution of the households to the total CO_2 emissions in this region is around 10.0 %.

In the **Mediterranean Region**, the results of inventory show that the highest emission is observed from the industries. Industries are responsible for 57.3% of the regional CO_2 emission with a value of 16.5 million tones in 2003. As can be seen from Table 4.1, the regional contribution to the annual CO_2 emissions from all sources is around 28.8 million tones (13.8 % of total CO_2 emissions).

However, in the **South-Eastern Anatolia Region**, the total CO_2 emission is approximately 5 million tones per year. Total contribution of this region to the CO_2 emission of Turkey is not more than 3.0% throughout the years. This means that there isn't much fossil fuel combustion in this region, because climate is mild and industrialization is low.

In the **Black Sea Region**, the regional CO_2 emission trend of industries has shown peak values for the period of 1990-2003. These are 15.8 million tones in 1997 and 15.1 million tones in 2003. The contribution of this region to the annual CO_2 emission of Turkey is around 12.0%.

The inventory of the **Eastern Anatolia Region** shows 3.0% regional contribution to the total CO_2 emissions in Turkey. However, the CO_2 emission trend is increasing. In 2003, the CO_2 emission is 6.6 million tones. Households are responsible for 61.5% of the regional CO_2 emissions because the climate is cold and people burn a lot of fossil fuel during winter to warm up their houses.

Table 4.1 Regional total CO_2 emission between the years 1990-2010

Emissions (million tones)	Regional CO_2 Emission	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	Mediterranean	21,41	21,06	21,61	21,05	21,88	23,37	27,93	28,11	30,75	26,57	25,39
	Eastern Anatolia	4,82	4,87	4,96	5,24	5,14	5,41	5,30	5,35	5,31	5,26	5,87
	Aegean	28,28	30,08	32,09	32,95	34,31	42,25	45,98	48,11	47,79	48,70	50,05
	South-Eastern	4,16	4,20	4,38	4,62	4,49	4,51	4,86	4,95	4,91	4,46	5,35
	Central Anatolia	24,29	25,51	25,48	26,53	27,25	28,47	30,56	31,63	31,33	32,32	35,59
	Black sea	16,87	17,70	18,70	19,07	18,29	24,35	26,41	26,92	25,83	20,70	22,32
	Marmara	42,64	43,90	46,16	47,49	47,44	51,29	56,64	57,14	57,60	58,14	63,41

Emissions (million tones)	Regional CO_2 Emission	2001	2002	2003	PREDICTIONS	2004	2005	2006	2007	2008	2009	2010
	Mediterranean	24,78	25,74	28,78		30,74	32,10	33,31	36,71	37,72	43,16	45,13
	Eastern Anatolia	5,83	6,20	6,55		6,97	7,22	7,47	7,72	7,95	8,23	8,52
	Aegean	44,05	43,06	40,70		51,81	50,78	52,00	55,40	56,47	58,11	59,90
	South-Eastern	5,59	6,02	6,41		6,86	7,18	7,50	7,82	8,13	8,48	8,84
	Central Anatolia	34,53	34,12	35,53		40,77	42,49	43,84	45,25	46,56	48,13	49,83
	Black sea	21,08	23,76	26,24		29,61	30,71	31,68	32,58	33,35	34,83	36,46
	Marmara	65,28	65,84	63,70		76,72	79,40	81,99	84,54	86,97	90,27	93,85

Note: Total CO_2 emissions between 2004-2010 were calculated according to the predicted fuel consumption data.

As an overall evaluation, the lowest CO_2 emission of all the regions is observed in 1990 and the highest in 2000. Although, Marmara and Aegean regions are responsible for half of the emission of Turkey, the other regions also show an increasing trend in CO_2 emissions. The CO_2 emissions are also increasing after 2003 and it is estimated that it will reach approximately 300 million tones in 2010, because Turkey is a developing country and rate of growth of the economy is about 6-7% per year. Therefore, there is a great need for the energy and rate of energy production increases with the growth in the economy. Increase in the CO_2 emissions is quite expected in order to cooperate with the economy.

4.1.1.1. Industries

The CO_2 emission from industries is approximately 35% of the total emissions.

The high CO_2 emissions are observed in Hatay, İzmir and Zonguldak provinces with values of 11.1, 10.5 and 8.8 million tones in 2003, respectively. Figure 4.6 shows that the provinces of the South-Eastern Anatolia and the Eastern Anatolia regions have the lowest CO_2 emissions in Turkey.

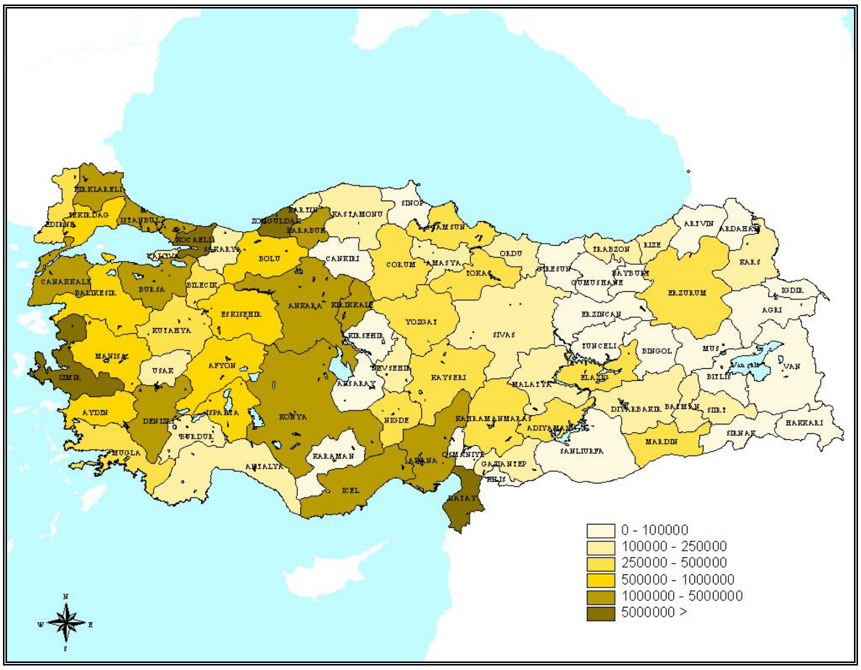


Figure 4.6 Industrial CO_2 emission from provinces for 2003 in tones

The industrial CO_2 emissions from districts are shown in Figure 4.7. The highest CO_2 emissions are observed in İskenderun district of Hatay province, Ereğli district of Zonguldak and Gebze district of Kocaeli with respective values of 8.2, 6.2 and 4.5 million tones in 2003.

The CO_2 emissions from various sources are shown in the maps in Appendix H.

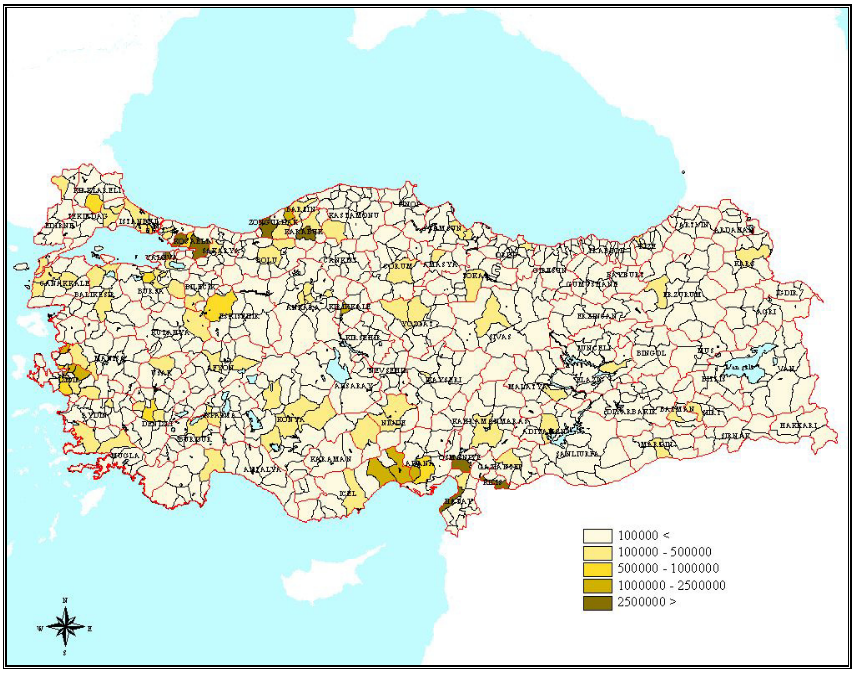


Figure 4.7 Industrial CO_2 emissions from districts for 2003 in tones

Table 4.2. Regional CO_2 emission from industries between the years 1990-2010

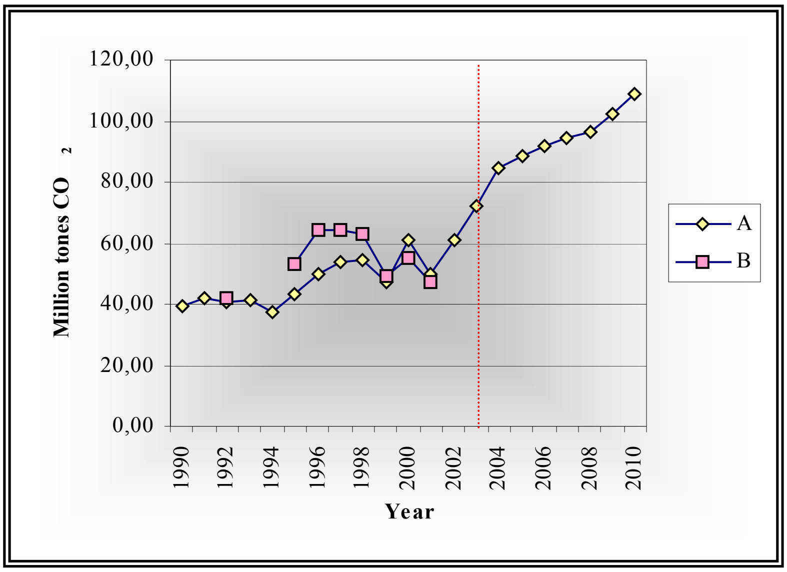
Emissions (million tones) — Industrial CO_2 Emission	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Mediterranean	10,06	10,72	10,73	10,54	9,57	10,24	14,86	15,77	15,53	10,80	12,22
Eastern Anatolia	0,79	0,84	0,84	0,82	0,75	0,92	0,75	0,88	0,86	0,59	1,00
Aegean	5,17	5,50	5,51	5,41	4,92	12,18	12,94	13,05	13,09	12,99	13,03
South-Eastern	0,97	1,04	1,04	1,02	0,93	0,77	0,81	0,86	0,93	0,20	0,83
Central Anatolia	3,14	3,35	3,35	3,29	2,99	3,70	4,63	4,94	4,79	4,26	4,87
Black sea	8,50	9,05	9,18	8,90	8,08	13,99	15,61	15,93	15,00	9,73	11,18
Marmara	10,67	11,36	11,38	11,17	10,15	11,57	14,72	13,05	12,48	10,69	12,06

Emissions (million tones) — Industrial CO_2 Emission	**2001**	**2002**	**2003**	PREDICTIONS **2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Mediterranean	10,80	13,97	16,53	19,39	20,25	20,93	21,53	22,01	23,33	24,80
Eastern Anatolia	0,84	1,08	1,28	1,51	1,57	1,63	1,67	1,71	1,81	1,93
Aegean	8,01	10,36	12,26	14,38	15,02	15,53	15,97	16,33	17,31	18,39
South-Eastern	0,92	1,19	1,41	1,65	1,72	1,78	1,83	1,87	1,98	2,11
Central Anatolia	4,46	5,77	6,83	8,01	8,36	8,64	8,89	9,09	9,63	10,24
Black sea	9,88	12,78	15,12	17,74	18,53	19,15	19,70	20,14	21,35	22,69
Marmara	12,38	16,00	18,94	22,22	23,20	23,98	24,67	25,22	26,73	28,41

Note: Total CO_2 emissions between 2004-2010 were calculated according to the predicted fuel consumption data.

The regional contribution to the total industrial CO_2 emission varies greatly from region to region. The highest emissions were observed in Marmara, Mediterranean, Black Sea and Aegean regions with annual average values of 12.6, 12.3, 11.6 and 9.6 million tones, respectively, for the period of 1990-2003.

In order to see what the CO_2 emission load will be in future years due to industries, CO_2 emission projection was made until year 2010 by using the projected fuel consumption data of MOE. Predictions of CO_2 emissions until 2010 are given in Table 4.2 and shown in Figure 4.8. As can be seen from the figure, there is a sharp increase in CO_2 emission expected until 2010.



A: Inventory results-fuel comsumption data source was MOE; B: Inventory results-fuel comsumption data source was SIS.

Figure 4.8 Annual CO_2 emission trend of industries

4.1.1.2. Households

Domesting heating is another important source for CO_2 emissions in Turkey. Approximately 34.22% of total CO_2 emission in Turkey is due to households. CO_2 emissions from households mostly depend on the population density and the type of fuel used for domestic heating. Mainly, coal is burned in households for domestic heating. In large cities, like Ankara, İstanbul, Bursa, Eskişehir, natural gas is used for heating wherever it is available.

Figure 4.11 gives the annual CO_2 emission trend of households between 1990-2010. The values between 1990-2003 are real emission values and the values between 2004 and 2010 are predicted values. Two sources were used to calculate the CO_2 emissions from households: i) fuel consumption data of MOE, ii) Fuel consumption data of SIS. SIS data gives higher fuel consumption than the MOE data. According to the fuel consumption data obtained from the SIS, there is a smooth increasing trend in CO_2 emissions. On the other hand, emission curve obtained using the fuel consumption data of MOE shows approximately 10 million tones decrease between 1997-2001 and the CO_2 emission value to be reached in 2010 is about 53 million tons. However, in the first case it is predicted as 90 million tons. There is an important difference between these two sources of data.

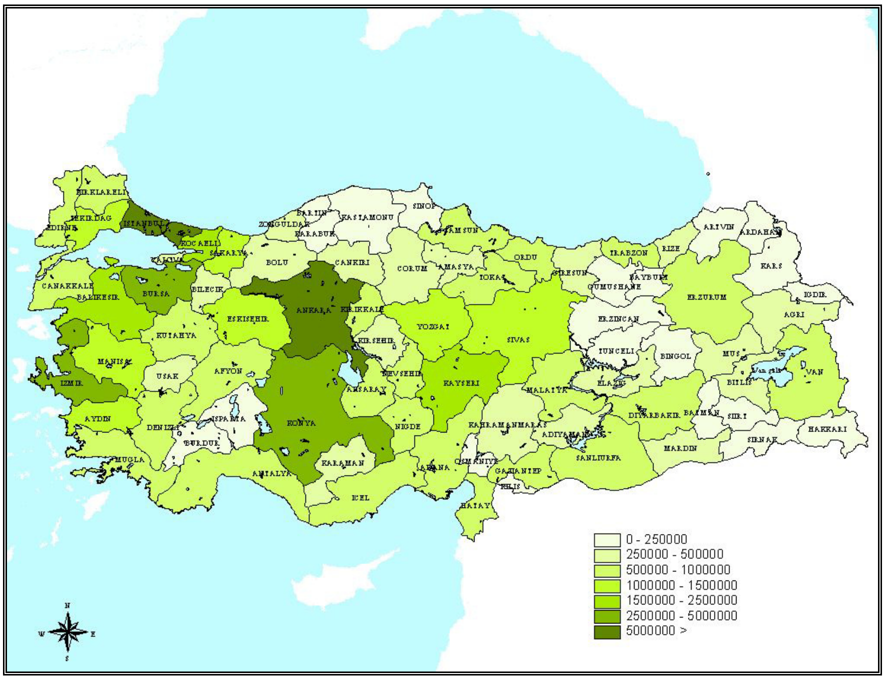


Figure 4.9 CO_2 emission of households from provinces for 2003 in tones

İstanbul, Ankara and İzmir show 70%, 46% and 48% increasing tendency in CO_2 emissions as compared with base year and reach the 17.3, 7.0 and 4.0 million tones per year in 2003. The map showing provincial CO_2 emissions from households is given in Figure 4.9.

The highest emissions are observed in the districts of İstanbul. As can be seen from the Figure 4.10, the highest CO_2 load is 3.7 million tones from the Bakırköy district of İstanbul. The CO_2 emission of Kartal and Gaziosmanpaşa of İstanbul province follow the Bakırköy district with 1.9 and 1.4 million tones, respectively.

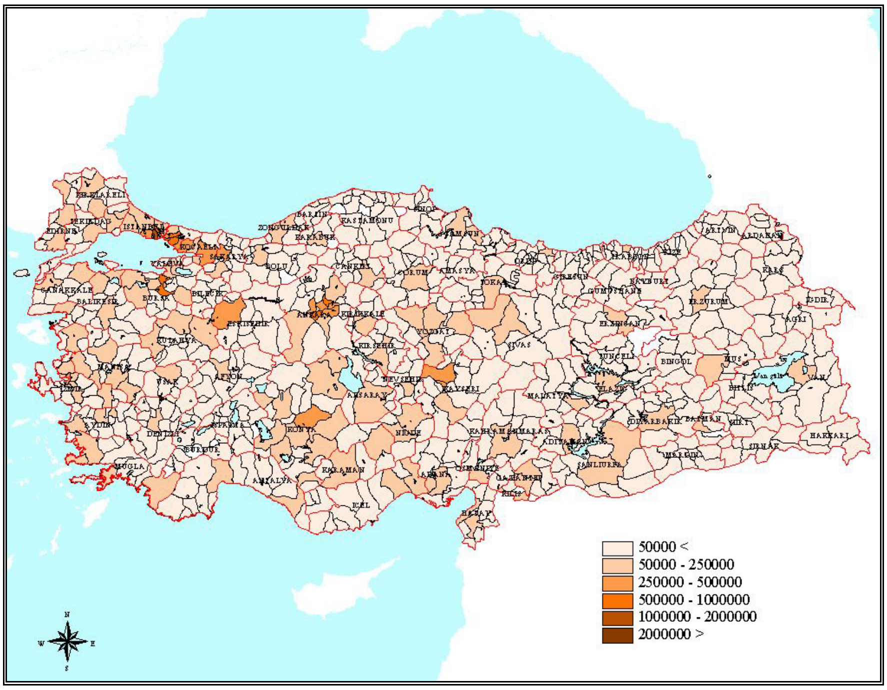


Figure 4.10 CO_2 emission of households from districts for 2003 in tones

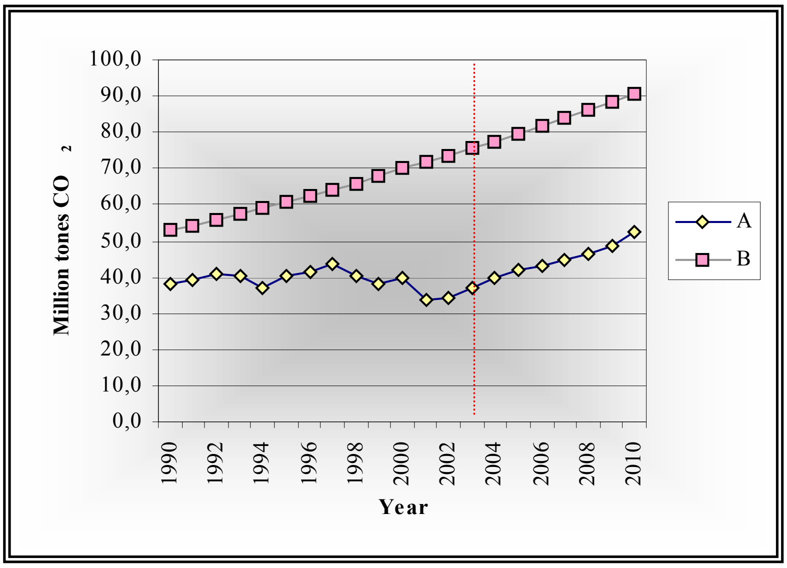
The contributions of each region to the total CO_2 emission are given in Table 4.3. The highest regional contribution to the total residential CO_2 load was observed in Marmara Region. It is about 35%. The next one is the Central Anatolia Region with an approximate percentage of 25%.

Table 4.3 Regional CO_2 emissions from households between the years 1990-2010

	Households CO_2 Emission	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Emissions (million tones)	Mediterranean	2,83	2,90	3,00	3,09	3,19	3,28	3,39	3,49	3,60	3,70	3,83
	Eastern Anatolia	3,00	3,06	3,13	3,21	3,28	3,35	3,43	3,51	3,59	3,67	3,76
	Aegean	7,53	7,68	7,90	8,10	8,30	8,51	8,74	8,96	9,18	9,40	9,67
	South-Eastern	2,14	2,20	2,28	2,36	2,44	2,52	2,61	2,70	2,79	2,88	3,00
	Central Anatolia	14,60	14,90	15,31	15,69	16,08	16,47	16,91	17,32	17,74	18,15	18,67
	Black sea	5,06	5,12	5,20	5,27	5,34	5,41	5,48	5,55	5,61	5,67	5,73
	Marmara	18,84	19,38	20,13	20,86	21,62	22,39	23,24	24,06	24,90	25,76	26,86

	Households CO_2 Emission	2001	2002	2003		2004	2005	2006	2007	2008	2009	2010
Emissions (million tones)	Mediterranean	3,93	4,04	4,16	PREDICTIONS	4,27	4,39	4,52	4,65	4,78	4,90	5,04
	Eastern Anatolia	3,83	3,91	4,00		4,08	4,16	4,26	4,35	4,45	4,53	4,62
	Aegean	9,87	10,09	10,35		10,58	10,81	11,07	11,33	11,60	11,83	12,10
	South-Eastern	3,07	3,17	3,28		3,38	3,48	3,59	3,71	3,83	3,94	4,06
	Central Anatolia	19,04	19,47	19,94		20,37	20,81	21,30	21,79	22,29	22,74	23,24
	Black sea	5,79	5,84	5,90		5,94	5,98	6,04	6,09	6,13	6,16	6,19
	Marmara	27,60	28,52	29,52		30,48	31,45	32,53	33,62	34,74	35,80	36,96

Note: Total CO_2 emissions between 2004-2010 were calculated according to the predicted fuel consumption data.



A: Inventory results-fuel comsumption data source was MOE; B: Inventory results-fuel comsumption data source was SIS.

Figure 4.11 Annual CO_2 emission trend of households

4.1.1.3. Thermal Power Plants

Thermal power plants are the third important CO_2 sources in Turkey. Approximately 20.0 % of total CO_2 emission in Turkey is attributed to the thermal power plants. The annual CO_2 emission trend of thermal power plants is given in Figure 4.14. The emission series show approximately 2.5 million tones increment per year between the years of 1990-2000. But for the following years, there is a decreasing trend about 7.5 million tones per year. The predicted CO_2 emission shows an increasing tendency until 2010. According to the "safety production capacity" of plants, the predicted CO_2 emission quantity reaches 51.9 million tones in 2010.

Between 1990 and 2003, Afşin-Elbistan Thermal Power Plant in K.Maraş and Soma Thermal Power Plant in Manisa are responsible for 29.3 % of total CO_2 emissions. From power plants, these two districts have very high CO_2 emission rates in Turkey (Figure 4.12 and Figure 4.13).

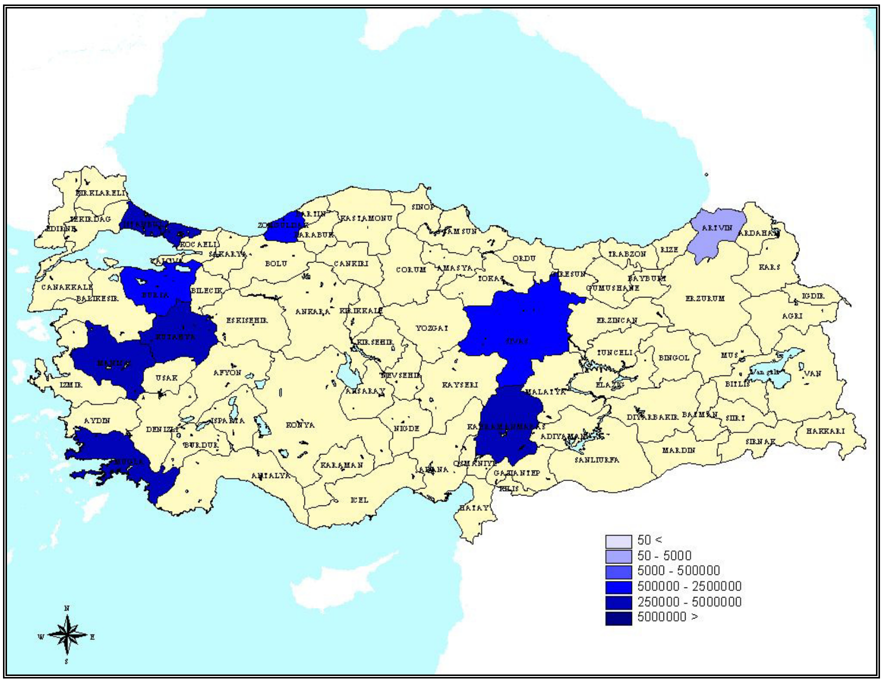


Figure 4.12 CO_2 emission of thermal power plants from provinces for 2003 in tones

The highest emissions for two plants are observed in 1999 with 8.4 million tones from Afşin-Elbistan and 6.5 million tones from Soma. The annual average CO_2 emissions from two plants are 11.0 million tones totally.

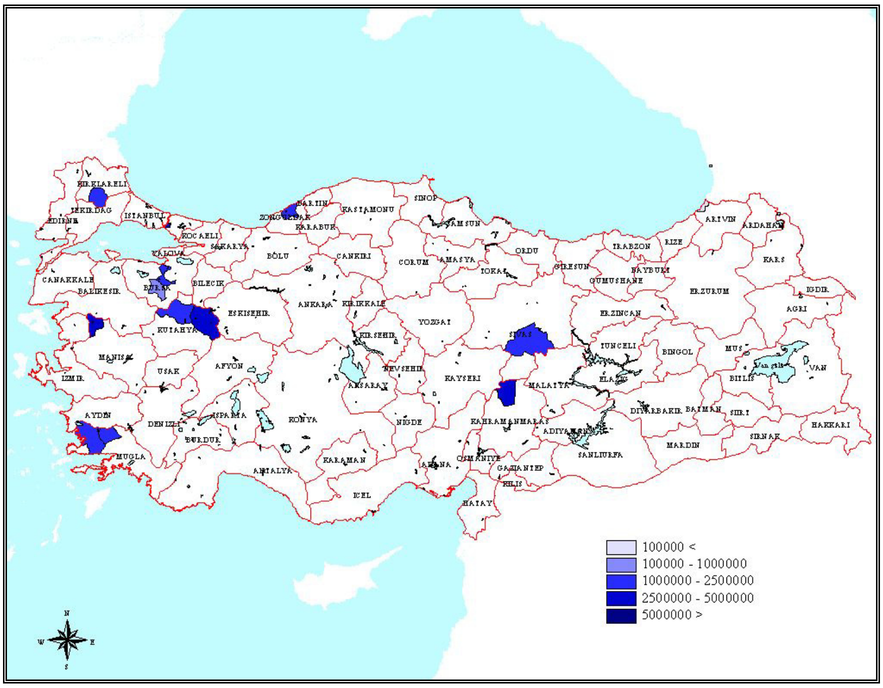


Figure 4.13 CO_2 emission of thermal power plants from districts for 2003 in tones

Table 4.4 shows that almost 10.0 % of the annual total CO_2 emission is due to the thermal power plants in Aegean region.

4.1.1.4. Road Vehicles

Generally local emission inventories are not available in Turkey. Also no data is available for active traffic even on the provincial level. For that reason, only the main highways were included in this inventory in order to fulfill the traffic option.

Table 4.4 Rregional CO_2 emission from power plants between the years 1990-2010

	Power Plant CO_2 Emission	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Emissions (million tones)	Mediterranean	5,59	4,71	5,09	3,94	5,80	6,18	5,79	5,22	8,26	8,39	5,38
	Eastern Anatolia	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Aegean	11,86	13,43	15,17	15,17	17,03	17,08	19,56	21,60	21,32	21,78	22,54
	South-Eastern	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Central Anatolia	1,68	2,68	2,12	1,76	2,75	2,44	2,82	3,51	3,25	3,80	5,52
	Black sea	0,54	0,93	1,66	1,63	1,82	1,66	1,91	2,42	2,49	2,24	2,23
	Marmara	5,87	6,31	7,66	6,98	7,73	8,71	9,43	11,14	11,84	12,87	15,42

	Power Plant CO_2 Emission	**2001**	**2002**	**2003**		**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Emissions (million tones)	Mediterranean	6,02	3,50	3,59	PREDICTIONS	2,29	2,29	2,29	4,55	4,55	8,18	8,18
	Eastern Anatolia	0,01	0,00	0,00		0,05	0,05	0,05	0,05	0,05	0,05	0,05
	Aegean	21,37	17,63	12,86		21,29	18,95	18,95	21,18	21,18	21,18	21,18
	South-Eastern	0,00	0,00	0,00		0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Central Anatolia	4,55	2,26	1,92		5,09	5,45	5,43	5,47	5,47	5,47	5,47
	Black sea	2,17	1,78	1,74		2,24	2,24	2,24	2,24	2,24	2,24	2,24
	Marmara	16,69	12,88	6,57		14,79	14,79	14,79	14,79	14,79	14,79	14,79

Note: Total CO_2 emissions between 2004-2010 were calculated according to the predicted fuel consumption data.

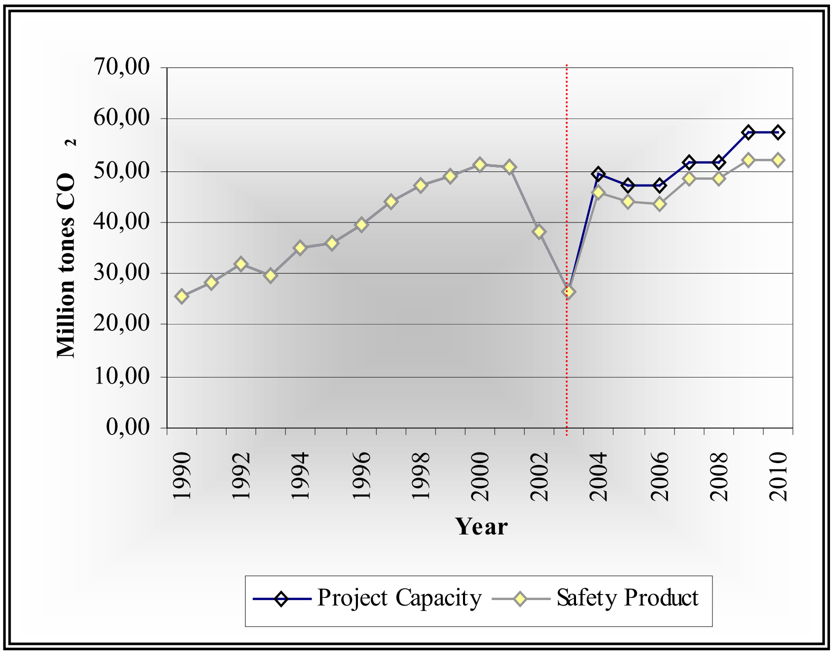


Figure 4.14 Annual CO_2 emission trend of thermal power plants

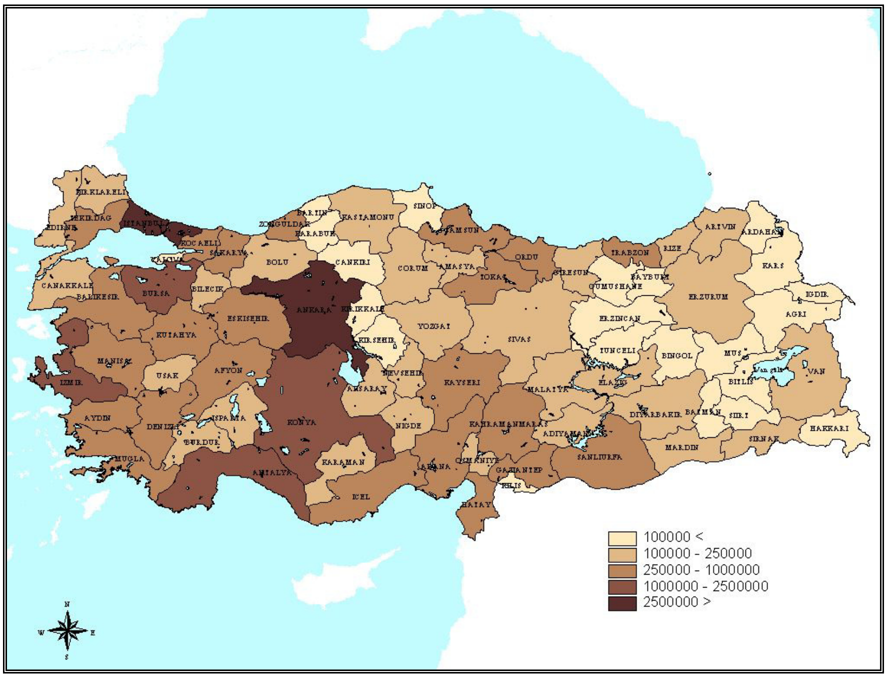


Figure 4.15 CO_2 emission of road vehicles from provinces for 2003 in tones

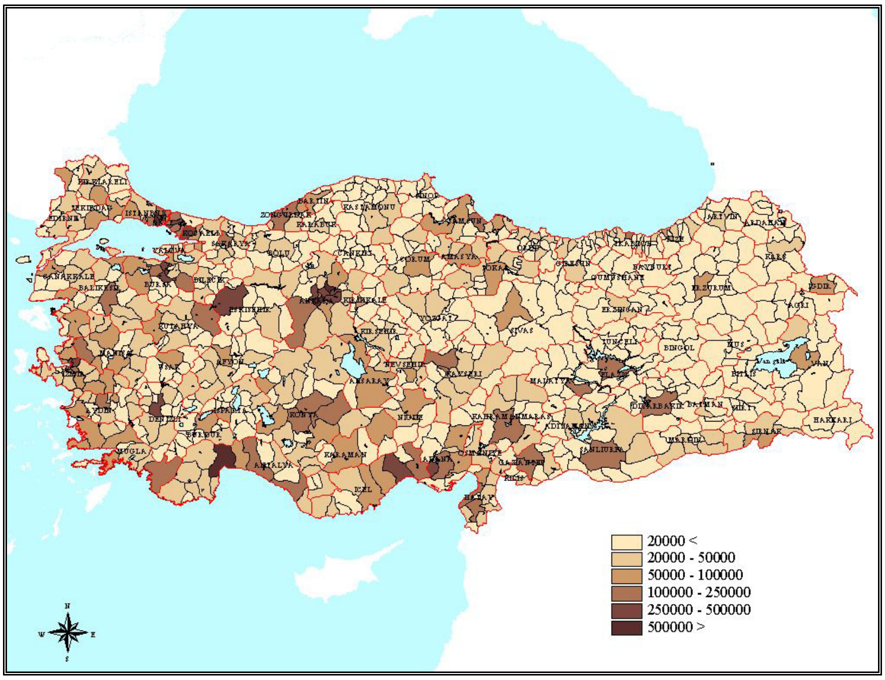
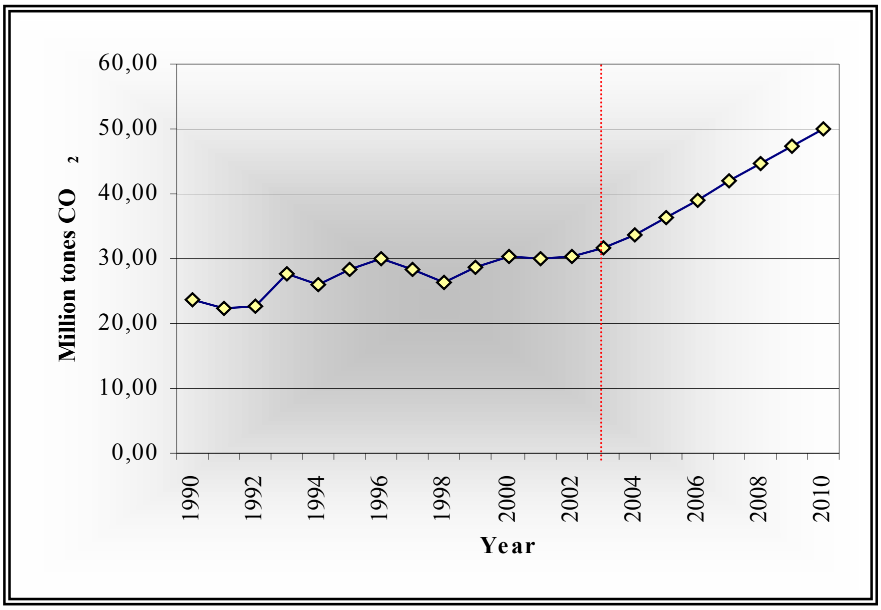


Figure 4.16 CO_2 emission of road vehicles from districts for 2003 in tones

The highest regional contribution to the CO_2 emissions by traffic are obtained in Marmara, Central Anatolia and Aegean regions with the annual average values of 8.3, 5.8 and 4.4 million tones per year as given in Table 4.5.

According to the inventory results in 2003, Bakırköy district of İstanbul, Çankaya district of Ankara and Konak district of İzmir show the highest emission with the value of 1.0, 0.7, and 0.5 million tones CO_2 emission. The approximate increments in the CO_2 emission of Bakırköy, Çankaya and Konak compared with the base year are obtained 9.4 %, 26.8 % and 17.6 % for the year 2003. The vehicle CO_2 emission on the roads of districts and provinces are given in the Figure 4.15 and Figure 4.16.

The annual CO_2 emission trend of road vehicles is given in Figure 4.17. It is to be noted that there is a sharp increasing trend in CO_2 emissions after 2000 and based on predictions, the CO_2 emissions from road vehicles are expected to reach 50 million per year in 2010.



A: Inventory results-fuel comsumption data source was MOE; B: Inventory results-fuel comsumption data source was SIS.

Figure 4.17 Annual CO_2 emission trend of road vehicles

Table 4.5 Regional CO_2 emission from road vehicles between the years 1990-2010.

	Road Vehicles CO_2 Emission	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Emissions (million tones)	Mediterranean	2,93	2,73	2,79	3,48	3,32	3,66	3,88	3,63	3,37	3,67	3,96
	Eastern Anatolia	1,03	0,98	0,99	1,21	1,11	1,14	1,12	0,96	0,86	1,01	1,11
	Aegean	3,72	3,47	3,50	4,27	4,06	4,47	4,74	4,51	4,21	4,53	4,81
	South-Eastern	1,04	0,97	1,06	1,24	1,12	1,22	1,43	1,39	1,19	1,38	1,53
	Central Anatolia	4,86	4,58	4,70	5,79	5,42	5,86	6,19	5,86	5,55	6,11	6,53
	Black sea	2,77	2,59	2,65	3,27	3,05	3,29	3,40	3,02	2,73	3,06	3,18
	Marmara	7,26	6,86	6,99	8,48	7,95	8,62	9,25	8,89	8,39	8,82	9,06

	Road Vehicles CO_2 Emission	**2001**	**2002**	**2003**		**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Emissions (million tones)	Mediterranean	4,03	4,23	4,50	PREDICTIONS	4,79	5,18	5,58	5,99	6,39	6,75	7,12
	Eastern Anatolia	1,15	1,20	1,26		1,33	1,43	1,54	1,64	1,75	1,83	1,92
	Aegean	4,80	4,97	5,23		5,56	6,00	6,45	6,92	7,37	7,79	8,22
	South-Eastern	1,60	1,66	1,73		1,83	1,98	2,13	2,29	2,43	2,55	2,67
	Central Anatolia	6,48	6,62	6,85		7,29	7,87	8,47	9,09	9,71	10,29	10,88
	Black sea	3,23	3,36	3,48		3,68	3,96	4,25	4,55	4,84	5,09	5,34
	Marmara	8,62	8,44	8,68		9,23	9,95	10,69	11,46	12,22	12,95	13,69

Note: Total CO_2 emissions between 2004-2010 were calculated according to the predicted fuel consumption data

4.1.2. CO_2 Uptake Inventories

The statistical data to calculate the CO_2 uptake with respect to years is not easy to obtain. The inventories are not periodical and they are based on field surveys. For that reason all possible sources of data were tapped to form the CO_2 uptake inventories. The IPCC provides a common structure to categorize CO_2 sinks. According to the IPCC [30] and UNFCCC [96], the following areas should be evaluated in the inventories to improve the comparability of the CO_2 uptake inventories:

- *Forest and biomass stocks:* CO_2 removals are estimated from biomass growth.
- *Grassland conversion:* CO_2 removals and emissions change seasonally. The net emission or uptake should be considered.
- *Land-use change:* According to the cultivated land, it could result in either CO_2 emission or CO_2 uptake. Satellite images, aerial photography and land-based surveys are the possible sources of

data. Natural forest fires (not anthropogenic in origin) are also not considered.

- *Agricultural growing:* Burning of agricultural biomass produces CO_2 emissions. However, the burned biomass is replaced by regrowth over the following year. The net CO_2 uptake and emissions are considered as equal to zero.
- *Uptake or release by seas (oceans):* The activities do not result in a net source or sink of CO_2. Basically, it is excluded from the national inventories of countries.

According to the IPCC, the activities that are not anthropogenic in origin or do not result in a net source/sink of greenhouse gas emissions are intentionally excluded from the inventories. For that reason, the priority calculations of CO_2 uptake, in this study, focused on the increment in forest biomass stocks. The forest area is the key sink for calculating the CO_2 removals.

4.1.2.1. Forest

The inventory of the annual increment of biomass started in 1980s and finished in 1999 by the Ministry of Forestry. The entire forest area in Turkey was covered. This inventory is not periodical and the main aim is not the determination of the increment of forest area. For that reason, there are some uncertainties and errors associated with these informations. However, this inventory is the only data source to estimate the CO_2 uptake of forest. The data categorized for each type of forest biomass was gathered from MOF at provincial level. Then, the inventory was linked to the provincial forest map. This map was intersected with district map on GIS in order to obtain the inventory at district level. The resulting maps are shown in Figure 4.19 and Figure 4.20.

Figure 4.18 digitized map and Table 4.6 show that, the coastline of Turkey is covered with forests. Forest area is not broad enough in Central Anatolia, Eastern Anatolia and South-Eastern Anatolia regions. The CO_2 uptakes in these regions are 2.6, 1.9 and 1.1 million tones/year, respectively.

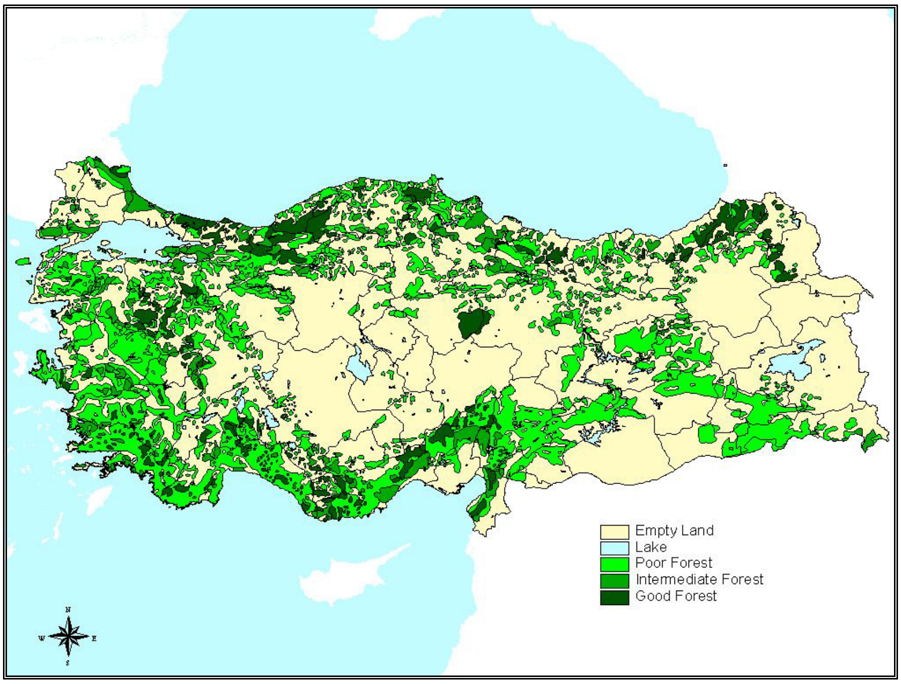


Figure 4.18 Forest cover of Turkey

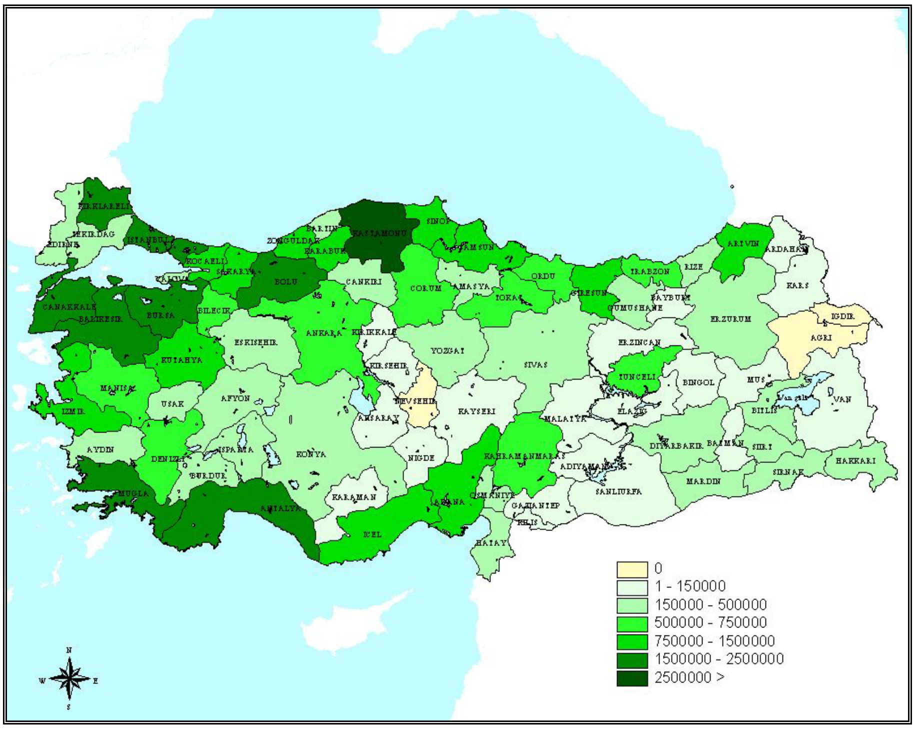


Figure 4.19 CO_2 uptake of the provinces in tones

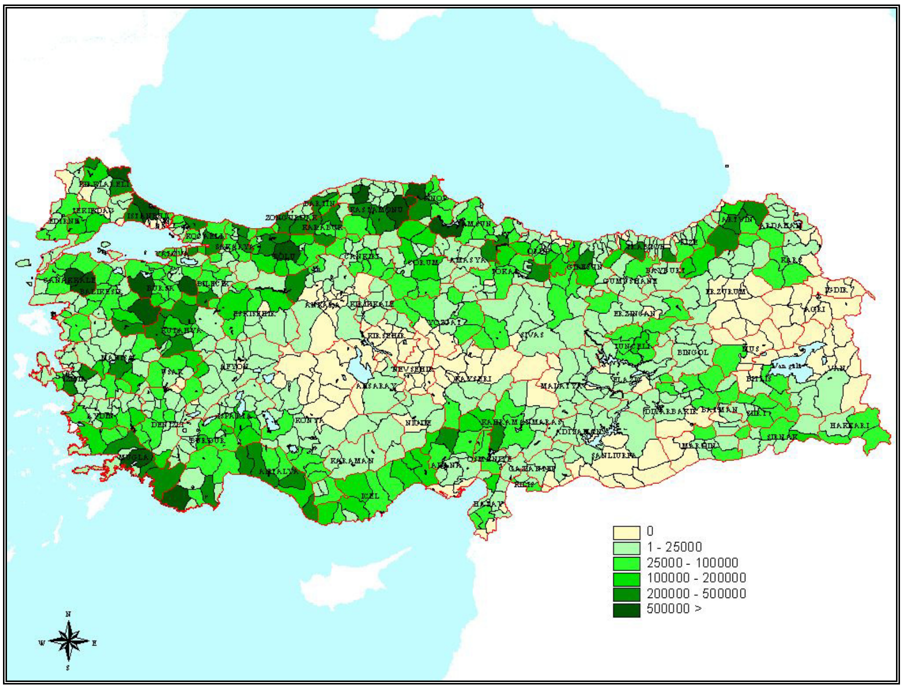


Figure 4.20 CO_2 uptake of the districts in tones

The forests are classified into three different kinds: i) bad forest area, ii) standard coppice area, and iii) high forest area. The bad forest and standard coppice areas spread in the Mediterranean, Aegean and Marmara regions. On the other hand, high forest areas are present densely in the Mediterranean and Blacksea regions. In the Blacksea region, Zonguldak and Bolu provinces are important high forest areas. If we look at the districts, Devrek district of Zonguldak province, Dursunbey (Balıkesir), Özvatan (Kayseri), Aladağ (Adana), Uzundere (Erzurum) and Ardanuç (Artvin) are important high forest areas. However, there are not high forest areas in the South-Eastern Anatolia region, because this area is mainly plain.

According to the analysis, the percentages for the three different kinds of forests (bad forest, standard coppice and high forest) are 73.1%, 12.0% and 14.9%, respectively. It is also observed that 38.1% of high forest is in the Black Sea Region and 21.4% in the Mediterranean region. The regional distributions of forest are given in Table 4.6.

Table 4.6 Distribution of the forest area within geographical regions and regional CO_2 uptake

REGIONS	Empty Land	Poor Forest	Intermediate Forest	Good Forest	Lake	Total (unit: km^2)	CO_2 Uptake (tones)
Mediterranean	32615	38889	8060	8952	1302	**89818**	6066457
Eastern Anatolia	119927	20167	1965	2393	1878	**146330**	1900288
Aegean	34863	44538	4808	4809	862	**89881**	5749523
South-Eastern	49815	25106	271	0	1316	**76509**	1093184
Central Anatolia	155657	23086	1754	3925	3630	**188052**	2635381
Black sea	59616	32574	7640	15931	479	**116240**	16351045
Marmara	36987	20312	8970	5846	913	**73027**	12014619
Total	**489480**	**204672**	**33468**	**41856**	**10381**	**779857**	**45810497**

The CO_2 uptake in the coastal zone is higher than that in inland zone as seen in the Figure 4.19 and Figure 4.20. The CO_2 uptake in the Central Anatolia, Eastern Anatolia and South-Eastern Anatolia regions are 2.6, 1.9 and 1.1 million tones/year, respectively. The maximum CO_2 uptake is in the Black Sea region with a value of 16.4 million tones/year. As can be seen from the Figure 4.21, the CO_2 uptake in the Black Sea region was approximately 36% of the total CO_2 uptake of forests in Turkey.

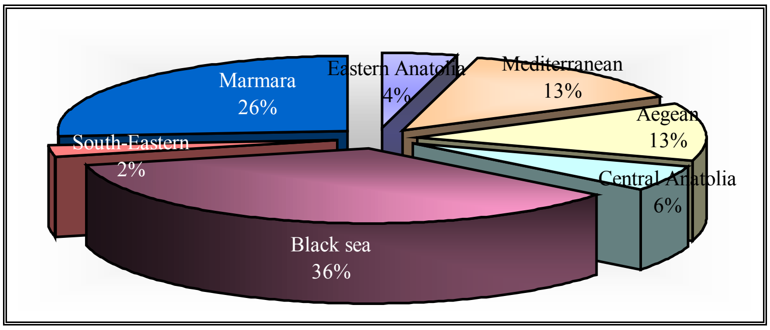


Figure 4.21 Regional CO_2 uptake

The Marmara region has the second biggest CO_2 uptake value which is 12.0 million tones/year. It is also observed that CO_2 uptake in the Aegean and Mediterranean regions are 5.7 and 6.1 million tones/year, respectively (Table 4.6).

The maximum CO_2 uptake values observed in the Demirköy district of Kırklareli province, Dursunbey of Balıkesir, Can of Çanakkale are 1.16, 0.96 and 0.90 million tones/year. There is no CO_2 uptake in the districts of Ağrı, Igdır and Nevşehir provinces. Moreover, there is also no CO_2 uptake in 14 districts of Ankara, 12 districts of Istanbul, 11 districts of Kayseri and 10 districts of Konya as seen in Figure 4.20. Finally, the CO_2 uptake is present in the 741 districts out of 910 districts considered in Turkey.

4.1.2.2. Other

The existing statistics for the CO_2 removal activities are collected during the study period. However, the comparability and consistency criteria of the IPCC methods require skipping some of the activities listed below [30], [96]:

Grassland conversion: The CO_2 is removed during the growing. However, it is emitted back during the decaying. Therefore, the net annual CO_2 removal is equal to zero.

Land use change: The most important land type is considered as forest area. However, determining the annual forest/grassland conversion is not easy. Satellite images, aerial photography and land-based survey are required in order to find out the net changes. The conversion from grassland to forest is included in the MOF inventory. However, the conversion from forest to grassland, such as the forest fires, is not included. The main reason is the reforestration of these zones. MOF associated with local authorities prepares reforestration programs for the burned fields immediately. Forest fires are prohibited strictly by Turkish Regulations with law no: 6831. In Turkey, most of the forest fires were recorded as natural event throughout the years. Since, the rate of anthropogenic forest fires compared to total forest fires is very small for taking into account [44].

Agricultural growing: As explained in Section 4.1.2, burning of agricultural residue after harvesting produces CO_2 emissions. However, the burned biomass is replaced by regrowth over the next growing season. Therefore, the net CO_2 removal is equal to zero.

CO_2 uptake or release by oceans (seas): The activities do not result in a net source or sink of CO_2. According to the IPCC and the UNFCCC, this activity is also defined as natural in origin. Therefore, it is excluded from the inventories.

4.1.3. Uncertainties of Emission Inventories

The inaccuracy and imprecision in the calculations are termed as uncertainty estimates of the inventories [41]. Moreover, uncertainty estimates are an essential element of the complete emission inventories [31]. It can be seen in the range of standard deviation around the mean value of the sample [91] and it is usually associated with different parts of the inventories. These parts are stated by IPCC [31] as:

- Fuel Consumption Data
- Emission Factors
- Fugitive Emissions
- Methodology

The statistical differences give an indication of the uncertainties of the data. Moreover, the characteristics of the emission data are also estimated with statistical approaches [92].

By using the results of the statistical evaluations, it is concluded that the correlations between CO_2 emission of the base year and that of the each related year between 1991-2010 are very high for regional and provincial emission series. By the way, the year 1990 should be the base year for the Annex I countries [96]. The highest correlation implies that there is an association between the series. However, the correlations of districts emission series throughout the years compared to base year are not high as much as regional and provincial ones.

According to the results given in Table 4.7, the highest correlation of **regional** series compared to base year between 1991-2003 is observed in 1991 with an value of 0.999. The correlation for the future estimation emission series is also high with a value of 0.999 in 2010. The lowest correlation, which also implies that there is a great association between two series, is observed as 0.982 between the emission series of 1997 and 1990.

Table 4.7 Correlations between Emission Series of districts, provinces and regions

Paired	Districts		Provinces		Regions	
	N	Correlation	N	Correlation	N	Correlation
1991 & 1990	911	0,893	80	0,997	7	0,999
1992 & 1990	911	0,898	80	0,996	7	0,998
1993 & 1990	911	0,875	80	0,989	7	0,996
1994 & 1990	911	0,896	80	0,990	7	0,996
1995 & 1990	911	0,859	80	0,965	7	0,978
1996 & 1990	911	0,850	80	0,970	7	0,982
1997 & 1990	911	0,842	80	0,969	7	0,978
1998 & 1990	911	0,855	80	0,976	7	0,982
1999 & 1990	911	0,849	80	0,969	7	0,979
2000 & 1990	911	0,820	80	0,966	7	0,981
2001 & 1990	911	0,814	80	0,969	7	0,990
2002 & 1990	911	0,812	80	0,964	7	0,993
2003 & 1990	911	0,807	80	0,957	7	0,998
2004 & 1990	911	0,784	80	0,956	7	0,993
2005 & 1990	911	0,785	80	0,954	7	0,995
2006 & 1990	911	0,784	80	0,954	7	0,995
2007 & 1990	911	0,809	80	0,961	7	0,997
2008 & 1990	911	0,808	80	0,961	7	0,997
2009 & 1990	911	0,833	80	0,966	7	0,999
2010 & 1990	911	0,829	80	0,964	7	0,999

N: Sample Size

The highest correlation for the **provincial** series is again observed in 1991 with 0.997. The correlations are decreasing throughout the years. Therefore, the series relationship compared to base year is also decreasing. The correlation coefficients are not less than 0.95 for the years. It means there is still a high association between series.

The correlation coefficients of CO_2 emission series for **districts** are changing between 0.784 and 0.898 during 1991-2010. Hence, the relationship for the series compared to base years is low and the correlation coefficients are not more than 0.9.

In an emission inventory, the statistical evaluation of the annual series rather than the differences is also important to understand the representativeness and appropriateness of the emission series.

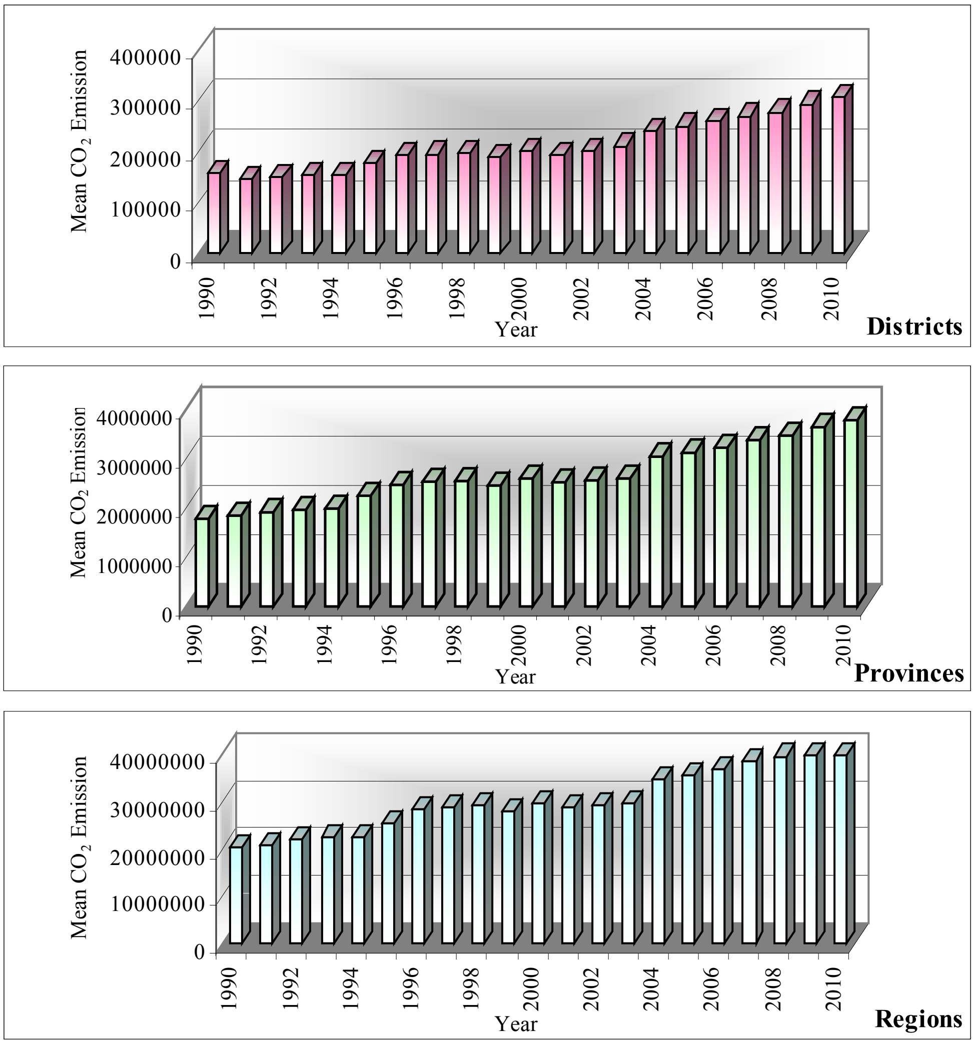


Figure 4.22 Mean CO_2 emission from districts, provinces and regions

The regional, provincial and district mean CO_2 emission trends showed an increase between 1990-2003. The rise in the mean emission is also estimated for the years between 2004-2010. The mean CO_2 emission of provinces in the year 2000 is the highest with a value of 2.6 million tones. For the same year, the regional mean CO_2 emission is 29.7 million tones, which is also the highest throughout the years. The lowest mean emission is observed in 1990 for both provinces and regions. The provincial lowest mean emission is 1.8 million tones and the regional one is 20.4 million tones. The mean CO_2 emission of districts also showed variations between 1990-2003. The lowest mean emission is observed as 0.14 million tones per district in 1991. However, the highest one is observed in 2003 with a value of 0.21 million tones (Figure 4.22).

Another important statistical variable is the SEM, which is the indication of the spread of the mean. The SEM of the annual emission series is decreasing while the number of the sample size is increasing. Briefly, the more the data are gathered, the less the uncertainty is observed in the measurement. Therefore, the uncertainty in emissions data of district is less than that of regions. Between 1990-2003, the highest SEM of district is observed in 1998 with a value of 22646.22. However, the SEM values of provinces and regions are the highest in 2000. The highest SEM value is 502035.29 for provinces and it is 8192269.22 for regions. The SEM is, still, increasing after 2003.

The mean values, standard deviation and standard error of the annual CO_2 emissions are given in Appendix J.

Uncertainty interval is not intended to dispute the validity of the inventory estimates, but it helps to improve the accuracy of the inventories and actual reliability of the total estimates. For this reason, the used methods have to be practical, scientific, applicable and comprehensive to non-specialist inventory users [31].

Under this circumstance, the uncertainty intervals are determined by using two main statistical concepts. These are the "probability density function" and "confidence intervals". Briefly, the "probability density functions" describe the ranges and the confidence intervals give the range within the underlying value.

The method used in this study determines the significance of year-to-year differences and it takes into account the long-term trends in the inventories. A key issue in the compilation of uncertainties within inventories is the distinction between the "standard deviation" of the data set and the standard error of the sample mean. The use of the standard deviation to estimate the limits of the confidence interval is directly dependent on the probability distribution of the data set.

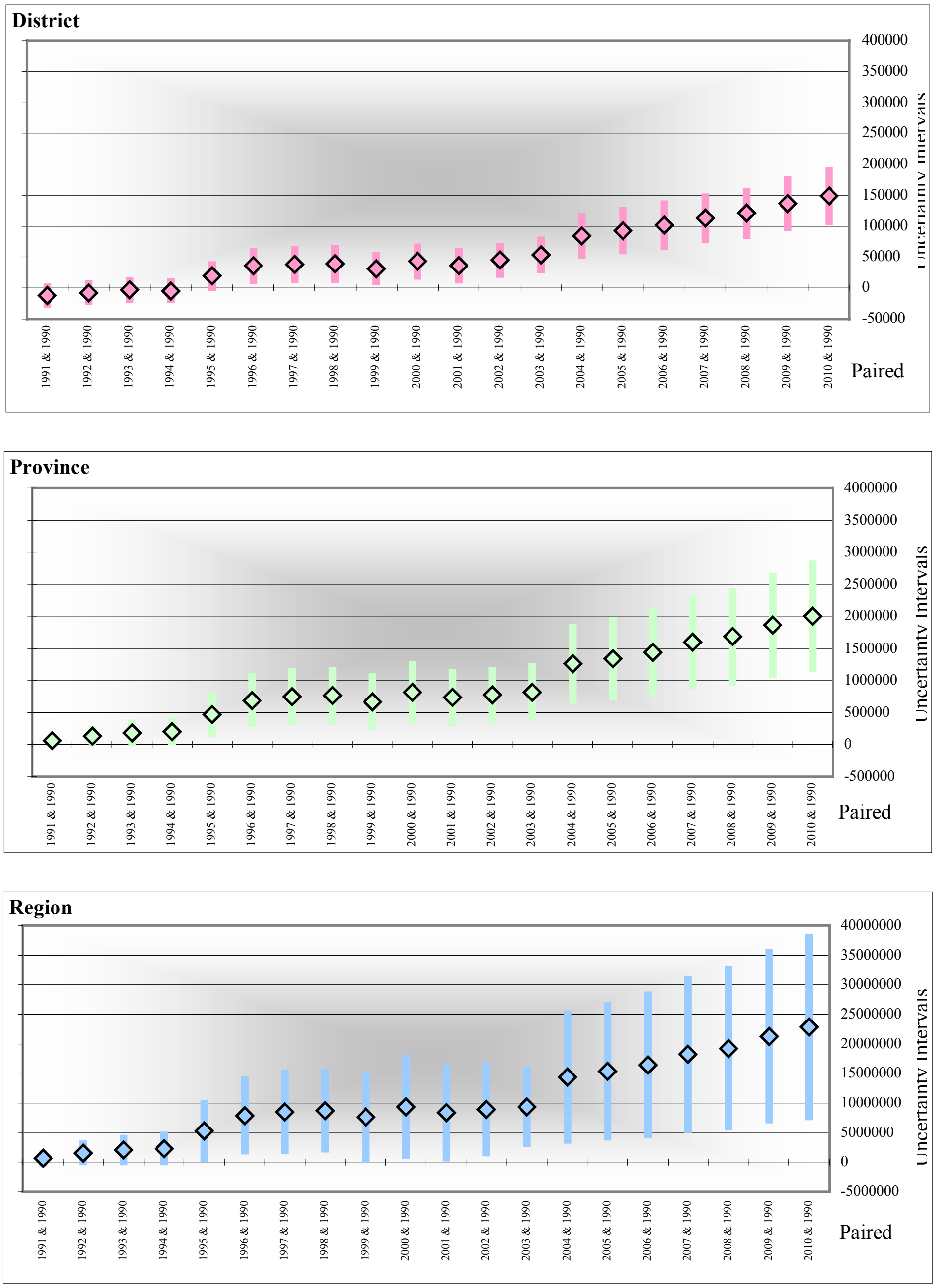


Figure 4.23 Uncertainty interval of the districts, provinces and regions

As can be seen from the results of uncertainty analyses shown in Table J.3 in Appendix J, the uncertainty interval of the district is very small compared to provincial and regional emission series. Between 1991-2003, the highest uncertainty interval for the emission series of district observed in 1998 with a value of 48806.54. The estimated uncertainty intervals are also increasing for the future years. Throughout the same years, the highest interval for provinces is seen as 849897.26 in 2000. For the regional case, it is 16336405.95 that is again observed in 2000. In order to compare the uncertainty interval of the regional, provincial and district emission series, the graphical approach as shown in Figure 4.23, is used. As the sample size is increasing the uncertainty is decreasing tremendously. Therefore, the reliability of the regional data is very small as compared to districts and provincial series.

For the estimation of atmospheric emission from biomass burning, varieties of procedures, most of which involve chain multiplication, are used. The terms in the chain are often poorly quantified and this is the reason to suspect the uncertainties in the inventories [51].

Although it is recognized that there are many causes of uncertainties, most important ones in this study are believed to be due to followings:

- Application of IPCC emission factors, since the fuel data characteristics are changing locally and regionally.
- The quality of the fuel consumption data also changes from source to source. Although the official data sets are used for emission estimates.
- There is inconsistency in gathering the data, because of the total fuel consumptions obtained from the different annual fuel consumption reports of sectors by MOE.
- For future years, the fuel consumption data does not exist. Therefore, the future estimation means some amount of uncertainties.

The uncertainties in emission estimates of greenhouse gases are major concern to the countries. And most countries state that the uncertainty of the CO_2 emission is very low as compared to the other gases.

4.2. Results of Dispersion Modelling

This section briefly describes the results of the dispersion studies based on the ISCLT3 model. The ground level estimation of the CO_2 concentrations has been based on the CO_2 emission inventory explained before in Section 4.1. However, some other factors need to be taken into account when determining local CO_2 concentrations.

The reliable model estimates can only be expected with good meteorological data [47]. The wind speed and the wind direction are important for transfering and diluting the gases. However, the other meteorological data, such as air temperature, cloudiness and sunbathing, are important for the stability or instability of the atmosphere. Therefore, the model estimation can be considered as the artificial state of the atmospheric transportation of the CO_2 [46].

As needed by the ISCLT3 model, the STARDATA and RUNSTREAM files contain the meteorological parameters (given in Chapter 3) and CO_2 emission inventory (given in Section 4.1) were used to estimate the ground level CO_2 concentrations. These concentrations are considered as the highest interest to scientists because all the CO_2 sinks are at the ground level.

4.2.1. Dispersion of CO_2 Without Sink Effect

The results of dispersion modeling calculations for CO_2 from different sources on annual basis are given in this section.

Total ground level CO_2 concentrations without any sink effect included due to forests are given in Figure 4.1 for the year 1990. As it is shown in Figure 4.24, it can be concluded that some regions were affected highly with the ground level concentrations. In 1990, the east of Mediterranean Region (around K.Maraş province), the west of Marmara Region (around Edirne province), the east of Central Anatolia Region (around Kırıkkale and Kırşehir provinces) and the west of Aegean Region (around İzmir Provinces) were determined as the maximum polluted areas with the respective values of 18.2, 26.0, 20.0 and 16.0 x10^3 $\mu g/m^3$.

In Marmara Region, the observed result seems markedly noticeable. Although the industrial zones, the thermal power plants, the areas with high population and traffic density seem to be in the center and east of Marmara Region, the high CO_2 pollution was observed in the west of the Marmara Region. The main reason for this result can be the high transporting capacity of the winds and mainly due to the winds blowing from the North-East (NE) direction.

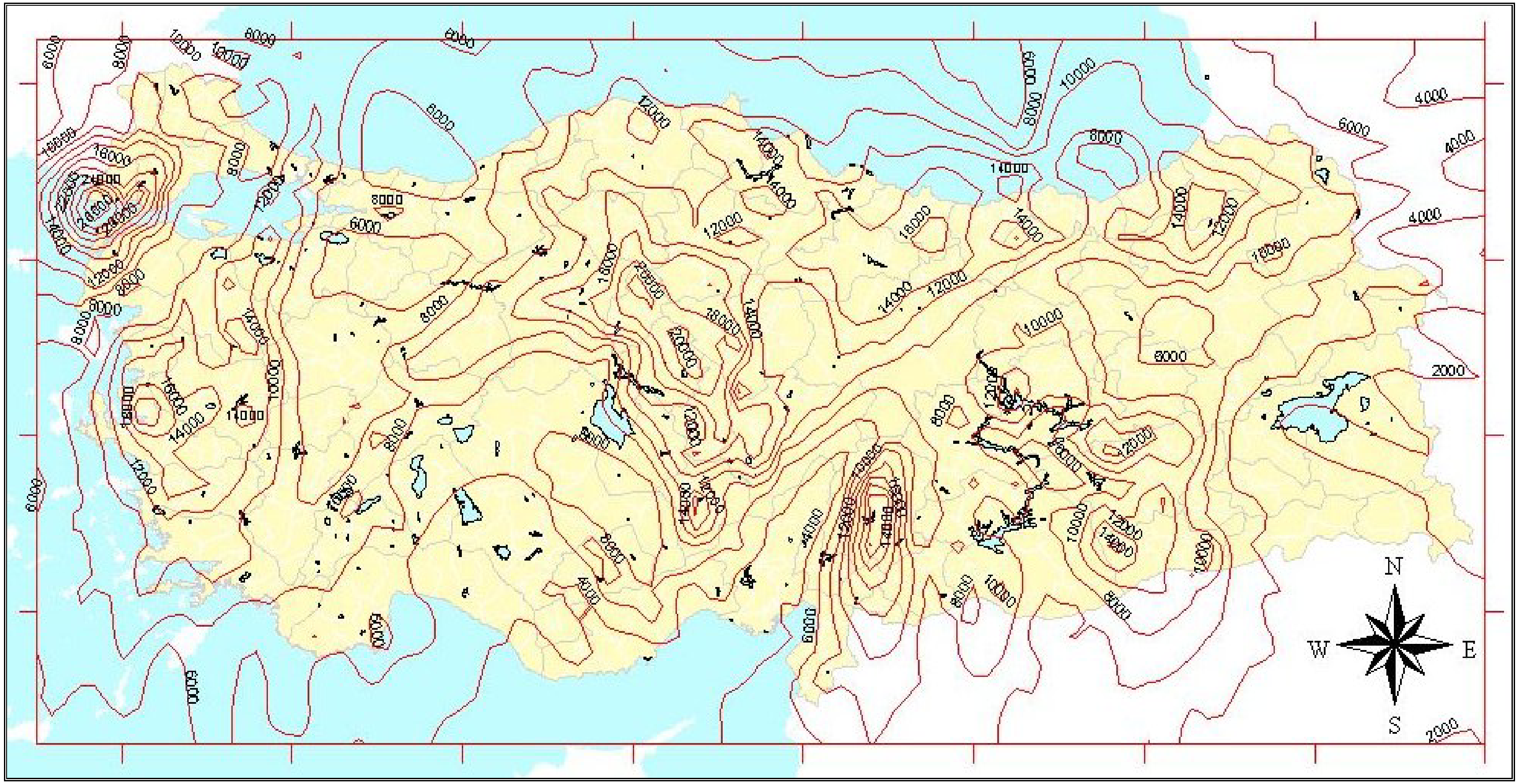
In Figure 4.25, the total ground level CO_2 concentrations without any sink effect due to forests are given for the year 1995. As compared with the results of 1990's, the high concentration regions seemed to be changed in 1995. 8 $x10^3$ $\mu g/m^3$ contour line showing the CO_2 concentration on the map and passing over the Central and the Eastern Anatolia Regions was also due to the high frequency winds blowing in the Eastern (E) and Western(W) directions. The maximum concentrations in these regions were obtained as 30.0 $x10^3$ $\mu g/m^3$ in Cihanbeyli district of Konya province and 26.0 $x10^3$ $\mu g/m^3$ in Tatvan district of Bitlis province, respectively.

In 1998, Zonguldak province and Kastamonu province in the Blacksea Region and the intersection region of Ankara, Konya and Eskişehir provinces in the Central Anatolia Region were also highly polluted areas with the respective maximum CO_2 concentrations that were 38.0 and 24.0 $x10^3$ $\mu g/m^3$.

As one can see, the CO_2 pollution is also increasing gradually in 1999 and 2000. The Blacksea, Marmara, Central Anatolia and Aegean Regions were also polluted with CO_2 in these years.

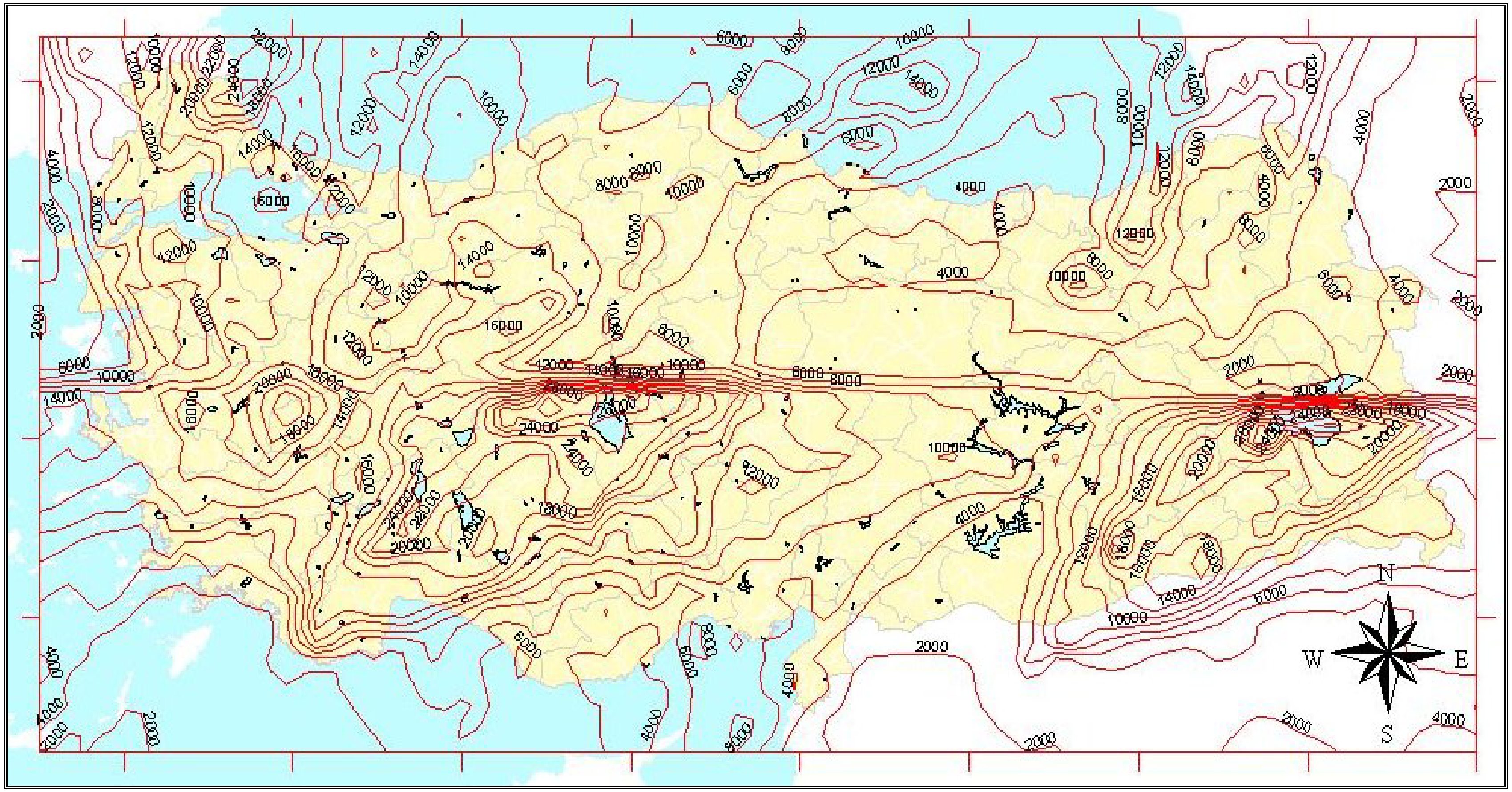
For 1999, the maximum ground level CO_2 concentrations in the Blacksea, Marmara, Central Anatolia and Aegean Regions were 36.7, 30.0, 24.0 and 24.0 $x10^3$ $\mu g/m^3$, respectively. And the respective concentrations for 2000 (as seen in Figure 4.26) were 26.0, 38.0, 25.0 and 26.0 $x10^3$ $\mu g/m^3$.

According to the results obtained, there was a sharp decline in the CO_2 concentration in 2002. The Marmara (around Kırklareli province) and Eagean Region (around Manisa province) were the highest polluted areas.



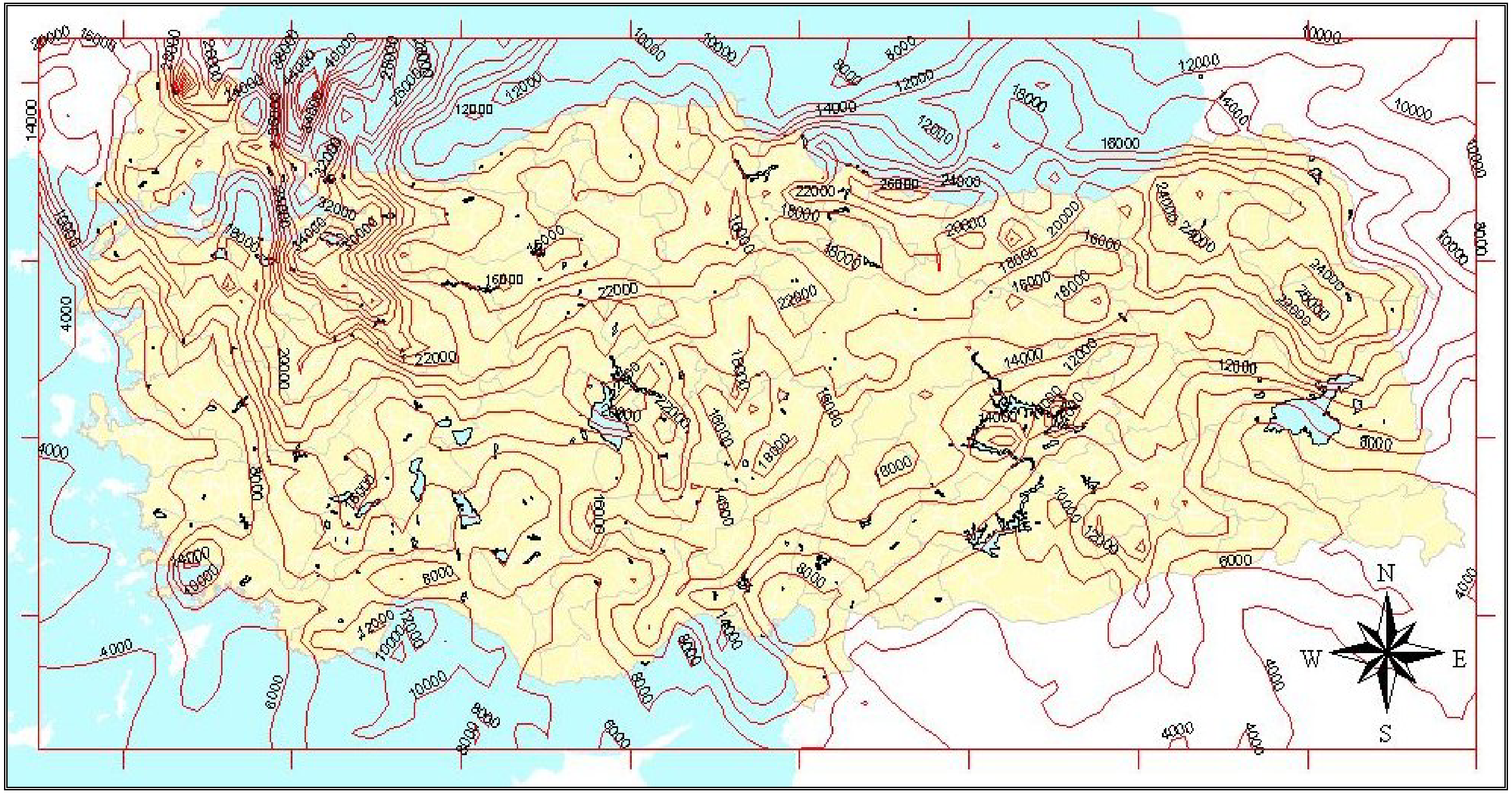
Unit: µg/m^3

Figure 4.24 Total ground level CO_2 concentrations without uptake in 1990



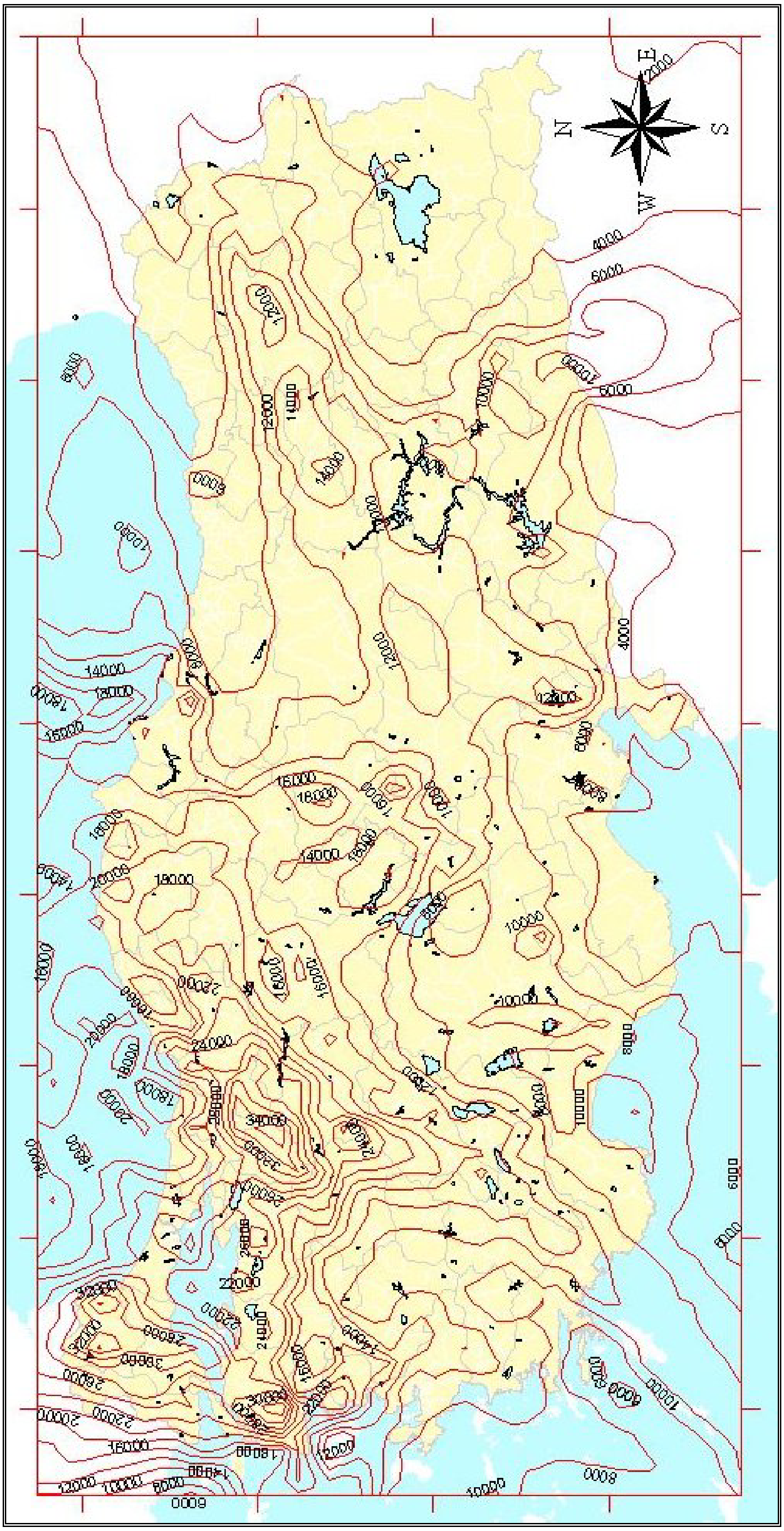
Unit: µg/m^3

Figure 4.25 Total ground level CO_2 concentrations without uptake in 1995



Unit: µg/m^3

Figure 4.26 Total ground level CO_2 concentrations without uptake in 2000



Unit: μg/m^3

Figure 4.27 Total ground level CO_2 concentrations without uptake in 2004

The respective maximum CO_2 concentration values in these regions were observed as 18.0 and 22.0 x103 µg/m3.As can be seen from Figure 4.27, the highest concentrations in 2004 were observed in Kırklareli, Bilecik and Bursa provinces in Marmara Region with a CO_2 concentration of 34.0 x10^3 µg/m^3.

From the results obtained results, it may also be concluded that the Eastern and the South-eastern Anatolia Regions were the least polluted areas throughout the years.

Change of average ground level CO_2 concentrations over Turkey is given in Figure 4.28. As can be seen from Figure 4.28, there was a gradual rise in the average CO_2 concentration over Turkey throughout the years. The maximum average CO_2 concentration was observed in 2001 with 33.7 x10^3 µg/m^3. Next highest to the 2001 value was the average concentration in 2000. This value was estimated as 26.5 x10^3 µg/m^3. From the figure, it can also be concluded that, the lowest average CO_2 concentration over Turkey was 14.0 x10^3 µg/m^3 in 2002. For the years of 1996, the concentrations were 15.0 x10^3 µg/m^3. Figure 5.5 and Figure 5.13 are also important for the model results evaluations as explained in section 5.3. The CO_2 concentration of 1990 is quite important because 1990 is the base year for CO_2 emissions in the Kyoto Protocol. A low CO_2 emission of 1990 is a disadvantage for Turkey.

The main reason for high CO_2 concentrations is high fossil fuel consumption. However, it may also be concluded that the effect of meteorological conditions, wind directions as well as the wind speed are quite important factors for the dispersion of CO_2.

Although the total CO_2 emission in 2002 and 2004 were as high as that in 2000 and 2001, the average ground level CO_2 concentration in these years were lower than those years. This result can be attributed to the local winds as well as other meteorological conditions, like precipitation. In another words, contribution of some nearby sources to the concentration of some receptor points in the district could be determined as zero or very small value owing to the transportation of the pollutant into the different area by wind. Finally this homogenous distribution of CO_2 concentration over Turkey was obtained.

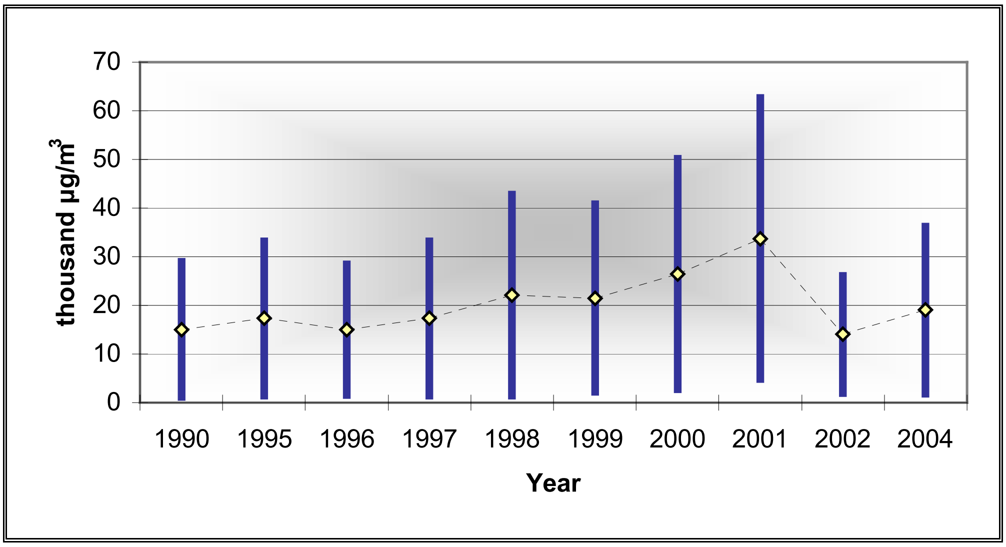


Figure 4.28 Average ground level CO_2 concentrations over Turkey

4.2.1.1. Industries

The annual ground level concentrations of CO_2 in 1990 estimated from the industrial sources are shown in Appendix K. As can be seen from the figures in Appendix K, the CO_2 concentrations in most of the regions except the Central Anatolia Region were below 5.0 $x10^3$ $\mu g/m^3$. The highest CO_2 concentration was observed in Yozgat province with a value of 7.21 $x10^3$ $\mu g/m^3$.

The CO_2 concentrations of Marmara Regions, especially Istanbul province, from the industrial sources were always the highest throughout the years. The values obtained were 14.30 in 1995; 8.02, 8.71, 7.4 in 1998; 7.0 in 2000; 14.0, 8.0 in 2002 and 15.1 $x10^3$ $\mu g/m^3$ in 2004. In fact, the industries in Istanbul Province have accounted for the 35% of the total industries in the country. The total numbers of industries employing more than 10 and employing more than 500 people are shown in Figure 4.29a and 4.29b, respectively. As can be seen from these figures, the total numbers of industries in both categories show an increasing trend. About 33.3% of the (10+) industries are located in İstanbul area, However, the number of (500+) industries located in İstanbul area is about 15-20%. For the years 1990 and 2001, the numbers of the large industries, which have more than 500 employees, are 92 in 1990 and 90 in 2001 [79]. The number has not changed much throughout the years. For that reason, the contribution of the industries in this region to the ground level CO_2 concentrations needs to be estimated more accurately. A better result can be obtained by looking at the emission inventories.

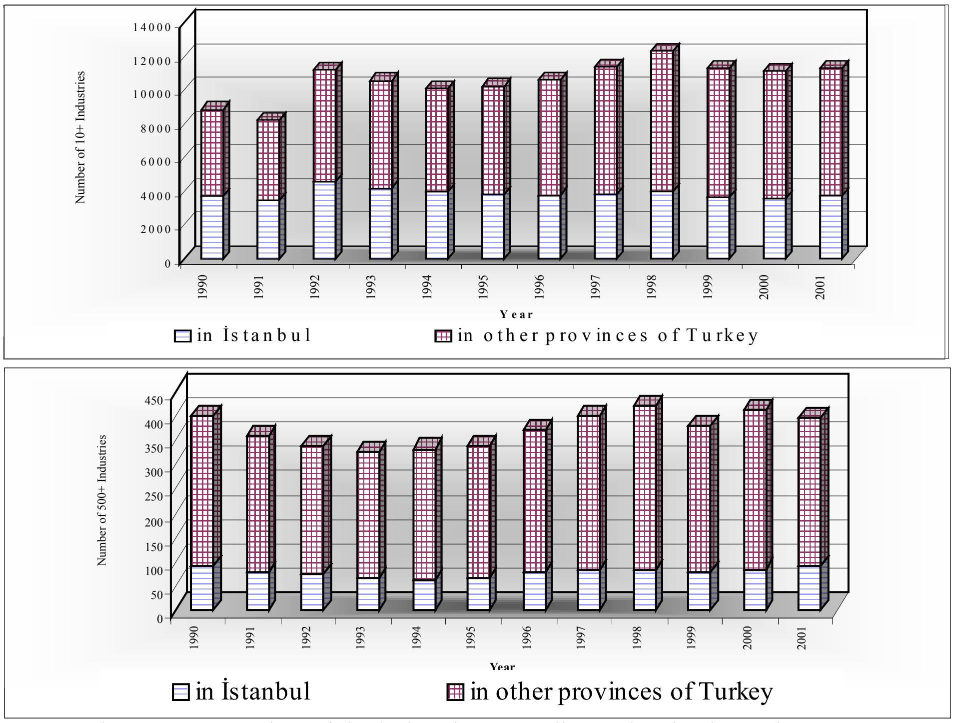


Figure 4.29 Number of the industries according to its size in Turkey [79]

The area between Tekirdağ, Kırkareli and Edirne provinces was also highly polluted with CO_2 in 1999. The CO_2 concentration was estimated as 15.0 $x10^3$ µg/m^3. In 2000, CO_2 concentration in Sivas province in Central Anatolia Region was also high with a value of 7.0 $x10^3$ µg/m^3.

In 2001, the CO_2 concentration in Bolu province of Blacksea Region and Eskişehir province of Central Anatolia Region were also high with values of 15.0 and 14.0 $x10^3$ µg/m^3, respectively.

However, the industrial contribution to the total CO_2 pollution was estimated very low in Eastern and the South-Eastern Anatolia Regions. The highest industrial CO_2 concentration in these regions was estimated as 6.0 $x10^3$ $\mu g/m^3$ in 2004.

Between 1990-1993, the industries contributed approximately 28% of the total CO_2 concentration. This percentage has increased to approximately 35% up to 2004.

4.2.1.2. Households

According to the results of the CO_2 dispersion studies for 1990, the highest annual CO_2 ground level concentration estimated from the households was observed in Kırıkkale province of the Central Anatolia Region with a CO_2 concentration of 11.06 $x10^3$ $\mu g/m^3$. As can be seen from the wind rose figure of Ankara province in Appendix G, the CO_2 was transported from Ankara provinces by West-North-West (WNW) winds.

In the Marmara Region, the area covering the south of Edirne province and the northwest of Çanakkale provinces was the highest polluted region with CO_2. The Pollution was estimated around 8 $x10^3$ $\mu g/m^3$. The annual ground level CO_2 concentration for İzmir province in the Eagean Region was also as high as the Marmara Region. Except for these regions, the concentration over Turkey was below 6.0 $x10^3$ $\mu g/m^3$.

From the results of 1995, the CO_2 pollution of Marmara Region was increased to 14.0 $x10^3$ $\mu g/m^3$. In the Central Anatolia Region, the CO_2 concentration in Beypazarı and Nallıhan districts of Ankara province were also estimated highly with a value of 11.90 $x10^3$ $\mu g/m^3$. In Eastern Anatolia Region except for Erzurum province and in South-Eastern Anatolia Region, there was not too much CO_2 pollution. The highest CO_2 concentration in these regions was around 2.0 $x10^3$ $\mu g/m^3$.

In 1996 and 1997, Marmara Region was again the highest polluted region. The ground level CO_2 concentrations in İstanbul province for these years were

11.9 and 14.34 x10^3 μg/m^3, respectively. Moreover, the Mediterranean Region and the South-Eastern Anatolia Region were estimated as the least polluted regions. The concentrations for both regions were lower than 4.0 x10^3 μg/m^3. The CO_2 concentration in Pasinler district of Erzurum province for 1996 was around 7.0 x10^3 μg/m^3. This estimated value was the highest value in Eastern Anatolia Region. According to the results, the other provinces in this region were not highly polluted.

The Zonguldak province in Black Sea Region and the Kırşehir province in Central Anatolia Region were the highest polluted provinces in 1998. The CO_2 concentration in these provinces was around 14.0 x10^3 μg/m^3. In Marmara Region, the highest annual ground level CO_2 concentration in 1998 was 11.1 x10^3 μg/m^3. In other regions, the concentration for 1998 was below 6.0 x10^3 μg/m^3.

In Central Anatolia Region, the average annual ground level concentration for CO_2 was estimated in 1999 as 10 x10^3 μg/m^3. In this year, Kargı district of Çorum province was the highest polluted area with a value of 18.95 x10^3 μg/m^3. Moreover, the Mediterranean Region was estimated below 2.0 x10^3 μg/m^3, which means it was the least polluted region in 1999.

The ground level CO_2 concentration of Ağrı province in the Eastern Anatolia Region, İstanbul province in the Marmara Region and Ankara province in the Central Anatolia region were estimated as 15.0, 15.64 and 13.17 x10^3 μg/m^3. These values were the highest in 2000. For this year, the coastal provinces of Aegean Region were not polluted. However, the CO_2 concentrations of interior provinces from households were high and it was estimated around 8.0 x10^3 μg/m^3.

In 2001, the highest ground level CO_2 concentration with 22.03 x10^3 μg/m^3 was estimated in Bolu province of the Blacksea Region. The central Anatolia Region was also highly polluted in this year. In Nallıhan district (of Ankara province) and in Kırşehir province, the CO_2 concentrations from households were 18.0 and 20.0 x10^3 μg/m^3 respectively. Probably, the reason for this poor dispersion would be the low wind speed over Turkey. For most of the time in the year, the wind speed was 1.5 to 3 m/s.

In 2002, it can also be inferred from the trend in the Figure 4.28, there was a sharp decline in the ground level CO_2 concentration. The concentration in most of the region was below the 6.0 x10^3 μg/m^3. The estimated CO_2 concentrations over Turkey did not differ too much from region to region. This situation was also observed in 2004. However, the CO_2 concentrations in Marmara Region were again high for 2002 and 2004. They were 12.13 and 15.29 x10^3 μg/m^3, respectively.

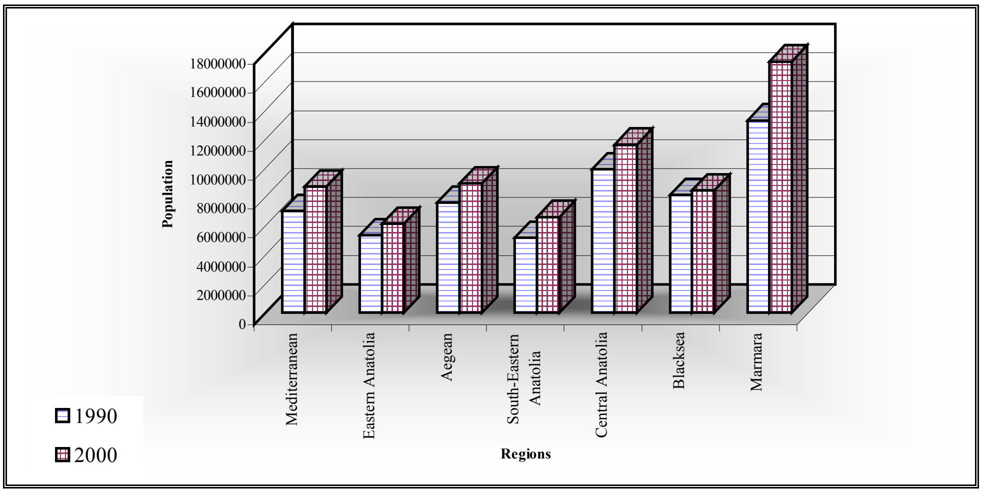


Figure 4.30 Regional populations for 1990 and 2000 [78]

Between 1990 and 2004, the contribution of the Households to the ground level CO_2 concentration had risen approximately 7%. Compared with the overall results, the Marmara Region was also highly polluted with CO_2 from the households. The main reason is the high population of the Marmara Region. In 2000 census, the population of Turkey was 67.8 million people and, as shown in Figure 4.30, approximately 26% of this population was living in Marmara Region [78]. It may be thought that the low wind speed causes the poor dispersion and results in highly polluted local areas.

4.2.1.3. Thermal Power Plants

The ground level CO_2 concentration variations contributed by the thermal power plants are given in this section. The changes in the CO_2 concentrations can be observed easily from the maps given in Appendix K. In these maps, as one can see that, there are serious local variations in the CO_2 concentrations. Between the years 1990 and 2004, the contribution of thermal power plants to the total CO_2 pollution was approximately 20%. Moreover, there has not been any thermal power plant in Eastern Anatolia Region and South–Eastern Anatolia Region for 15 years. Therefore, the CO_2 pollution estimated in these regions was the result of transportation of the pollutant from the other regions by winds.

The highest CO_2 concentration for 1990 was estimated in Kahramanmaraş with a CO_2 concentration value of 15.36 $x10^3$ $\mu g/m^3$. The main reason of this pollution was the Afşin-Elbistan Thermal Power Plant. The energy production capacity of this thermal power plant is around 1360 Megawatts (MW) which is the highest installed energy production capacity by using lignite in Turkey [86]. If the wind speed is low, this will cause a poor dispersion and it will result in highly polluted local areas. As a result, one can always expect to estimate high ground level CO_2 pollution in this region, when wind speed is low.

According to the results, the entire Mediterranean and the South-Eastern Anatolia Regions and the south of the Eastern Anatolia, Central Anatolia and Aegean Regions were polluted by CO_2 in 1995. The highest polluted districts were Sariyahşi in Aksaray province and Tatvan in Bitlis province. The ground level CO_2 concentrations in these districts were approximately 14.0 $x10^3$ $\mu g/m^3$. On the contrary, the north of the Turkey covering the north of Eastern Anatolia, Central Anatolia, Aegean Regions and the entire Marmara and the Black Sea Regions were polluted lower than 1.0 $x10^3$ $\mu g/m^3$.

In 1996, the highest polluted provinces and districts were estimated with a CO_2 concentration of 8.29 $x10^3$ $\mu g/m^3$ in İstanbul (Marmara Region), 7.0 $x10^3$ $\mu g/m^3$ in Kırklareli (Marmara Region), 7.57 $x10^3$ $\mu g/m^3$ in Dikilli district of İzmir province (Aegean Regions) and 3.04 $x10^3$ $\mu g/m^3$ in Afşin district of

Kahramanmaraş province (Mediterranean Region). Although, the fuels used in Ambarlı Thermal Power Plant of İstanbul province are natural gas and fuel-oil, this province was also highly polluted. The main reason is the 1350 MW_e (by natural gases) and 630 MW_e (by fuel-oils) installed capacity of these plant. Moreover, the power plants using natural gas are designed to operate with fuel-oil as well [86]. In this year, the other regions, provinces and districts were below 1.0 $x10^3$ $\mu g/m^3$ CO_2 concentration.

For the results of 1997, it was seen that the contribution of Seyitömer and Tunçbilek Thermal Power Plants in the annual CO_2 concentrations at Kütahya province was 6.8 $x10^3$ $\mu g/m^3$ and it was the most polluted province in Turkey for this year. Both plants are using lignite and the installed capacities of these plants are 600 MW_e and 429 MW_e, respectively [86]. The other polluted provinces were İstanbul and Kırklareli in the Marmara Region. The concentration in both provinces was 6.0 $x10^3$ $\mu g/m^3$. Kahramanmaraş in Mediterranean Region was also estimated highly compared with other provinces in these regions. Afşin-Elbistan Power plant is effective in this area. According to the results, the maximum CO_2 concentration in the Mediterranean region was estimated as 2.16 $x10^3$ $\mu g/m^3$.

The ground level CO_2 concentration in the Central Anatolia Region was 10.54 $x10^3$ $\mu g/m^3$ in 1998. Çayırhan Thermal Power Plant contributes the concentration highly. The installed capacity of the plant is 460 MW_e and Beypazarı lignite is used for the production of energy [86].

The highest ground level concentrations in 1999 were estimated in Manisa province with a value of 10.75 $x10^3$ $\mu g/m^3$ and in İstanbul province with a value of 9.57 $x10^3$ $\mu g/m^3$. The other highest polluted local areas were 7.9 $x10^3$ $\mu g/m^3$ in Bolu province and 6.0 $x10^3$ $\mu g/m^3$ in Kırklareli, Kahramanmaraş and Bursa provinces. The CO_2 concentration in Manisa is mainly caused by from the Soma Thermal Power Plants. The installed capacity of these plant is 1034 MW_e and the lignite is used for the production of energy [86].

It may be concluded that, the Marmara Region and the northwest of Central Anatolia Region were polluted highly by CO_2 in 2000. The highest ground level concentration in Marmara Region was estimated as 19.38 $x10^3$

μg/m^3. In the northwest of Central Anatolia Region, especially in Eskişehir province, the concentration was about 12.0 x10^3 μg/m^3. In addition southeast local winds in Marmara Region and the northwest local winds in Central Anatolia Region were affective for the pollution of Eskişehir province.

It can also be seen from the results that the CO_2 pollution was estimated high in 2001. The main reason was the low wind speed. In most of the regions (Marmara, Aegean, Central Anatolia, west of Blacksea), the annual ground level CO_2 concentrations were between 8.0 and 15.0 x10^3 μg/m^3. The other regions were not polluted highly.

Compared with other years, the CO_2 pollution in 2002 was not high. The highest pollution was observed in Bursa with a value of 7.15 x10^3 μg/m^3. Bursa-Orhaneli Thermal Power Plant is contributing effectively to the ground level CO_2 concentration in Bursa. The energy production capacity of this plant is 239 MW_e. Lignite is used as fuel for the production of energy [86]. The Afşin district of Kahramanmaraş province was the second highest polluted local area with 6.03 x10^3 μg/m^3 CO_2 concentration.

In 2004, the highest pollution was observed in Zonguldak province in Blacksea Region. Due to the contribution of Çatalağzı Thermal Power Plant in the ground level CO_2 concentration, the concentration was around 10.8 x10^3 μg/m^3. Kırklareli province in Marmara Region was also polluted with a CO_2 concentration of 10.0 x10^3 μg/m^3. The installed capacity of Çatalağzı Thermal Power Plant is 300 MW_e and the lignite is used for the energy production [86]. This power plant is thought to be responsible from the high CO_2 concentration in this area.

4.2.1.4. Road Vehicles

Dispersion of ground level CO_2 concentration was also studied for road vehicles. Although high ground level CO_2 concentration were not observed from the road vehicles during the period between 1990 and 2004, some dispersion results give high ground level CO_2 concentrations. The highest polluted region was determined as Marmara Regions throughout the years.

Figure K.7 in Appendix shows that, the highest ground level CO_2 concentration in 1990 was observed in the Marmara Region with a value of 6.05 $x10^3$ µg/m^3. Road vehicles also polluted the Yeşilhisar district of Kayseri province and the Karşıyaka district of İzmir province. The CO_2 concentrations were 5.0 $x10^3$ µg/m^3. In this year, the numbers of vehicles for these provinces are 35969 and 192118, respectively. Moreover, 21.60% of the vehicles in Kayseri and 12.77% of the vehicles in İzmir have the diesel motor system [58]. The diesel vehicle always emits higher CO_2 than the gasoline vehicle.

The highest ground level CO_2 concentrations from road vehicles in 1995 were observed in Kırklareli, Uşak, Ankara and İstanbul provinces. The concentrations were 8.0, 7.0, 6.0 and 5.0 $x10^3$ µg/m^3, respectively. In the other provinces of Turkey, the ground level CO_2 concentration was not as high as these provinces. In this year, the numbers of registered vehicles were 20548 in Kırklaereli province, 20784 in Uşak province, 908021 in İstanbul province and 503308 in Ankara province. The percentages of the diesel vehicles were 17.53%, 13.52%, 9.23% and 9.49% respectively [63].

In 1996, the ground level CO_2 concentrations in the Marmara, Central Anatolia and Blacksea Regions and in the west of Aegean Regions were estimated between 3.0 and 6.0 $x10^3$ µg/m^3. In the South-Eastern Anatolia Region and in the west of Eastern Anatolia Region, the CO_2 concentration was 2.0 $x10^3$ µg/m^3 that was very low. It was estimated as 3.0 $x10^3$ µg/m^3 in the Mediterranean Region and in the east of Eastern Anatolia Region.

As can be inferred from the results, the highest CO_2 concentration in 1997 was estimated in the Lapseki district of Çanakkale province with 7.0 $x10^3$ µg/m^3, in Maçkara district of Tekirdağ province with 6.0 $x10^3$ µg/m^3 and in the center of Kırıkkale province with 6.0 $x10^3$ µg/m^3. Therefore, the Marmara Region was the highest polluted region with road vehicles. For this year, the numbers of the road vehicles were 1071818 in İstanbul, 30648 in Tekirdağ, 23785 in Kırklareli and

33865 in Çanakkale. The percentages of the diesel vehicles in these provinces were 10.0%, 19.61%, 17.86% and 20.82% respectively [65].

It can be concluded that in most of the Marmara Region, the annual ground level CO_2 concentrations from the Road Vehicles in 1998 were between 3.0 and 6.0 $x10^3$ μg/m^3. In the west of Blacksea Region, the concentrations were between 3.0 and 7.0 $x10^3$ μg/m^3. In 1998, the highest CO_2 concentration was observed in Pınarbaşı district of Kastamonu province in Blacksea Region with a value of 7.0 $x10^3$ μg/m^3. The lowest CO_2 concentrations were observed in the east of Blacksea Region with around 2.0 $x10^3$ μg/m^3 and in the Eastern Anatolia and South Eastern Anatolia Regions with a value of 1.0 $x10^3$ μg/m^3.

In most of the regions in 1999, the CO_2 concentrations were between 2.0 and 5.0 $x10^3$ μg/m^3. However, in the intersection area of Osmaneli district of Çorum province in the Central Anatolia, Vezirköprü district of Samsun province and Saraydüzü district of Sinop province in the Blacksea Region, the ground level CO_2 concentration was estimated as highest with a value of 8.0 $x10^3$ μg/m^3.

The Marmara Region, especially Istanbul province, was again obtained as the highest polluted region and province in 2000. The concentration was 9.57 $x10^3$ μg/m^3. The area between Samsun, Ordu and Giresun provinces in the Blacksea Region was also high as much as İstanbul province. In the other Regions, the CO_2 concentrations were changing between 2.0 and 5.0 $x10^3$ μg/m^3. The numbers of gasoline and diesel road vehicles in İstanbul in 2000 were 1080113 and 137126, respectively [68].

The highest ground level CO_2 concentration was determined in 2001 during the period between 1990 and 2004. In 2001, the average CO_2 concentrations in the Marmara Region and in the west of Blacksea and Central Anatolia Regions were approximately 8.0 $x10^3$ μg/m^3. The highest regional CO_2 concentrations were estimated in Akyazı district of Sakarya province in the Marmara Region, in Bolu province in the Blacksea Region and in Eşkişehir province in the Central Anatolia Region with 12.0 $x10^3$ μg/m^3. The concentration in the Mediterranean Region was around 4.0 $x10^3$ μg/m^3. However, it was between 6.0 and 8.0 $x10^3$ μg/m^3 for the Aegean Region especially in İzmir province. The CO_2 concentrations in the Eastern and the South-Eastern Anatolia Region were changing between 1.0 and 4.0 x10^3 µg/m^3. In the center and in the east of Central Anatolia Region, the CO_2 concentrations were estimated as between 6.0 and 8.0 x10^3 µg/m^3.

The ground level CO_2 concentrations in 2002 were the lowest during the period between 1990 and 2004. The average concentrations were approximately 2.5 x10^3 µg/m^3. However, the Mediterranean Region, the Marmara Region and the Aegean Region were polluted slightly more than the other regions.

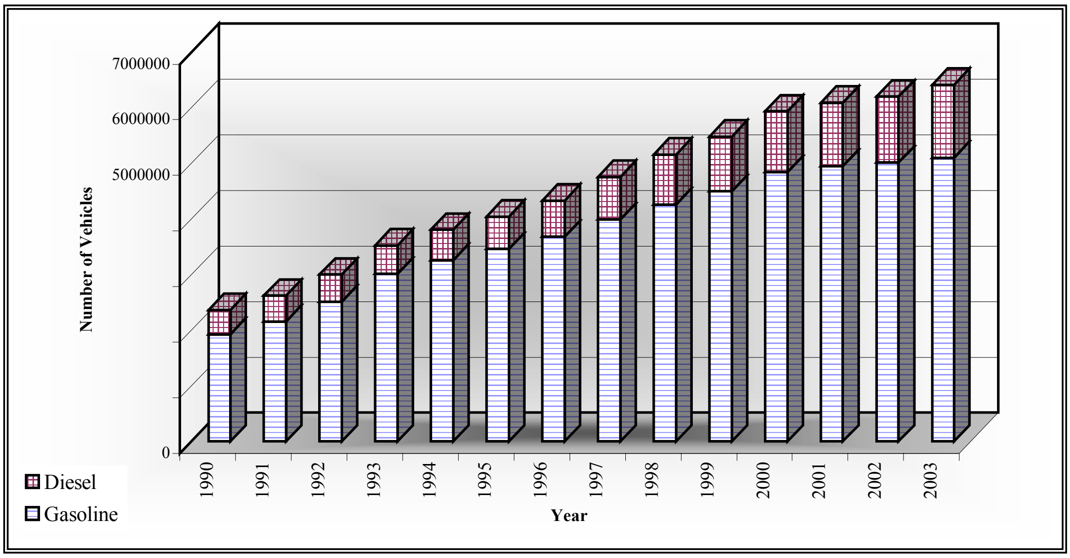


Figure 4.31 Registered road vehicles between 1990 and 2003

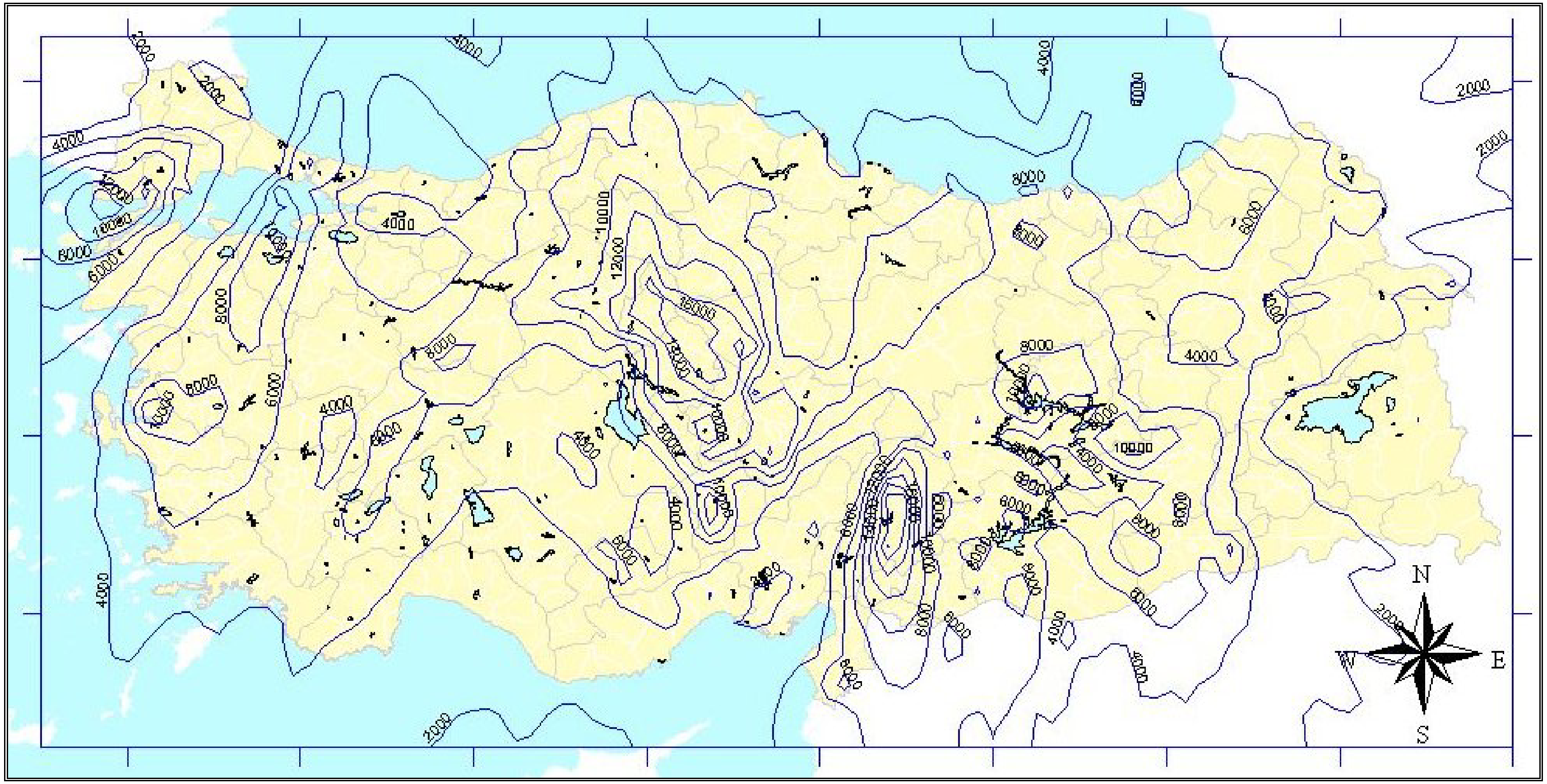
According to Figure K.8 in Appendix, the highest CO_2 concentration in 2004 was observed in Sarköy district of Tekirdağ province. The ground level CO_2 concentration was 9.68 x10^3 µg/m^3. In the Marmara Region, the ground level CO_2 concentrations were changing between 5.0 and 9.0 x10^3 µg/m^3. However, CO_2 concentrations were varying between 2.0 and 6.0 x10^3 µg/m3 in the west of Aegean Region. Moreover, the ground level CO_2 concentrations in the east of Aegean Region and in the west of Central Anatolia Region were estimated between 4.0 and 7.0 x10^3 µg/m^3. In the other regions, the concentrations were not so high.

Between the years 1990 and 2004, the contribution of road vehicles to the ground level CO_2 concentrations was approximately 15%. Although the percentage seems small, the registered number of the vehicles, which can be seen from Figure 4.31, has increased sharply since 1990. Therefore, it can be concluded that the trend shows an increase in the CO_2 pollution from the road vehicles.

4.2.2. Dispersion of CO_2 With Sink Effect

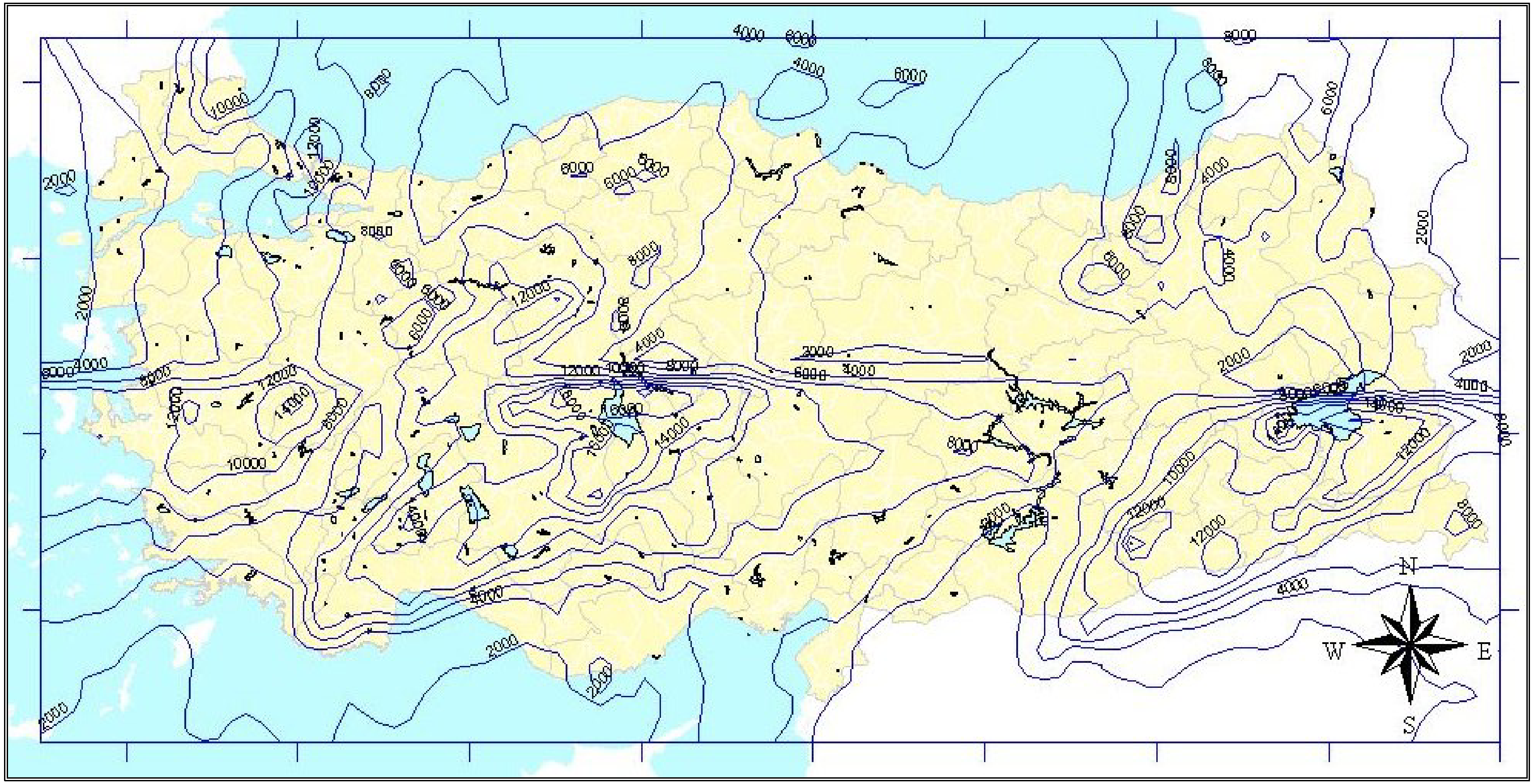
ISCLT3 model was used for dispersion of pollutants as it was mentioned before in section 3, ISC model does not consider the chemical reactions in the plume and assumes all the pollutants as inert chemicals. This means that there is no adsorption, deposition or reaction of pollutants at the ground surface. Therefore, CO_2 uptake for each district was calculated based on the forest area of the province. This amount was subtracted proportionally from the CO_2 emissions of that district. Then, the emission values after the CO_2 uptake by the forests were used for the dispersion calculations. Then the emission inventory with CO_2 uptake was used for the modeling.

It can be seen from Figure 4.32 that some regions were affected highly from the ground level concentrations. In 1990, the east of Mediterranean Region (around K.Maraş province), the west of Marmara Region (around Edirne province), the east of Central Anatolia Region (around Kırıkkale and Kırşehir provinces) and the west of Aegean Region (around İzmir Provinces) were determined as the maximum polluted areas with the respective values of 16.7, 13.5, 16.0 and 10.0 x10^3 µg/m^3. According to these results, the CO_2 concentrations in these areas were 8.2%, 48.1%, 20.0% and 37.5%, respectively with CO_2 uptake of forest.



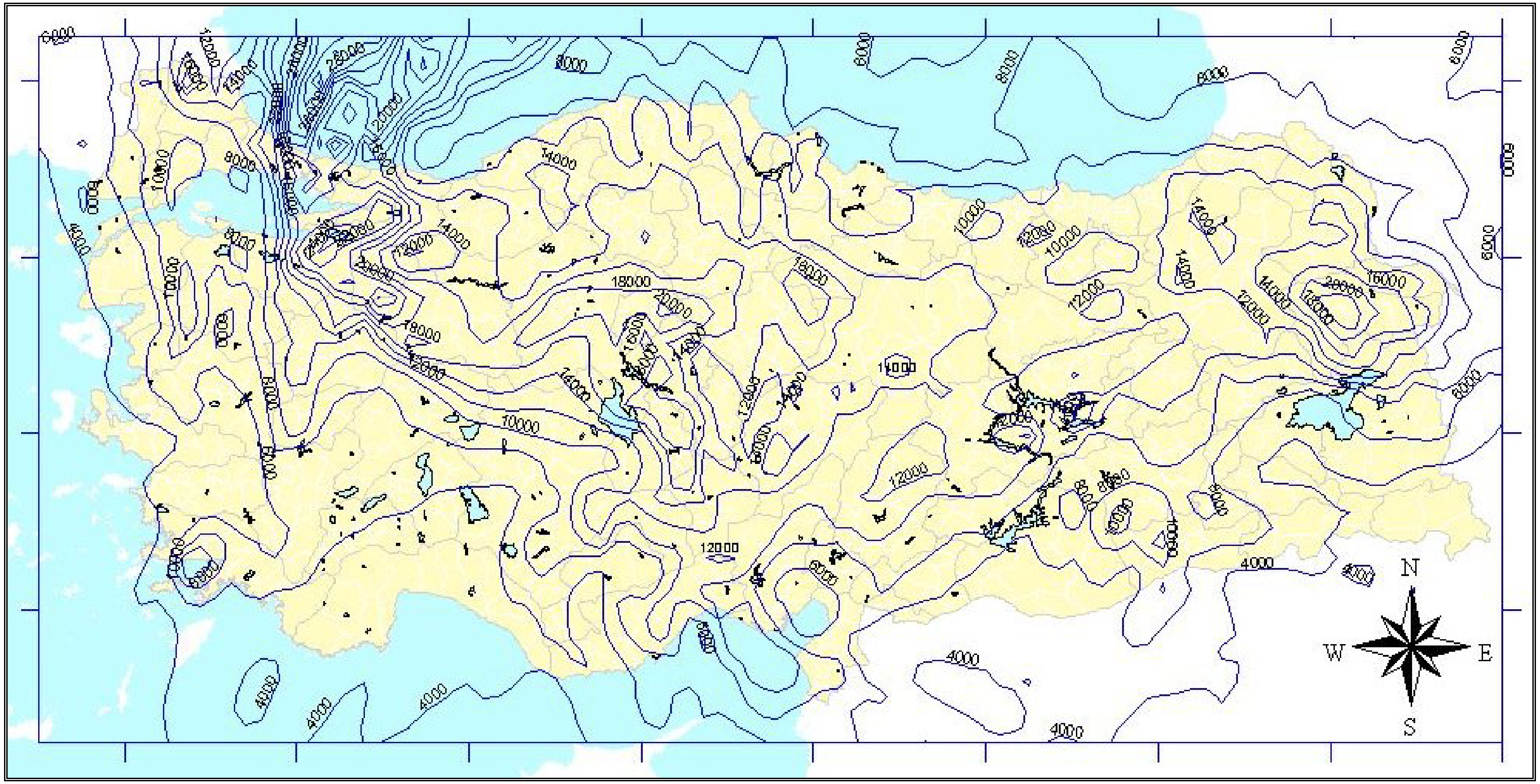
Unit: μg/m^3

Figure 4.32 Total ground level CO_2 concentrations with uptake in 1990



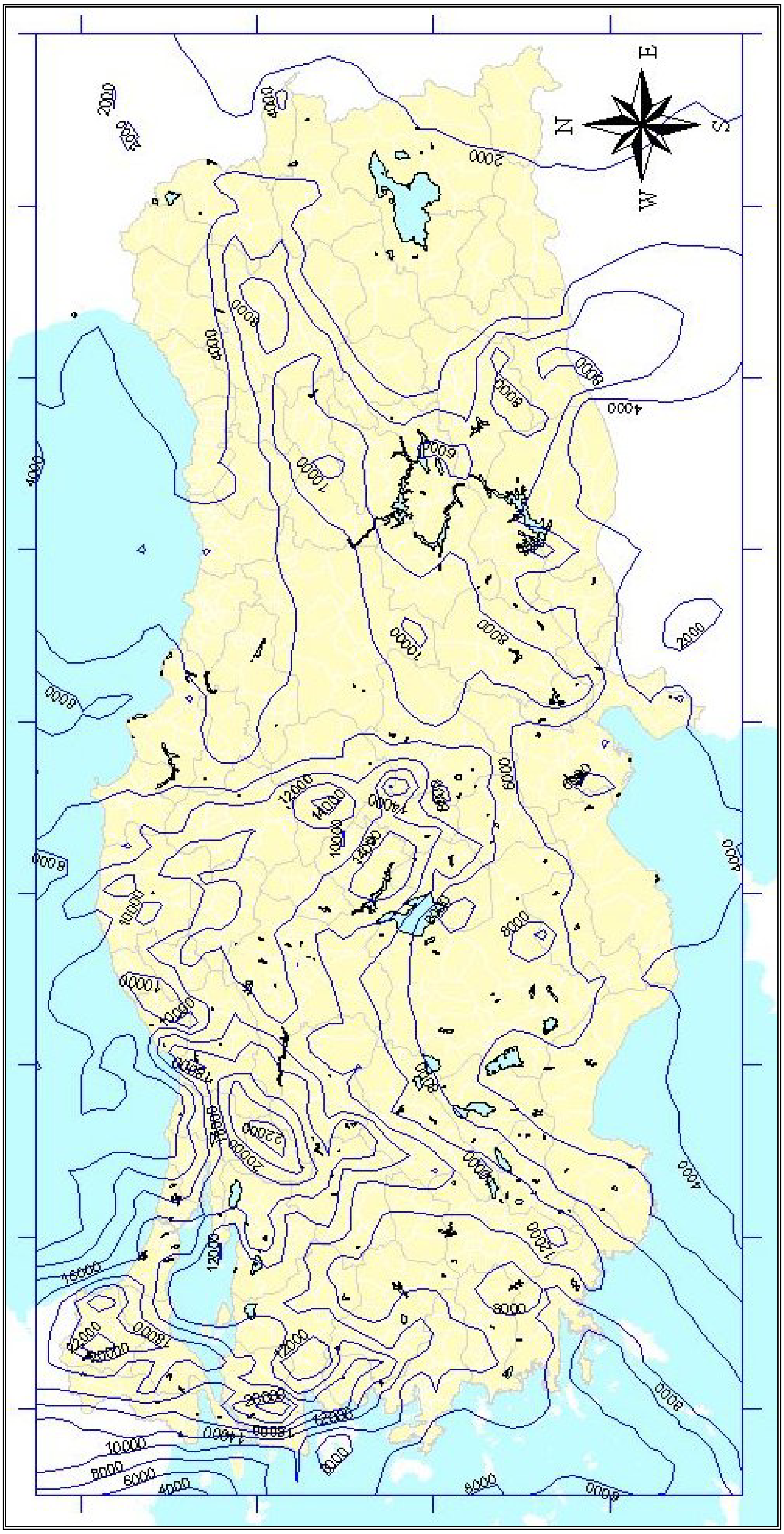
Unit: $\mu g/m^3$

Figure 4.33 Total ground level CO_2 concentrations with uptake in 1995



Unit: μg/m^3

Figure 4.34 Total ground level CO_2 concentrations with uptake in 2000



Unit: µg/m^3

Figure 4.35 Total ground level CO_2 concentrations with uptake in 2004

Total ground level CO_2 concentrations with forest sink effect are given in Figure 4.33. As shown in Figure 4.33, the maximum concentrations in 1995 obtained as 18.0 x10^3 μg/m^3 in Cihanbeyli district of Konya province and 14.0 x10^3 μg/m^3 in Tatvan district of Bitlis province, respectively. The forest CO_2 uptake decreases the ground level CO_2 concentrations in these districts 40% and 46.2% respectively. Moreover, the CO_2 concentrations were also high in Esme district of Uşak province, in Alasun district of Burdur province and Beykoz district of İstanbul province with a value of 14.0 x10^3 μg/m^3.

The CO_2 concentrations of Marmara Region were always the highest throughout the years. The values obtained were 22.84 in 1996; 17.11 in 1997; 20.15 in 1998 and 20.0 x10^3 μg/m^3 in 2001. The respective percentages of decrease in the ground level CO_2 concentrations by forest uptake were calculated as 12.15%, 28.71%, 22.50% and 60.0% for these years.

As a result of high rate CO_2 uptake of forest in the Marmara Region in 2001, the places of the highest CO_2 concentrations with uptake were changed to Eskişehir province of the Central Anatolia Region and Bolu province of the Blacksea Region with a value of 35.0 x10^3 μg/m^3.

In 1998, the area around Zonguldak province and Kastamonu province in the Blacksea Region and the area between Ankara, Konya and Eskişehir provinces in the Central Anatolia Region were also estimated highly. The maximum CO_2 concentrations were 35.9 and 23.1 x10^3 μg/m^3 in these respective areas. According to the comparison of the model results obtained with and without sink effect, the decreases by forests were calculated as 5.53% and 3.75%, respectively.

The Blacksea, Marmara, Central Anatolia and Aegean Regions were highly polluted with CO_2 in 1999 and 2000. For 1999, the ground level CO_2 concentrations in these regions were 29.3, 19.8, 23.3 and 21.1 x10^3 μg/m^3. Therefore, the ground level CO_2 concentrations of these regions were decreased 20.3%, 34.14%, 3.10% and 12.17% by forest, respectively. For these regions, the respective CO_2 concentrations in 2000 were 12.0, 24.0, 20.0 and 10.0 x10^3 μg/m^3. It is also shown in Figure 4.34. As a result, the forests of these regions decreased the ground level CO_2 concentrations 53.9%, 36.8%, 20.0% and 61.54%, respectively.

The Eagean Region especially around Manisa province was estimated as the highest polluted area in 2002. The CO_2 concentration in this region was observed as 18.0 $x10^3$ μg/m^3. The forest effect on this concentration was about 18.2%. As can be seen from the Figure 4.35, the highest ground level CO_2 concentrations in 2004 were observed in Kırklareli and Bilecik provinces of Marmara Region with a value of 22.0 $x10^3$ μg/m^3. And, the forest effect on this concentration was calculated as 35.3%.

From the obtained results, it may also be concluded that the South-Eastern Anatolia Region were not affected with CO_2 sink, because there are not much forest areas.

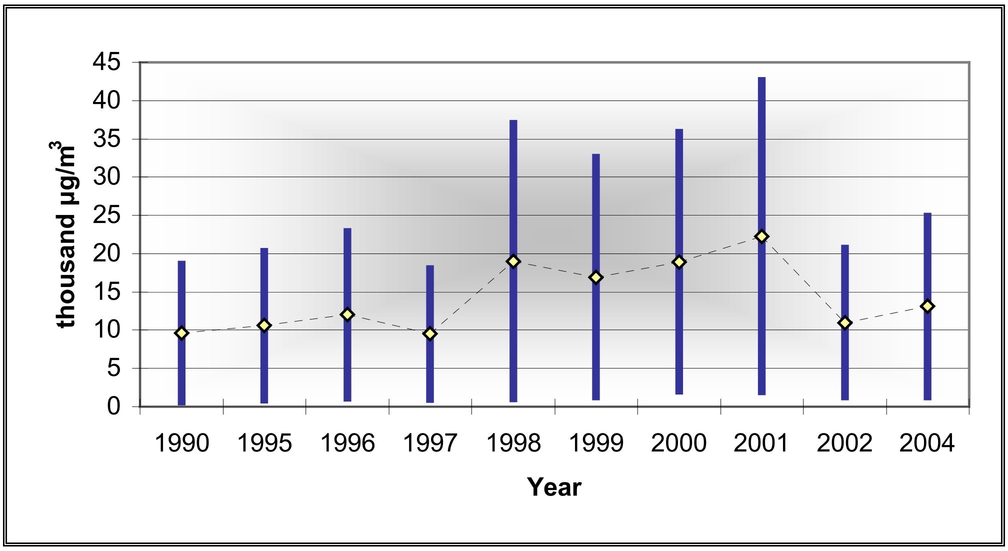


Figure 4.36 Average ground level CO_2 concentrations with CO_2 uptake over Turkey

As a general, the ground level CO_2 concentrations were decreasing considerably after running the dispersion model using the emissions with sink effect. The decrease in the average CO_2 concentration in 1997 was around 45% and it was the highest one during the period between 1990 and 2004. The lowest decrease in the average CO_2 concentration was obtained in 2002 with a value of 21.6%. Therefore, it may be concluded that forest are very important for decreasing the ground level CO_2 concentration.

Although the concentrations mentioned in this section with sink effect were lower estimations compared to the results without sink effect, the values were still high.

As shown in the Figure 4.36, there was a small rise in the average CO_2 concentration throughout the years. The maximum annual average CO_2 concentration was observed in 2001 with 22.3 $x10^3$ $\mu g/m^3$. Moreover, the values estimated as 19 $x10^3$ $\mu g/m^3$ for the years of 1998 and 2000 were the second highest concentration. From the figures, it can also be concluded that, the lowest average CO_2 concentration value was observed as 9.5 $x10^3$ $\mu g/m^3$ in 1997. For the years of 1990 and 2002, the concentrations were also as low as the value of 1997. The concentrations of these years were 9.6 and 11.0 $x10^3$ $\mu g/m^3$, respectively. According to the comparison of the dispersion model results obtained with and without CO_2 uptake, the annual average CO_2 uptake percentage of the forest was obtained approximately 29% during the period between 1990 and 2004.

4.2.2.1. Industries

The annual ground level concentrations of CO_2 in 1990 estimated from the industrial sources are shown in figure K.9 in Appendix. As can be seen from the figure, the highest CO_2 concentration was observed in Yozgat and Kırşehir provinces with a value of 5.7 $x10^3$ $\mu g/m^3$. The forest effect on this concentration was 20.94%.

The CO_2 concentrations of Marmara Regions were always the highest throughout the years. The values obtained were 5.61 in 1996; 4.48, 4.0 in 1998; 5.0 in 2000; 4.0 in 2001; 4.0 in 2002 and 9.0 $x10^3$ $\mu g/m^3$ in 2004. The contribution of the industries in this region to the ground level CO_2 concentrations was obtained considerably high. According to the comparison of the model results obtained with and without sink effect, the decreases of the CO_2 concentrations throughout the years were determined as 86.01% in 1995, 30.05%, 48.56%, 45.95% in 1998, 28.57% in 2000, 71.43%, 50.0% in 2002 and 40.4% in 2004.

According to the results of 1999, the CO_2 concentration in the area between the Tekirdağ, Kırkareli and Edirne provinces was estimated as 6.0 x10^3 $\mu g/m^3$. The forest effect on this concentration was about 61.7%. In addition, Emirdağ district of Afyon province and Dörtyol district of Hatay province were also polluted as much as this area. However, the highest concentration in this year was observed in Mengen district of Bolu province with a value of 8.0 x10^3 $\mu g/m^3$.

For the year of 2000, the concentration in Sivas province in the Central Anatolia Region was high with a value of 6.62 x10^3 $\mu g/m^3$. In this province, forests decreased the ground level CO_2 concentrations around 5.43%.

In 2001, the CO_2 concentration in Bolu province of the Blacksea Region and Eskişehir province of the Central Anatolia Region were also high with values of 9.0 and 6.0 x10^3 $\mu g/m^3$, respectively. The ground level CO_2 concentrations of these provinces were decreased 40.0% and 57.14% by CO_2 uptake. Because of high rate CO_2 uptake of forest around the same area, the places of the highest ground level CO_2 concentration were changed from Eskişehir to Ankara province with a value of 8.0 x10^3 $\mu g/m^3$. The concentration in Bolu province was also as high as that in Ankara province.

From the results of 2002, the highest CO_2 concentration was observed in Derinkuyu district of Nevşehir province with 5.5 x10^3 $\mu g/m^3$.

As can be seen from the Figure K.10 in Appendix, the ground level CO_2 concentrations of the area between Afyon and Kütahya provinces in Aegean Region and Eskişehir province in Central Anatolia Region in 2004 were 6.0 x10^3 $\mu g/m^3$. The concentration was decreased from 9.0 x10^3 $\mu g/m^3$, which was obtained without CO_2 uptake. Therefore, the forest effect on this concentration was about 33.3%.

According to the dispersion model results obtained with CO_2 uptake for the years between 1990 and 2004, the highest industrial CO_2 concentration observed in Eastern Anatolia Region and the South-eastern Anatolia Region was less than 4.0 x10^3 μg/m^3. The forests in these regions are not enough to decrease the ground level CO_2 concentration.

4.2.2.2. Households

As can be seen from the figure given in Appendix K for 1990, the highest CO_2 concentration with CO_2 uptake from the households was observed in Kırıkkale and Kırşehir provinces of the Central Anatolia Region with a value of 9.68 x10^3 μg/m^3. The forest effect on this concentration was 12.48%. In other regions, the ground level CO_2 concentrations were between 2 and 4 x10^3 μg/m^3.

From the results of 1995, the CO_2 concentration of the Marmara Region was 6.0 x10^3 μg/m^3. In the Central Anatolia Region, the CO_2 concentration in Ankara and Eskişehir provinces were also estimated highly with a value of 9.23 x10^3 μg/m^3. Therefore, the ground level CO_2 concentrations were decreased about 57.14% in the Marmara Region and 22.44% in the Central Anatolia Region.

In 1996 and 1997, Marmara Region was again the highest polluted region. The respective ground level CO_2 concentrations in İstanbul province for these years were 7.4 and 7.3 x10^3 μg/m^3. The forest effects on these concentrations were 37.8% and 48.47% respectively. The CO_2 concentration in Pasinler district of Erzurum province for 1996 was around 4.0 x10^3 μg/m^3. The ground level CO_2 concentrations were decreased 42.86% in this province.

The CO_2 concentrations in Zonguldak province of the Black Sea Region and in Kırşehir province of the Central Anatolia Region were 10.0 and 12.4 x10^3 μg/m^3. These concentrations were decreased by sink effect from 14.0 x10^3 μg/m^3. In Marmara Region, the highest annual ground level CO_2 concentration in 1998 was 8.0 x10^3 μg/m^3. The forest effects on these concentrations were approximately 27.9%.

In Central Anatolia Region, the average annual ground level concentration for CO_2 was estimated in 1999 as 9 x10^3 μg/m^3. Therefore, the ground level CO_2 concentration of this region was decreased 10.0%. In this year, Kargı district of

Çorum province was the highest polluted area with a value of 13.71 x10^3 μg/m^3. The decrease of the CO_2 concentrations was 27.65%.

The ground level CO_2 concentration of Ağrı province in the Eastern Anatolia Region, İstanbul province in the Marmara Region and Ankara province in the Central Anatolia region were estimated as 12.0, 8.0 and 13.17 x10^3 μg/m^3. These values were the highest in 2000. The forest effects on these concentrations were 20.0%, 48.9% and 24.07%, respectively. Moreover, in the area between Aksaray, Kırşehir and Nevşehir provinces and in Iğdır province, the concentrations were also high as much as in İstanbul.

As can be seen from results, the highest ground level CO_2 concentration in 2001 was estimated in Bolu province of the Blacksea Region with a value of 12.0 x10^3 μg/m^3. The forest CO_2 uptake was 45.5%. The central Anatolia Region was also polluted in this year. In Nallıhan district of Ankara province and in Kırşehir province, the CO_2 concentrations from households were 10.0 and 12.0 x10^3 μg/m^3 respectively. The ground level CO_2 concentrations of these areas were decreased 44.4% and 40.0% respectively.

The CO_2 concentrations in Marmara Region were 5.0 in 2002 and 8.0 x10^3 μg/m^3 in 2004. The respective decreases of the CO_2 concentrations were determined as 58.78% and 47.68%. In 2002, the highest ground level CO_2 concentration was observed in Aksaray district of the Central Anatolia Region. The CO_2 uptake was 22.2%.

4.2.2.3. Thermal Power Plants

For the year of 1990, the highest ground level CO_2 concentration was estimated in Kahramanmaraş with 14.04 x10^3 μg/m^3. The Afşin-Elbistan Thermal Power Plant contributed to the ground level CO_2 concentration highly in this province. However, the ground level CO_2 concentration of this province was decreased 8.59% by the CO_2 uptake of forest. This was also seen in the Figure K.13 in Appendix.

The entire Mediterranean and South-Eastern Anatolia Regions and the south of the Eastern Anatolia, Central Anatolia and Aegean Regions were polluted highly by CO_2 in 1995. The ground level CO_2 concentrations in Sariyahşi of Aksaray province and Tatvan of Bitlis province were obtained as 8.0 $x10^3$ $\mu g/m^3$. The decrease of the CO_2 concentrations for these districts was 42.86%. Moreover, the north of the Turkey covering the north of Eastern Anatolia, Central Anatolia, Aegean Regions and the entire Marmara and the Black Sea Regions were polluted lower than 0.5 $x10^3$ $\mu g/m^3$ with sink effect.

In 1996, the CO_2 concentrations were estimated as 7.7 $x10^3$ $\mu g/m^3$ in İstanbul (Marmara Region), 4.8 $x10^3$ $\mu g/m^3$ in Kırklareli (Marmara Region), 7.12 $x10^3$ $\mu g/m^3$ in Dikilli district of İzmir province (Aegean Regions) and 2.84 $x10^3$ $\mu g/m^3$ in Afşin district of Kahramanmaraş province (Mediterranean Region). According to the comparison of the dispersion model results obtained with and without CO_2 uptake, the respective decreases of the ground level CO_2 concentrations in these districts and provinces were obtained as 7.12% in İstanbul province, 31.43% in Kırklareli province, 5.94% in Dikilli district and 6.58% in Afşin district.

For the results of 1997, it was seen that the annual ground level CO_2 concentrations at Kütahya province was estimated as 4.54 $x10^3$ $\mu g/m^3$. The forest effect on this concentration was 33.24%. The other polluted provinces were İstanbul and Kırklareli in the Marmara Region. The concentrations in these provinces were 5.0 $x10^3$ $\mu g/m^3$. Therefore, the decrease on these concentrations was 16.67%.

The ground level CO_2 concentration in the Ankara province of the Central Anatolia Region was 8.0 $x10^3$ $\mu g/m^3$ in 1998. The rate of the forest uptake was 24.1%. However, the CO_2 concentrations in Devrek district of Zonguldak province, in Doğanyurt district of Kastamonu province and in Bolu province were also high as much as that in Ankara.

The highest ground level CO_2 concentrations with sink effect in 1999 were estimated in Manisa province with a value of 9.26 $x10^3$ $\mu g/m^3$ and in İstanbul province with a value of 7.8 $x10^3$ $\mu g/m^3$. The other highest polluted local areas were 6.0 x10^3 μg/m^3 in Bolu province, 4.0 x10^3 μg/m^3 in Kırklareli province and 3.0 x10^3 μg/m^3 in Kahramanmaraş province. The decreases of the ground level CO_2 concentrations in these provinces were obtained as 13.86% in Manisa, 18.50% in İstanbul, 24.05% in Bolu, 33.33% in Kırklareli and 50.0% in Kahramanmaraş.

The ground level CO_2 concentration in the Marmara Region was estimated as 18.74 x10^3 μg/m^3 in 2000. In the northwest of Central Anatolia Region, especially in Eskişehir province, the concentration was about 10.0 x10^3 μg/m^3. The forest effects on these concentrations were calculated as 3.30% and 16.67%, respectively.

It may be concluded that the CO_2 pollution was estimated highly in 2001. In most of the regions (Marmara, Aegean, Central Anatolia, west of Blacksea), the annual ground level CO_2 concentrations were between 4.0 and 10.0 x10^3 μg/m^3. The highest decreases of the ground level CO_2 concentrations were obtained in Bolu province with a value of 20%.

As we mentioned in section 4.2.1.3, the CO_2 pollution in 2002 was not high. From the results with sink effect, this conclusion can also be inferred. In this year, the highest pollution was observed in Bursa with a value of 5.7 x10^3 μg/m^3. The Afşin district of Kahramanmaraş province was the second highest polluted local area with a value of 4.0 x10^3 μg/m^3 CO_2 concentration. The rates of the decrease in CO_2 concentration in Bursa and Kahramanmaraş provinces were 20.28% and 33.67% respectively.

According to the Figure K.14 in Appendix, it may be concluded that the highest pollution in 2004 was observed in Zonguldak province in the Blacksea Region with a value of 10.0 x10^3 μg/m^3. In Kırklareli province in the Marmara Region was also estimated highly with a value of 7.9 x10^3 μg/m^3. The respective forest effects on these concentrations were estimated as 7.41% and 21.0%.

4.2.2.4. Road Vehicles

The highest polluted region was determined as Marmara Region throughout the years. However, the highest ground level CO_2 concentration in 1990 was observed in the area between Kırşehir and Yozgat provinces in the Central Anatolia Region with a value of 4.48 $x10^3$ $\mu g/m^3$. The second highest ground level CO_2 concentration from the road vehicles was seen in the Marmara Region with a value of 3.76 $x10^3$ $\mu g/m^3$. The rates of the decrease in CO_2 concentration in the Central Anatolia Region and in the Marmara Region were 10.40% and 37.85%. Therefore, it can be concluded that the forest in the Marmara Regions are very effective for decreasing the ground level CO_2 concentrations. Road vehicles also polluted the Karşıyaka district of İzmir provinces. The CO_2 concentration was 2.5 $x10^3$ $\mu g/m^3$. The forest effects were calculated as 50.0%.

The ground level CO_2 concentration in 1995 was estimated highly in Ankara province with a value of 5.46 $x10^3$ $\mu g/m^3$. The forest effect on this concentration was calculated as 9.0%. In the other province of Turkey, the ground level CO_2 concentrations were not high.

In 1996 and 1997, the highest ground level CO_2 concentrations were estimated in the Marmara Region with 5.74 and 4.87 $x10^3$ $\mu g/m^3$. The decreases of the ground level CO_2 concentrations for these years were 18.0% and 18.8%, respectively.

It can be concluded that in most part of the Marmara Region, the annual ground level CO_2 concentrations from the Road Vehicles in 1998 were between 2.0 and 4.0 $x10^3$ $\mu g/m^3$. In the west of Blacksea Region, the concentrations were between 3.0 and 5.0 $x10^3$ $\mu g/m^3$. In 1998, the highest CO_2 concentration was observed in Pınarbaşı district of Kastamonu province of the Blacksea Region with a value of 6.33 $x10^3$ $\mu g/m^3$. According to the comparison of the dispersion model results obtained with and without CO_2 uptake, the decrease of the ground level CO_2 concentration in this district was 9.57%.

From the results of 1999, it may be inferred that in most of the regions, the CO_2 concentrations were between 1.0 and 4.0 $x10^3$ $\mu g/m^3$. However, in the

Osmaneli district of Çorum province in the Central Anatolia Region, the ground level CO_2 concentration was estimated a little higher with a value of 5.0 $x10^3$ $\mu g/m^3$. The decrease on this concentration was about 37.50%. However, the highest concentration in this year was estimated in Bolu province with a value of 6.0 $x10^3$ $\mu g/m^3$. Although the concentration was high, 14.29% decrease was calculated in the ground level CO_2 concentration compared the results without CO_2 uptake.

The Marmara Region, especially Istanbul province, was again obtained as the highest polluted region in 2000. The concentration was 4.0 $x10^3$ $\mu g/m^3$. In the area between Ankara and Aksaray provinces and in Yozgat province, the concentrations were also high as much as İstanbul province. The decreases of the ground level CO_2 concentrations were 58.2% in the Marmara Region and 20.0% in the Central Anatolia Region.

The average annual CO_2 concentrations, for the year of 2001, in the Marmara Region and in the west of Blacksea and Central Anatolia Regions were approximately 6.0 $x10^3$ $\mu g/m^3$. The forest effect on these concentrations was estimated as 25.0%. The highest regional CO_2 concentrations were estimated 7.0 $x10^3$ $\mu g/m^3$ in Akyazı district of Sakarya province, 8.0 $x10^3$ $\mu g/m^3$ in Bolu province and 7.0 $x10^3$ $\mu g/m^3$ in Eşkişehir province. The rates of the forest uptake were calculated as 41.67%, 33.33% and 41.67% respectively. The concentration in the Mediterranean Region was around 1.5 $x10^3$ $\mu g/m^3$. However, it was between 2.0 and 4.0 $x10^3$ $\mu g/m^3$ for the Aegean Region especially in İzmir province. The concentrations in Eastern Anatolia and South-Eastern Anatolia Region were below 2.0 $x10^3$ $\mu g/m^3$. In the Central Anatolia Region, the concentrations were estimated as between 4.0 and 6.0 $x10^3$ $\mu g/m^3$. From these results, it may be concluded that forest affect the ground level CO_2 concentration considerably in 2001.

The average CO_2 concentrations in 2002 were approximately 2.0 $x10^3$ $\mu g/m^3$. However, the Mediterranean, Marmara and Aegean Regions were polluted slightly more than the other regions. Approximately 30% decrease on the ground level CO_2 concentration was estimated.

From the results, the highest CO_2 concentration in 2004 was observed in Sarköy district of Tekirdağ province. The concentration was 7.29 x10^3 µg/m^3. The CO_2 uptake by forest was as 24.7%. In the Marmara Region, the concentrations were between 3.0 and 5.0 x10^3 µg/m^3. However, CO_2 concentrations in the west of Aegean Region were varying between 2.0 and 4.0 x10^3 µg/m^3. Moreover, the ground level CO_2 concentrations in the east of Aegean Region and in the west of Central Anatolia Region were between 2.0 and 3.0 x10^3 µg/m^3. In the other regions, the concentrations were below 2.0 x10^3 µg/m^3. From these results, it may be concluded that the CO_2 concentration decrease was approximately 35%.

4.2.3. Evaluation of Model Results

The determination of the model performance is very important because several assumptions made during the prediction of ground level CO_2 concentrations may cause some significant errors. Basically there isn't any CO_2 concentration measurement station in Turkey. For that reason, the CO_2 concentration over Turkey is estimated by using the measured CO_2 concentration of the nearest stations around Turkey as explained in Chapter 2.

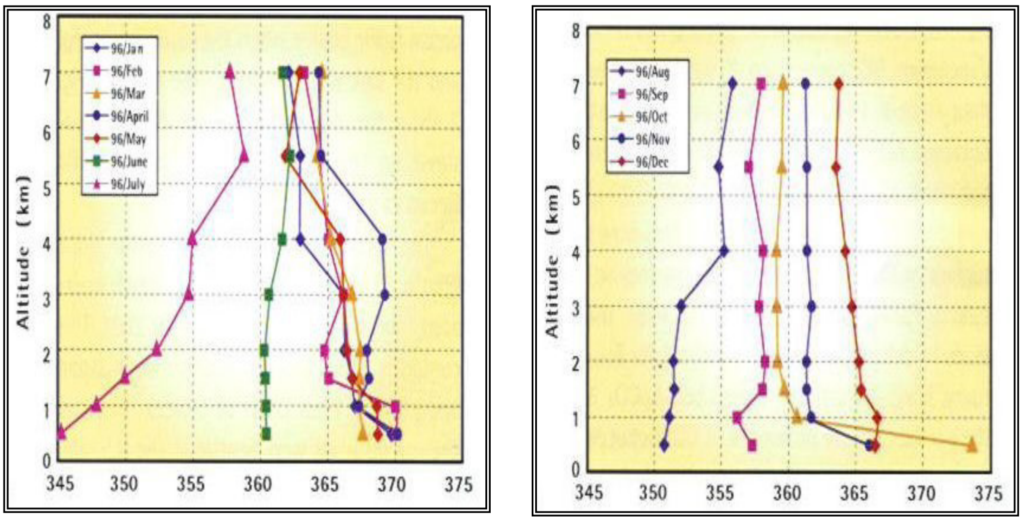


Figure 4.37 Vertical profiles of CO_2 concentration [15]

Two data sets could only be comparable statistically. Because the dispersion model values (predicted values) are the ground level CO_2 concentration and observed values (estimated by using station measurements around Turkey) are the upper atmospheric concentration.

As can be seen from the vertical profiles of CO_2 concentration given in Figure 4.37, there is a relationship between upper and ground level concentrations. However, there are some seasonal variations. The main reason is the effect of sinks and sources [15]. Therefore, annual trends in the atmospheric concentration of pollutants may indicate the change on the ground level concentration. Dlugokency et al. [10] used such type of approaches.

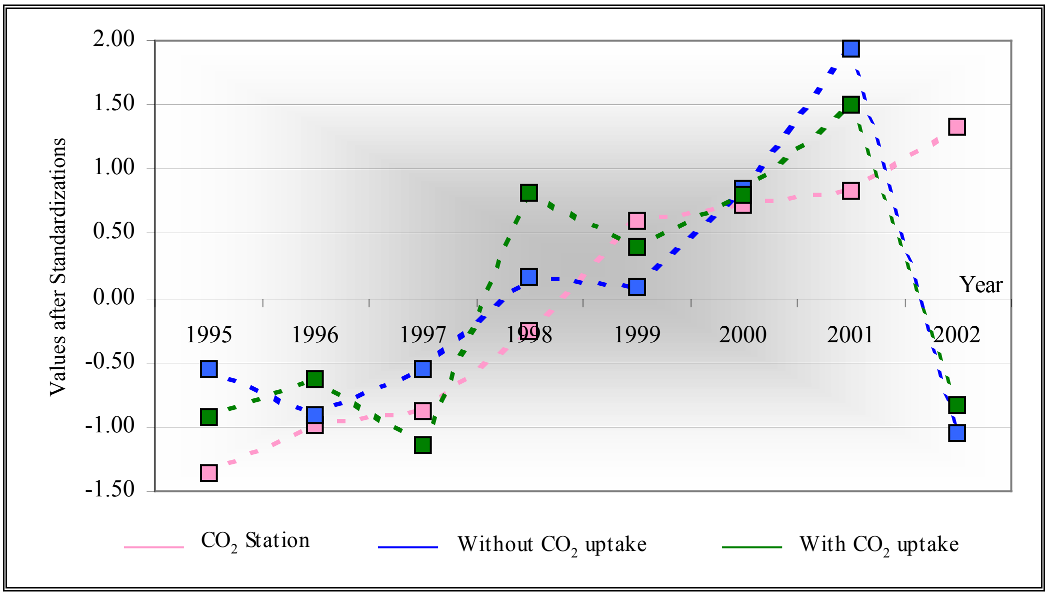


Figure 4.38 Standardization of the values

As explained in Chapter 3, in order to compare data sets formed by the ISCLT3 model predicted values and the upper atmospheric observed values, standardization (i.e., normalization according to the distribution characterized by mean and standard deviation of the values) is needed. The standardizations of the series calculated according to the formula given in section 3.4.5 are shown in Figure 4.38.

Table 4.8 Results of the K-Mean Cluster Analysis

Year	Case 1 Observed series & predicted series without CO_2 uptake		Case 2 Observed series & predicted series with CO_2 uptake	
	Cluster	Distance	Cluster	Distance
1995	1	0.929	1	0.887
1996	1	0.650	1	0.579
1997	1	0.441	1	0.477
1998	1	0.764	2	0.736
1999	2	0.877	2	0.505
2000	2	0.114	2	0.256
2001	2	0.989	2	0.722
2002	1	1.823	1	1.804

The two data sets including observed series and predicted series without uptake were paired and tested to determine the homogeneous groups by using K-Mean Cluster Analysis. Observed series and predicted series with uptake were also paired and tested. The results are given in the Table 4.8. According to the Table 4.8, the results show that the distances between the 2002 data and the cluster center were high compared to the other results. Moreover, the paired data for 2002 were inserted in the 1st cluster. In another words, it formed the homogenous group with the paired data of 1995, 1996, 1997 and 1998 for case 1 and it formed a group with the data of 1995, 1996 and 1997 for case 2. In order to understand whether the observed and predicted series are related to each other or not and to what extent, the internal consistency test named as Cronbach Alfa Reliability Analysis based on average correlation among items were used. The observed and predicted series were tested for four cases. In the first and the second cases, the data sets of 2002 were included. However, in the third and the fourth cases, the data sets of 2002 were not included. The explanation of the cases and the test results obtained are presented in Table 4.9.

Table 4.9 Cases and Results of the Cronbach Alfa Reliability Analysis

Cronbach Alfa Reliability Analysis	Observed series & predicted series without CO_2 uptake	Observed series & predicted series with CO_2 uptake
With 2002 data	**Case 1**	**Case 2**
Without 2002 data	**Case 3**	**Case 4**

Cases	**Case1**	**Case2**	**Case3**	**Case4**
Cronbach Alfa (α) Value	0.5940	0.6817	0.9191	0.9361

As can be seen from the Table 4.9, it can be concluded that the highest alfa values were observed for the cases 3 and 4 with 0.9191 and 0.9361, respectively. This means that the series reliability is higher without the data of year 2002. Moreover CO_2 uptake also increases the series reliability. Compared with case 1, the reliability of case 2 is increased approximately 14% and compared with case 3, the reliability of case 4 is increased only 2%.

Table 4.10 Correlation Coefficients and Covariance between series

Correlation Coefficient	Observed series & predicted series without CO_2 Uptake	Observed series & predicted series with CO_2 Uptake
With 2002 data	0.4229	0.5172
Without 2002 data	0.8504	0.8798

Covariance	Observed series & predicted series without CO_2 Uptake	Observed series & predicted series with CO_2 Uptake
With 2002 data	0.3705	0.4524
Without 2002 data	0.6509	0.6985

The Correlation Coefficients between series also shows that omitting the data of 2002 increased the relationship between series. Omitting the 2002 data, the correlations were increased about 101.1% for the series *without CO_2 uptake* and 70.1% for the series *with CO_2 uptake*. Moreover, the highest correlation coefficient without 2002 data was obtained as 0.8798 between the predicted with uptake and the observed series. This value shows a high relationship between two series. The results of the correlation coefficients were given in Table 4.10.

The deviations between variables were calculated by using the covariance between the series. According to the results given in Table 4.10, the deviations between the variables lower than 1. Therefore, it may be concluded that there were not significant deviations between the normalized series in all cases.

Trend analyses of the series, using Mann-Kendal Rank Correlation Test show that the observed series have statistically significant increasing trend. and the predicted series show no trend with 2002 data. However, without 2002 data, both predicted series show statistically significant increasing trend according to the 0.05 significance level. The test value u(t) for the series without CO_2 uptake is 2.55 and the test value for the series with CO_2 uptake is 1.97. The results of the analyses for series are given in Table 4.11.

Table 4.11 Results of the Mann-Kendall Rank Correlation

Mann-Kendall Rank Correlation		u(t)	TREND	Significance level
With 2002	**Observed series**	3.34	NO	0.05
	Predicted series without CO_2 Uptake	1.237	NO	0.1
	Predicted series with CO_2 Uptake	1.237	NO	0.1
Without 2002	**Observed series**	3.003	+	0.005
	Predicted series without CO_2 Uptake	2.553	+	0.05
	Predicted series with CO_2 Uptake	1.972	+	0.05

NO: NO trend; +: Increasing trend, -: Decreasing trend

4.2.4. Sensitivity Analyses for Dispersion Modeling

The parameters of ISCLT3 model were tested by using the sensitivity analysis. Each parameter in the “Runstream File” was increased and decreased with 10%, 5%, 3%, 2% and 1% and the variations of the ground level CO_2 concentrations were observed on the two-receptor points shown in Figure 4.39. The following variables were selected as the key parameters in these analyses.

For source pathway: Source elevation, emission rate, release stack height, temperature in stack, stack gas exit velocity and stack diameter

For receptor pathway: Receptor elevation

For meteorological pathway: Air temperature, mixing height

The normalized sensitivities were calculated by using the formula given by Ünlü and et al. [97];

$$\sum_i \equiv \frac{\partial(C/\overline{C})}{\partial(p_i/\overline{p_i})} = \frac{C(\overline{p_i}+\Delta p_i)-C(p_i)}{\Delta p_i}\cdot\frac{\overline{p_i}}{C(\overline{p_i})}$$

where, $\overline{p_i}$ is the base case value of the parameters

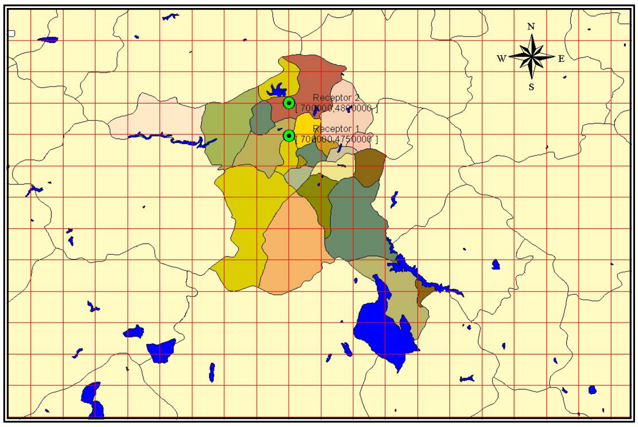


Figure 4.39 Selected two-receptor points for observing CO_2 concentration variations

According to the analyses, the emission rate, the mixing height and the release height were determined as the most important parameters for ISCLT3 model. The concentrations at the receptor points were increasing as the emission rate was increased. Therefore, it may be concluded that there is a direct relationship between the emission rate of stack and the CO_2 concentration at the selected receptor points. When the emission rates were increased 10% for each stack, the CO_2 concentrations at the receptors increased 10%. The results show that another important parameter is the mixing height. However, the relation between the mixing height and the ground level CO_2 concentration were inversely determined. As can be seen from the Table L.1, afternoon mixing height (Z_{PM}) was more effective than the morning mixing height (Z_{AM}). The 10% increase and decrease in the Z_{PM} values resulted in –8.8% and 10.9% change in the concentrations, respectively. The third important parameter was inferred as the stack height. However, the effect of this parameter was smaller compared to previous two parameters. The other parameters were not as significant as the mentioned parameters.

CHAPTER 5

CONCLUSIONS AND FUTURE RECOMMENDATIONS

5.1. Conclusions

The CO_2 emission inventory, the CO_2 uptake inventory and the dispersion modeling calculations in this detail (regional, provincial and district level) have not been done previously in Turkey. This type of study is very important especially for regional and provincial development programs of the governments. Therefore, this study could be used by policy makers, provincial authorities, air dispersion modelers, national inventory reporters and some scientist.

The CO_2 emission inventory studies carried out between the years 1990 and 2003 showed that the lowest CO_2 emission was in 1990 with a value of 142.45 million tones/year and the highest emission was in 2000 with a value of 207.97 million tones/year. There is an increasing trend seen in the CO_2 emissions.

In this study, it has been found that CO_2 emissions and concentrations in various parts of Turkey changes drastically. There are large differences in the CO_2 emissions between the regions. The lowest CO_2 emission of the regions is observed in 1990 and the highest is observed in 2000 in the period of 1990-2003 and there is an increasing emission trend for the period of 2004-2010.

Analysis of the regional results showed that the highest CO_2 emission is in the Marmara region with 65.8 million tones in 2002. The percentage increase of emission compared to the base year 1990 is found as 54.4%. The inventory of the Eastern and South-Eastern Anatolia Region only showed 3.0% regional contribution to the national emission. It could be concluded that Marmara and Aegean regions are responsible for half of the emission of Turkey, because these regions are the most industrialized regions of the country. Furthermore, emission estimations showed that CO_2 emission of Turkey will reach approximately 300 million tones in 2010.

As far as the CO_2 emissions in districts are considered, İskenderun district of Hatay province, Afşin district of K.Maraş province and Üsküdar district of İstanbul province emit the highest quantity of CO_2 in Turkey.

The result of this study also showed that forest areas are not broad enough in Central Anatolia, Eastern Anatolia and South-Eastern Anatolia Regions with the respective portion of 5.76, 4.16 and 2.39% of total forest areas. There is not enough sink areas for absorbing CO_2. The CO_2 uptake of forests in the coastal zone is higher than that in the inland zone. The CO_2 uptake in the Central Anatolia, Eastern Anatolia and South-Eastern Anatolia regions are 2.6, 1.9 and 1.1 million tones/year, respectively. The maximum CO_2 uptake is in the Black Sea region with a value of 16.4 million tons/year. The Marmara region has the second biggest CO_2 uptake value which is 12.0 million tons/year. It is also observed that CO_2 uptake in the Aegean and Mediterranean regions are 5.7 and 6.1 million tones/year, respectively, The maximum CO_2 uptake values are observed in the Demirköy district of Kırklareli province, Dursunbey of Balıkesir, Can of Çanakkale are 1.16, 0.96 and 0.90 million tones/year, respectively. There is no CO_2 uptake in the districts of Ağrı, Igdır and Nevşehir provinces. Moreover, there is also no CO_2 uptake in 14 districts of Ankara, 12 districts of Istanbul, 11 districts of Kayseri and 10 districts of Konya. Finally, the CO_2 uptake is present in the 741 districts out of 910 districts considered.

According to the results of dispersion modeling calculations, the highest ground level CO_2 concentration was estimated in the Marmara Region throughout the years. The maximum annual average ground level CO_2 concentration in this region was observed in 2001 with a concentration of 22.3 $x10^3$ $\mu g/m^3$.

Although the CO_2 emissions in 2002 were high, there was a sharp decline in the ground level CO_2 concentration in this year. This result can be attributed to the local winds as well as other meteorological conditions. In another words, contribution of some nearby sources to the concentration of some receptor points in the district could be determined as zero or very small owing to the transportation of the pollutant into the different area by wind.

From the results obtained in this study, it may also be concluded that the Eastern and the South-eastern Anatolia Regions were the least polluted areas throughout the years because of low level of industrialization.

The forests were found to decrease the ground level CO_2 concentration considerably. The annual average CO_2 uptake of forests was determined as 29%.

According to the increasing trend of CO_2 emissions, it can be concluded that Turkish government has to adopt emission reduction targets, because Turkey has ratified the UNFCCC and is listed in Annex I of the Convention. It means that the national CO_2 emission level has to be decreased below the level of year 1990. Turkey has not ratified the Kyoto Protocol yet. However, 189 countries have already signed the protocol and the emission reduction targets are binding the countries legally. One of the main objectives of Turkey is to be a member of the European Union. However, in the European Union, developed countries have 8% CO_2 reduction target due to the strict quantity norms in the Protocol. Therefore, this point should be kept in mind when the policies for CO_2 reduction are made.

5.2. Future Recommendations

5.2.1. Reduction of CO_2 Emissions

Although technologies and measures to reduce CO_2 emissions are continuously developing, the reduction of CO_2 emissions depends upon the high rate of application of these technologies [32]. Energy production is the main source for CO_2 emission in Turkey and it is very difficult to slow down the CO_2 emissions owing to the economical development programs and growth potential of Turkey.

This section mainly focuses on the estimation of the future CO_2 emissions in Turkey until the year 2050. Based on the results obtained in the previous chapters of this study, the average CO_2 emission in Turkey in tons per capita per year was calculated between the years 1990 and 2003, and the results are shown in Figure 5.1. The average value calculated for 2001 was 2.95 tones/capita-year. This value is very small as compared to developed European countries. CO_2 emissions per capita in some of the EU countries for the year of 2001 have been given in Figure 5.2. As can be seen from the figure, the CO_2 emissions in Germany, England and France are approximately 10.3, 6.3 and 9.2 tones/capita-year, respectively. Moreover, the average CO_2 emission per capita per year in OECD Europe is around 7.6 tones. Turkey is a developing country and the economic growth in the country is about 5-6% on the average over the last 10 years. The population in Turkey is also increasing at a rate of 1.7% on the average. According to SIS [53], the population of Turkey will reach to approximately 96.5 million in 2050. The estimated increase of population until the year 2050 is given in Figure 5.3.

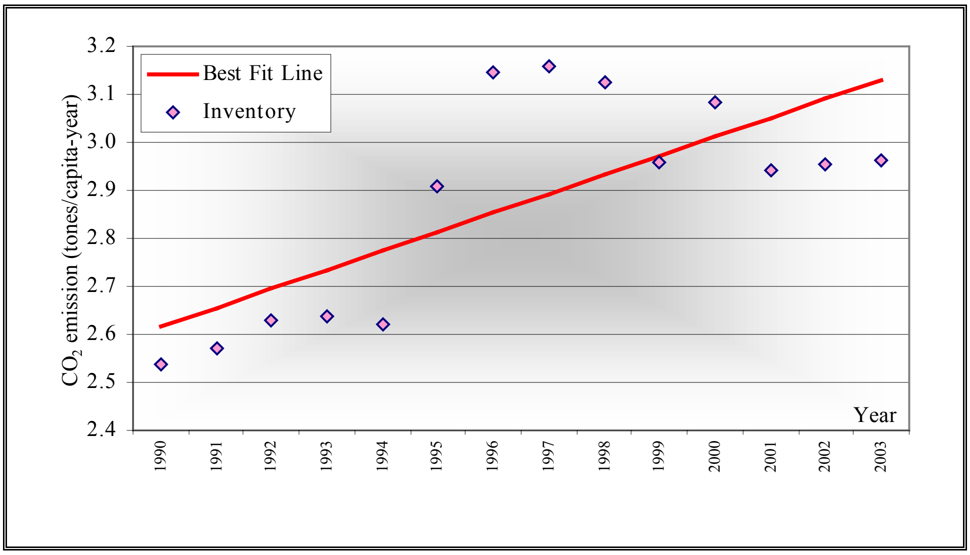


Figure 5.1 CO_2 emission per capita in Turkey

With the economical development of Turkey and with increase in the population, the CO_2 emissions are expected to increase. The increase in CO_2 emissions between the years 1990 and 2003 has been about 0.04 tones/capita-year on the average. Therefore, if this rate of economical and population growth is assumed until the year 2050, then the CO_2 emissions per capita per year will be 4.5 tones.

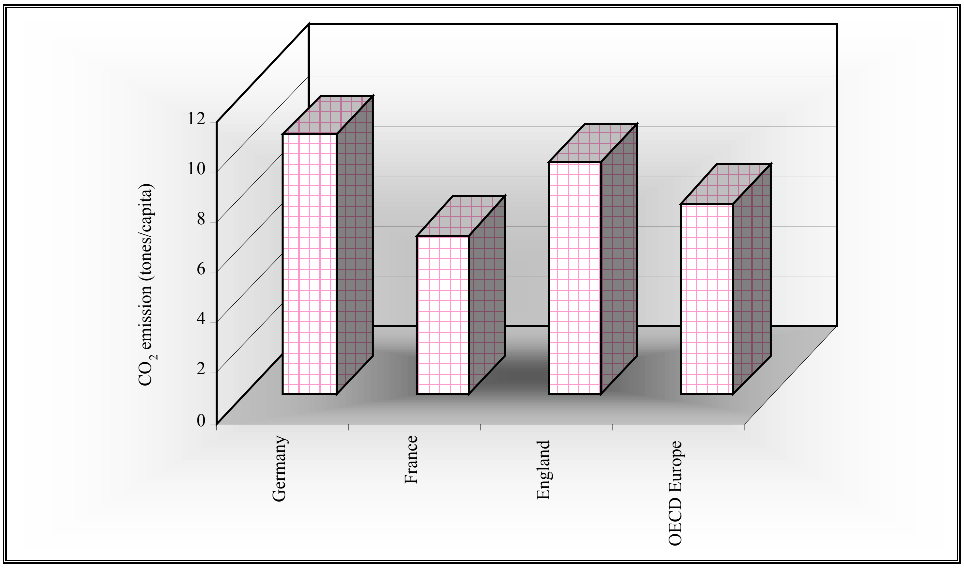


Figure 5.2 CO_2 emission per capita in Europe in 2001

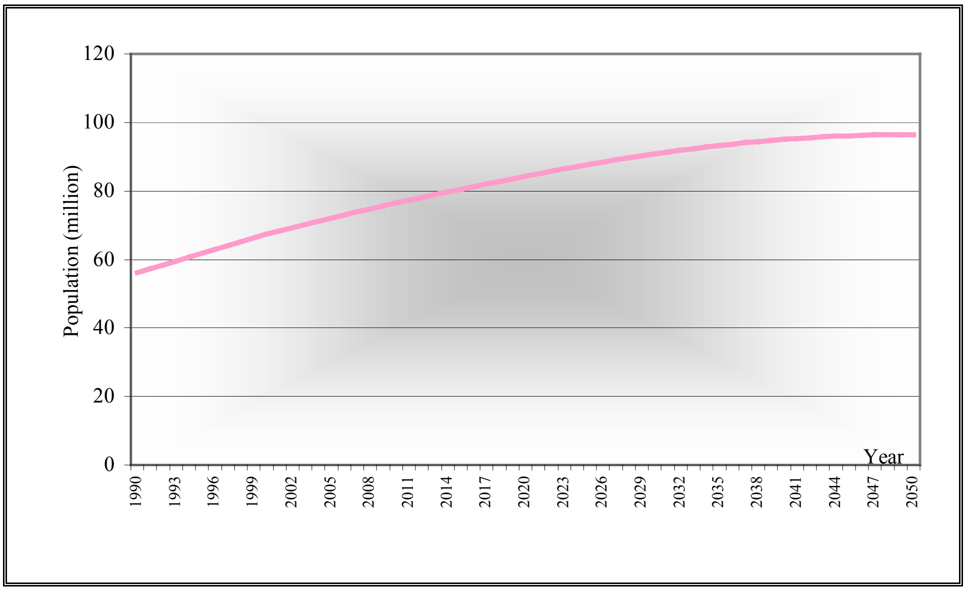


Figure 5.3 Future population of Turkey [53]

According to the IPCC [32], population growth and economical growth, technological change and environmental sensitivity are the key features in order to make future predictions, because long-term consideration of these critical factors may decrease the uncertainties of the future estimations.

In the scenarios introduced in this study, the ranges of the future trends show variations. Although the scenarios are constructed carefully, their actual outcomes can vary because the basis of the scenarios depends on assumptions.

5.2.1.1. Different Scenarios

Scenario 1: *No action is taken to decrease the CO_2 emissions and no attempt has been made to increase the forest areas*

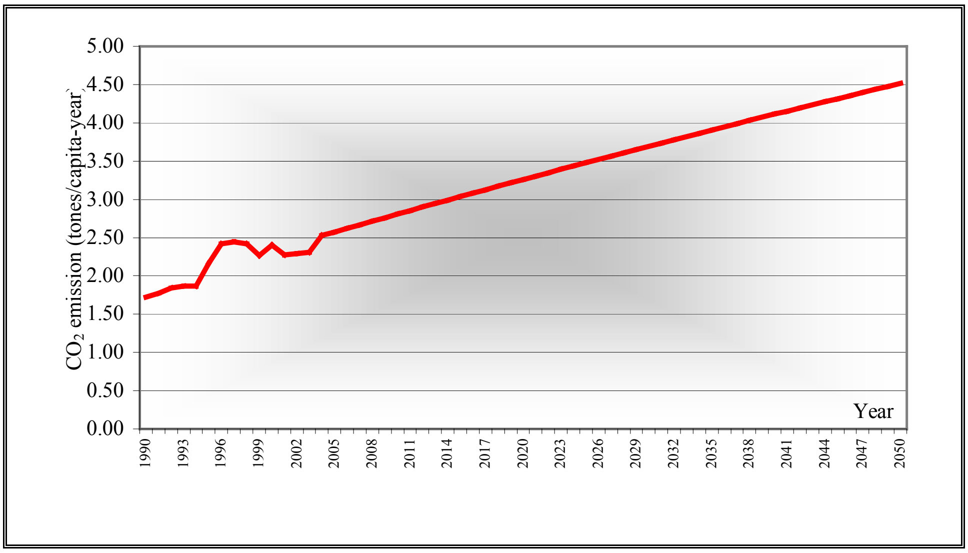


Figure 5.4 Future CO_2 emission assumptions

In order to make further predictions for the CO_2 emissions until the year 2050, demographic increase rate, the structure of economic growth and the possible CO_2 emission per capita were taken as the basis. In this scenario, it is assumed that there is no action taken to decrease CO_2 emissions. According to this assumption, CO_2 concentration will increase considerably until the year 2050 at the same rate as it did between the years 1990 and 2003. The results are given in Figure 5.4.

As can be seen from the figure, the CO_2 emission will go up to 4.5 tones per capita per year and this will cause about 436 million tones of CO_2 emission per year. From these calculations, it can be said that there is a high risk of contribution to the climate change without any action taken to decrease emissions.

Scenario 2: *Increase the good quality forest areas*

These cases depend on two strategic assumptions. These are;

- The conservation of already existing good forest areas as a carbon sink
- The increase of good forest areas further

The deforestation and socio-economic conditions are not considered in this study.

This scenario is based on increasing the forests areas in order to reduce the net CO_2 emissions.

The first alternative is to change the entire poor forests in Turkey into good forest areas by improving their quality and convert them at a rate of 4500 km^2 /year. The area of the poor forests in Turkey has been estimated as 41 856 km^2 by the MOEF [44]. The annual CO_2 uptake of this poor forest area was estimated in this study as 11.93 tones/km^2, as compared to 791.84 tones/km^2 for good quality forest area. Poor forest area will be replaced gradually with good forest area until 2050. As a result of this improvement CO_2 emission per capita per ton will drop down to 2.88 tones/year from 4.52 tones/year.

The second alternative is to change the entire poor forests in Turkey into good forest areas by improving their quality and convert them at a rate of 7500 km^2 /year in addition to the today's good forest areas. In this case the annual uptake of CO_2 is estimated in this study as 786.54 tones/km^2. As a result of this improvement, CO_2 emissions per capita per year will be 1.77 tons/year instead of 4.52 tones/year.

The third alternative is to change the entire poor forests in Turkey into good forest areas by improving their quality and convert them at a rate of 10000 km^2 /year in addition to the today's good forest areas. Based on this forested area, the annual uptake of CO_2 will be 784.68 tones/km^2. Therefore, CO_2 emissions per capita per year will be 0.85 tones/year instead of 4.52 tones/year in the case of no action taken.

The results of these 2 scenarios with alternative case studies have been shown in Figure 5.5. The total CO_2 emissions have been calculated and divided by the population to estimate the CO_2 emissions per capita per year.

As can be seen from Figure 5.5, the increase in forest area is very effective for decreasing the CO_2 emissions. The total CO_2 emissions will be 436 million tones/year in 2050 if no action is taken for CO_2 reduction.

In Case 1 of the second scenario, the total CO_2 emissions will be 278 million tons/year and there will be 36.24% in CO_2 reduction by improving the 4500 km^2 of poor forest areas into good forest area.

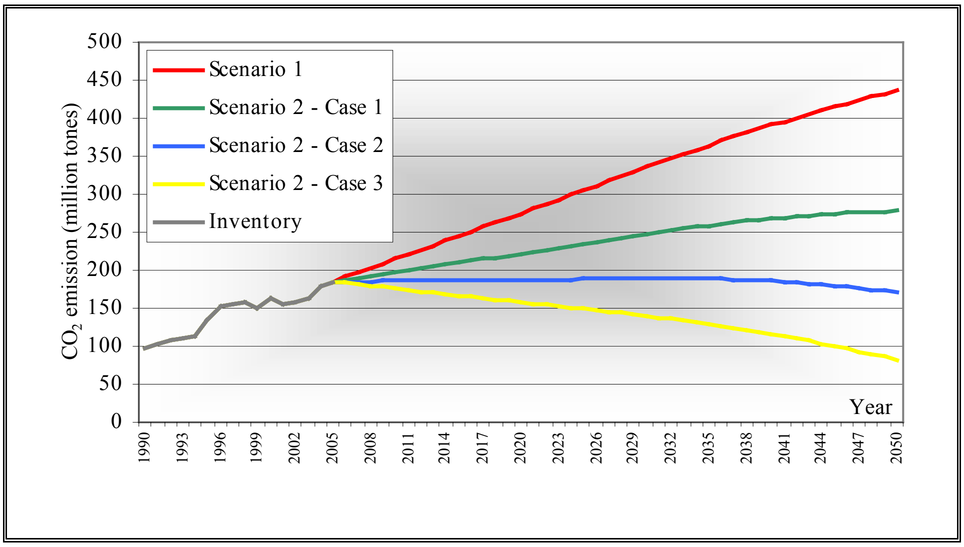


Figure 5.5 Future CO_2 emission assumptions

In Case 2 of the second scenario, the reduction in CO_2 emissions will be 60.77% by improving the 7500 km^2 of poor forest area until year 2033 and then establishing the good forest area.

In Case 3 of the second scenario, the total area of good forests are increased to 10 000 km^2 and the quality of poor forest area is improved until 2025 and then 10000 km^2 is the establishment of good forest area. The improvement in the annual CO_2 emissions with respect to the case of "no action" will be 81.21%.

5.2.2. Using Renewable Energy

Using renewable energy is a good way of decreasing CO_2 emissions. However, the trend of using renewable energy in Turkey shows a decrease between 1995 and 2004. The increasing rate of use of renewable energy will be the solution to emission problems in the long term. Most of the countries try to increase the rate of use of hydraulic, solar, geothermal and wind energy to decrease their CO_2 emissions. In Figure 5.6, the rate of use of renewable energy in Turkey between 1995 and 2004 is shown. According to the figure, Turkey's average percentage of use of renewable energy is around 10.6% between 1995 and 2004.

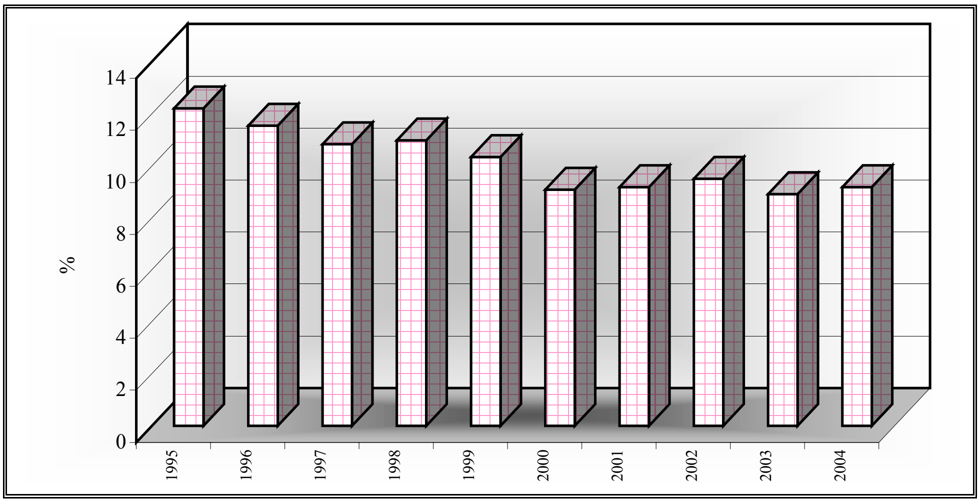


Figure 5.6 Usage rate of renewable energy between 1995 and 2004 [42]

5.2.3. Future Studies

The following studies could be done to improve this study.

- The emission inventory study could be done locally in details by studying monthly and seasonal fuel consumption data.
- The results obtained from dispersion model studies could be correlated with measured values. However, there isn't any CO_2 measurement station in Turkey. Therefore, the measured CO_2 concentration data of the nearest stations in countries around Turkey were used to estimate the synoptic CO_2 concentration over Turkey. CO_2 measurement stations can be established by investments supported by the government. The best places for the establishment of synoptic stations are Ankara, İstanbul and İzmir provinces. The CO_2 problem is in global scale and it is responsible for about 60% of the "Greenhouse Effect".
- In this study, IPCC Tier 1-method was used to estimate the CO_2 emission. However, the other IPCC methods (Tier 2 and Tier 3) could also be used to estimate the local or regional CO_2 emissions. However, these methods require additional input data.
- The private energy production companies and the mobile thermal power plants are not included in this study owing to the lack of data. However, the amounts of fuel consumption in these plants are considerably high. Consequently, a detailed inventory of these plants is needed for a complete coverage of the thermal power plants.
- Using country specific emission and uptake factors are very important for decreasing the uncertainties of the inventories. For that reason, some studies about the emission factors could be done to improve the results obtained in this study.
- Forest inventories have to be updated and regularly recorded by the responsible authorities. At present, the main data used for forest areas to calculate the CO_2 uptake amounts contains some uncertainties.
- Other dispersion models can be used to check the model results.
- Additionally, CO_2 is highly soluble in water. Therefore, precipitation effect on the ground level CO_2 concentration could be considered, because the

precipitation in Black Sea Region is very high. Average annual precipitations at Samsun, Trabzon and Zonguldak provinces in this region are 650.3, 833.8 and 1220.2 mm in 2004, respectively [43].

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APPENDIX A

In Appendix A, the following figures show the estimated CO_2 concentrations over Turkey by Kriging Method:

- CO_2 Concentration Map of Turkey in 1996
- CO_2 Concentration Map of Turkey in 1997
- CO_2 Concentration Map of Turkey in 1998
- CO_2 Concentration Map of Turkey in 1999
- CO_2 Concentration Map of Turkey in 2001
- CO_2 Concentration Map of Turkey in 2002

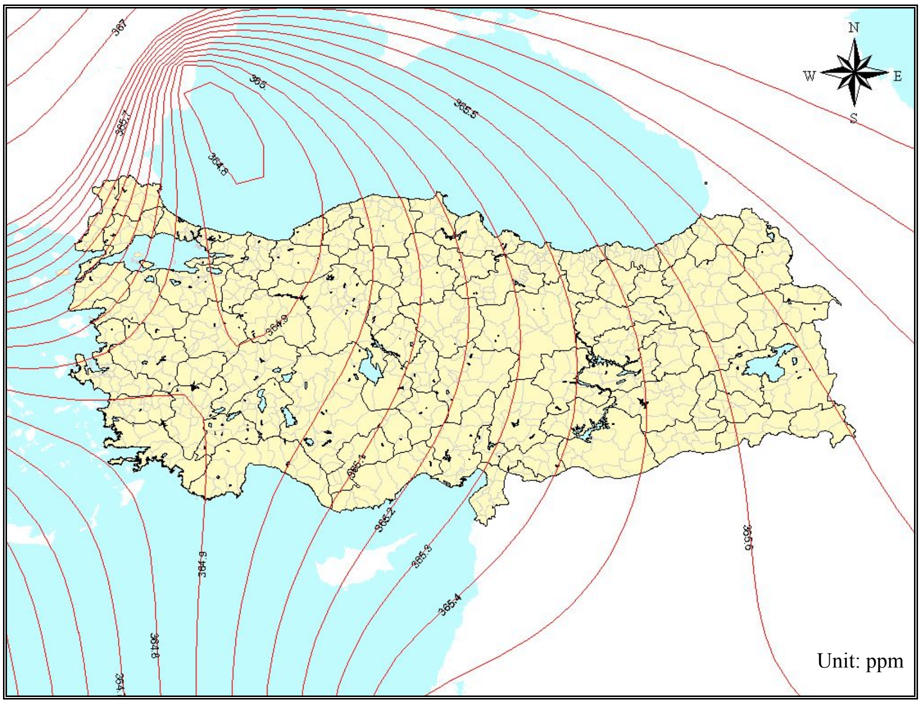

Figure A.1 CO_2 Concentration Map of Turkey in 1995

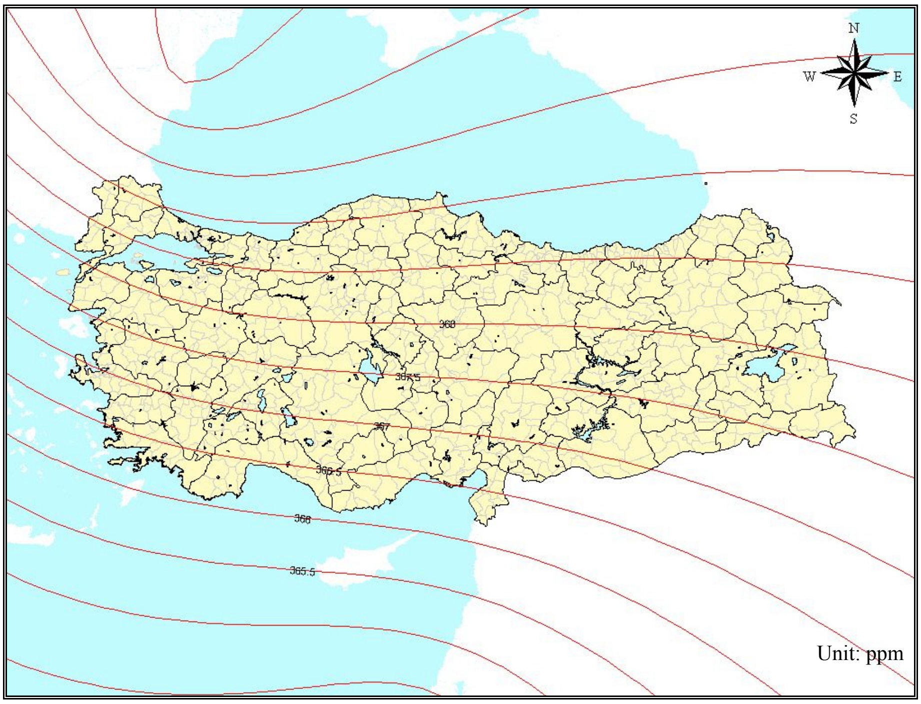

Figure A.2 CO_2 Concentration Map of Turkey in 1996

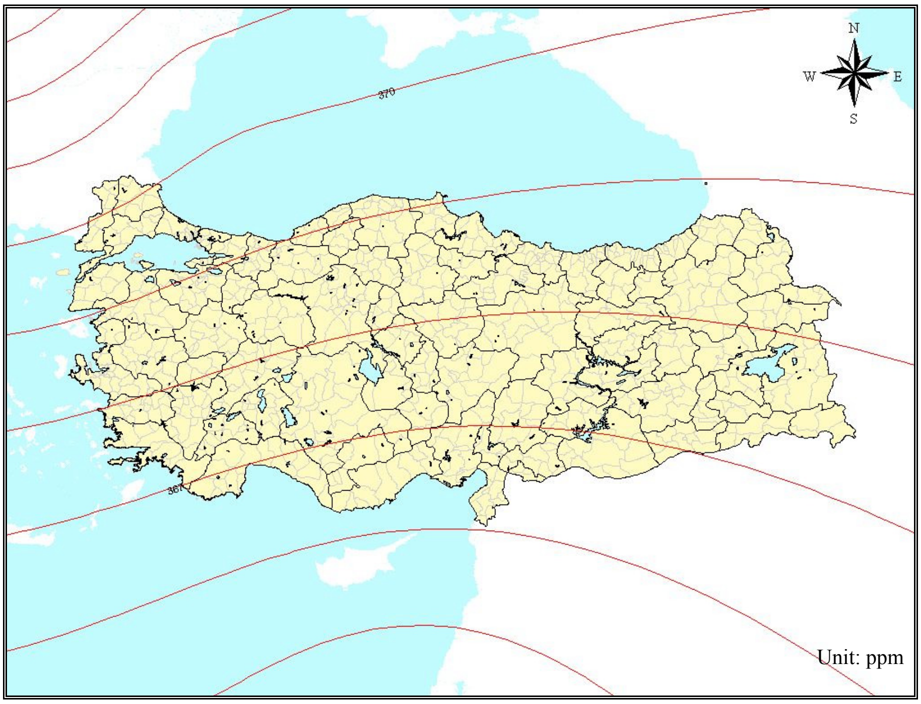

Figure A.3 CO_2 Concentration Map of Turkey in 1997

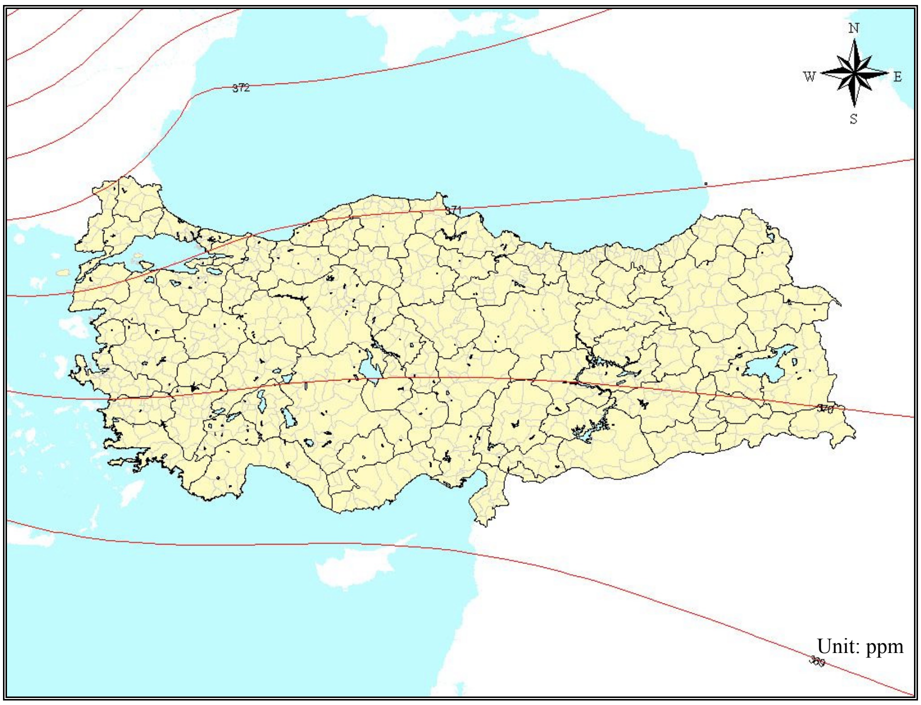

Figure A.4 CO_2 Concentration Map of Turkey in 1998

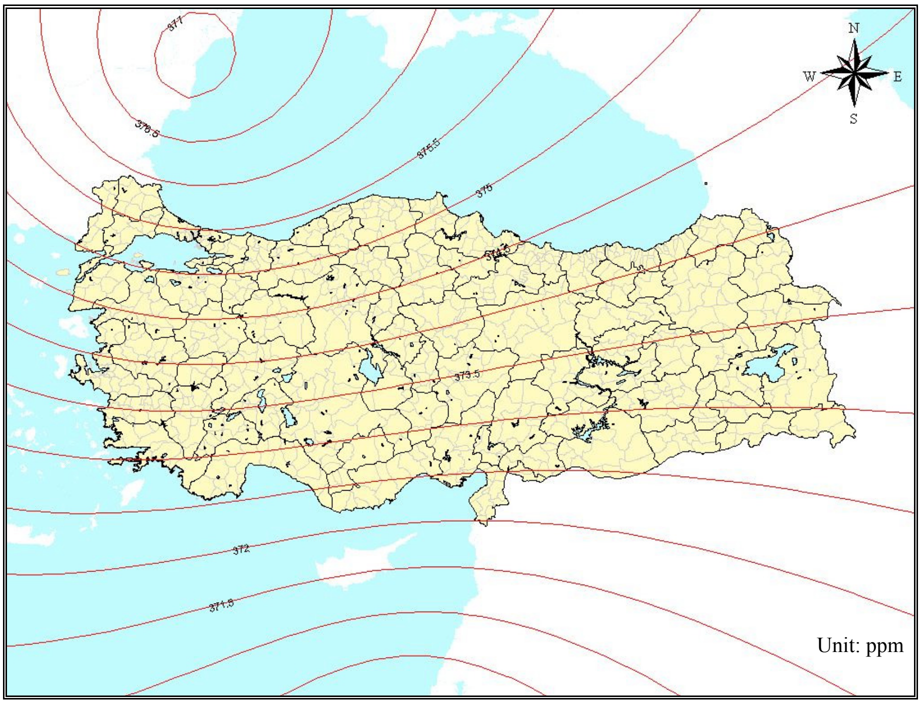

Figure A.5 CO_2 Concentration Map of Turkey in 1999

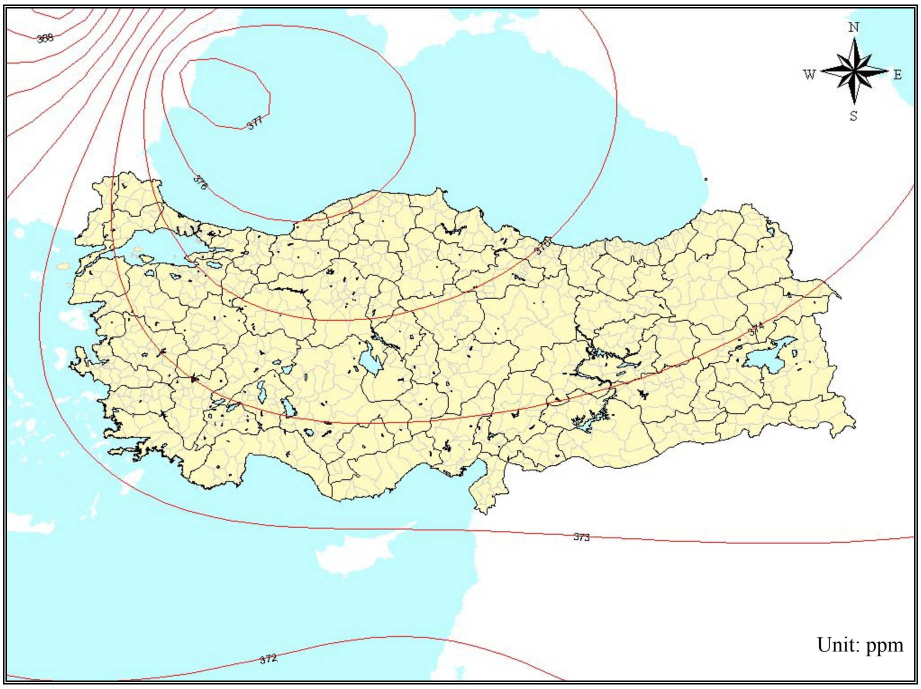

Figure A.6 CO_2 Concentration Map of Turkey in 2000

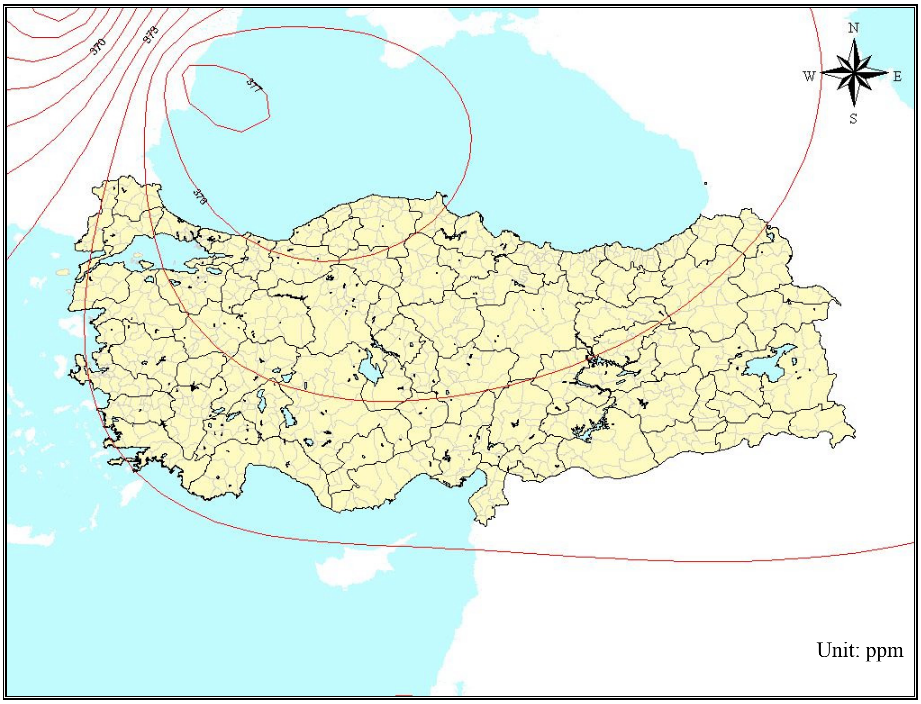

Figure A.7 CO_2 Concentration Map of Turkey in 2001

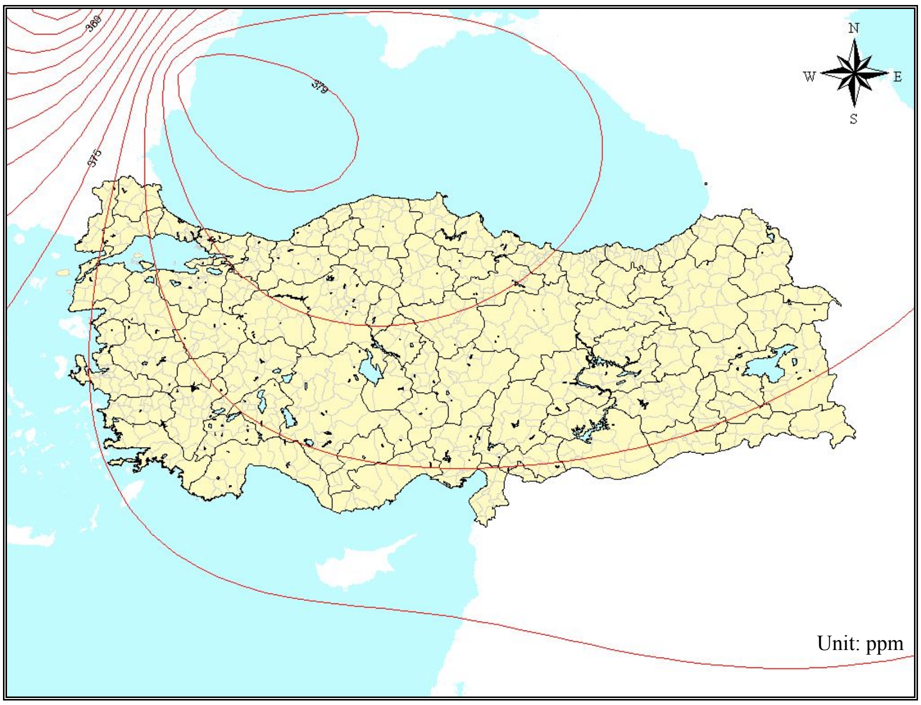

Figure A.8 CO_2 Concentration Map of Turkey in 2002

APPENDIX B

In Appendix B, the following tables are presented for the calculations of CO_2 emission inventories

- Fuel consumption calculations of road vehicles in Çankaya district for the years 1990-2010
- Amount of fuel consumed and the number of households in the regions
- Calculations of district’s energy consumption for the manufacturing industries
- Normalized energy consumption factor of manufacturing industries in Ankara
- Energy consumption of manufacturing industries in Ankara
- Example of CO_2 emission calculations for thermal power plants
- Example of CO_2 emission calculations for road vehicles
- Example of CO_2 emission calculations for households
- Number of manufacturing industries with respect to its size in Ankara’s districts
- Example of CO_2 emission calculations for manufacturing industries
- Forest biomass and its increment in Ankara
- Calculation of CO_2 uptake by forest in Ankara
- Land cover of Ankara's districts according to its types
- Total CO_2 uptake of forest in Ankara according to its types
- CO_2 uptake in forest area of Ankara's districts

Table B.1 Fuel consumption calculations of road vehicles in Çankaya district for the years 1990-2010

Year	Number of Households		Number of Cars				Fuel Consumption (tones)			Fuel Comsumption in Çankaya (tones)		
			in Ankara		in Turkey							
	in Cankaya	in Ankara	Gasoline	Diesel	Gasoline	Diesel	Diesel	Gasoline	LPG	Diesel	Gasoline	LPG
	A	B	$C^{gasoline}$	C^{diesel}	$D^{gasoline}$	D^{diesel}	$F^{gasoline}$	F^{diesel}	F^{LPG}	$H^{gasoline}$	H^{diesel}	H^{LPG}
1990	142471	645486	246453	37954	1925783	433955	4954663	2698435	-	139952	52091	-
1991	145091	662318	278618	40848	2154292	466957	4573530	2619631	-	129578	50201	-
1992	148048	683538	331608	42071	2510305	487327	4426348	2946504	-	126644	55095	-
1993	150847	704871	406433	44283	3009467	514340	5478490	3533735	-	158339	65110	-
1994	153482	726316	436605	45812	3257419	546434	4912182	3555025	-	139130	62982	-
1995	155945	747873	455557	47751	3458792	582131	5245145	3945675	-	144052	67488	-
1996	158635	771515	482224	52961	3680394	647491	5507139	4259870	-	148366	71643	-
1997	161130	795282	526987	63829	3986970	765512	4448150	4388170	405000	119122	74132	10846
1998	163425	819171	569692	76743	4261821	893490	3542895	4545391	550000	94481	77887	14667
1999	165510	843184	611540	86261	4497844	980253	4358322	4305850	705073	116316	74377	18817
2000	167591	873071	679841	100348	4838389	1094587	4942353	3655455	1307492	133303	64328	35265
2001	171610	894008	697851	103940	4950935	1137627	5327839	3171274	1302331	144154	55618	35237
2002	176770	920888	705770	108213	5012929	1187783	5728410	3143248	1095436	154813	54969	29605
2003	181960	947927	724418	117354	5098535	1311701	6193656	2958066	1212668	168924	50801	33074
2004	187175	975097	761185	123462	5355866	1380225	6442747	3353000	1225000	175765	57573	33419
2005	192445	1002550	797951	129569	5613196	1448749	6848783	3800000	1237000	186887	65237	33755
2006	198097	1031993	834718	135677	5870527	1517272	7297310	4231000	1249000	199171	72625	34090
2007	203811	1061763	871484	141785	6127858	1585796	7728841	4710000	1262000	210992	80836	34452
2008	209581	1091822	908251	147892	6385188	1654320	8093329	5244000	1275000	220984	89989	34813
2009	215394	1122105	945017	154000	6642519	1722844	8327508	5838000	1287000	227417	100171	35147
2010	221285	1152790	981784	160108	6899849	1791368	8508807	6500000	1300000	232405	111517	35508

Table B.2 Amount of fuel consumed and the number of households in the regions [54]

Type of Fuel	Aegean Region	Blacksea Region	Central Anatolia Region	Eastern Anatolia Region	Marmara Region	Mediterranean Region	Southeastern Anatolia Region
Natural gas	-	-	519457	-	1026183	-	-
LPG	6269	273	4756	-	19857	11119	693
Hard coal	1332136	376902	530641	130970	1303195	173684	230471
Imported coal	100504	411528	1686570	281616	2561342	97359	151713
Coke	7892	235091	123157	435984	86583	24596	70794
Coal	409196	308872	1070788	217277	822852	7426	31696
Lignite	1424128	253979	1164970	82940	1210723	454299	95234
Wood	1694558	1781411	1522477	855015	4072811	1769669	797931
Wood dust	2699	16821	8604	5771	82929	64981	80292
Fuel oil	35612	183191	242572	78420	115559	231189	156854
Kerosene	6051	734	-	-	-	-	-
Diessel oil	39705	25899	21319	9092	49002	5157	-
Plant waste	10568	133342	21625	24724	59467	69288	18969
Animal waste	2512	5821	89067	53577	6567	567	33013
Other	8671	74	2055495	1596	394929	6181	737727
# of Households	1848075	1799912	2402942	1275355	3506972	1778800	1340192

Table B.3 Calculations of district's energy consumptions for the manufacturing industries

Size of industries wrt. working employees(1) -	Energy consumption factor in Turkey (TOE) A	Number of industries in Turkey 2000 B	Number of industries in Ankara 2000 C	Energy consumption factor in Ankara (TOE) D	Number of industries in Çankaya 2000 E
10-24	0,001042017	3610	377	0,000108820	46
25-49	0,014902448	3362	251	0,001112586	25
50-99	0,028484307	1743	102	0,001666896	13
100-199	0,100063807	1202	66	0,005494352	7
200-499	0,170103070	789	40	0,008623730	5
500-999	0,179495564	291	9	0,005551409	0
1000+	0,505908786	122	5	0,020733967	0
Total	1	11119	850	0,043291760	96

(1) Size of establishments (person): It represents the size of establishments by annual average numbers of persons engaged.

Table B.4 Normalized energy consumption factor of manufacturing Industries in Ankara

Size of industries wrt. working employees -	Energy consumption factor in Ankara (TOE) D	Normalized energy consumption factor in Ankara (TOE) D_n
10-24	0,000108820	0,002513644
25-49	0,001112586	0,025699720
50-99	0,001666896	0,038503766
100-199	0,005494352	0,126914503
200-499	0,008623730	0,199200260
500-999	0,005551409	0,128232468
1000+	0,020733967	0,478935640
Total	**0,043291760**	**1**

Table B.5 Energy consumption of manufacturing Industries in Ankara

Fuel Type	unit	Fuel comsumption in industries in Ankara	TOE Factor	Energy consumption in Ankara (TOE) F
Hardcoal	tones	41888	0,610	25551
Lignite (2000)	tones	16656	0,200	3331
Lignite (3000)	tones	5350	0,300	1605
Lignite (4500)	tones	136391	0,450	61376
Wood	tones	1401	0,300	420
Acetylene	tones	7	1,423	10
Propane	tones	652	1,020	665
LPG	tones	12257	1,090	13360
Gasoline	tones	714	1,040	743
Kerosene	tones	5	0,829	4
Diesel Oil	tones	12513	1,020	12764
Fuel-Oil No:5	tones	10937	1,000	10937
Fuel-Oil No:6	tones	40611	0,986	40042
Petrocoke	tones	46765	0,760	35541
Coke Coal	tones	1700	0,600	1020
Electricity	MWh	544873	0,086	46859
Natural Gas	1000 m^3	35114	0,825	28969
Owen Gas	tones	111060	0,080	8885
Total				**292082**

Power plants	Fuel type[1]	Unit	Fuel[1]	TOE Factor	Tons of Oil Equivalent TOE	Energy Kcal 1000 Billion	Energy T joule[2]	Carbon Emission Factor tC/TJ	Carbon Oxidized	Convert to CO_2 emission tones
			A	B	C=A*B	$D=C*10^7$	$E=D*4.184*10^{-9}$	F	G	J=E*F*G*44/12
CATALAGZI	**Hard coal**	**tones**	1221273	0,3036	370778,48	3,71	15513,37	26,8	0,980	**1493958,38**
CAYIRHAN	**Lignite**	**tones**	1485458	0,1892	281048,65	2,81	11759,08	27,6	0,980	**1166218,09**
AMBARLI	**Fuel oil**	**tones**	715307	0,9600	686694,72	6,87	28731,31	20,0	0,990	**2085892,89**
ALIAGA	**Diesel oil**	**tones**	73285	1,0300	75483,55	0,75	3158,23	20,2	0,990	**231580,50**
AMBARLI	**Natural Gas**	**1000 m^3**	1461122	0,8100	1183508,82	11,84	49518,01	17,2	0,995	**3107321,09**
Total CO_2 emission from Thermal Power Plants										**36073690,14**

Table B.6 Example of CO_2 emission calculations for thermal power plants

(1) Source: [87]
(2) 1calorie=4.184 Joule; T=Tera ($1*10^{12}$)

Example CO_2 Emission calculation for CATALAGZI Thermal Power Plants:

(D) $= 1221273$ tones * 0.3036 * 10000 kcal/kg = $3.7078 * 10^{12}$ kcal
$= 3.7078 * 10^{12}$ kcal * 1000 cal/kcal * 4.184 J / cal
(E) $= 1.5513 * 10^{16}$ J = 15513.37172 TJ
= 15513.37172 TJ * 26.8 tones C / TJ * 0.98 * 44 / 12
(J) = 1493958.38117 tones CO_2

Table B.7 Example of CO_2 emission calculations for road vehicles

Fuel type[1]	Unit	Fuel[1]	TOE Factor	Tons of Oil Equivalent TOE	Energy Kcal	Energy T joule[2]	Carbon Emission Factor tC/TJ	Carbon Oxidized	Convert to CO_2 emission tones
		A	B	C=A*B	$D=C*10^7$	$E=D*4.184*10^{-9}$	F	G	J=E*F*G*44/12
Diesel oil	tones	119122	1,0200	121504,58	1215045782907,70	5083,75	20,2	0,990	**372771,17**
Gasoline	tones	74132	1,0400	77097,26	770972581545,10	3225,75	18,9	0,995	**222426,70**
LPG	tones	10846	1,0900	11822,10	118220983445,77	494,64	17,2	0,995	**31039,11**
Total CO_2 emission									**626236,98**

(1) Source: [42]
(2) 1calorie=4.184 Joule; T=Tera ($1*10^{12}$)

Example CO_2 Emission calculation from Road vehicles for Diesel oil:

(D) = 119122.14 tones * 1.020 * 10000 kcal/kg = $1.21504 * 10^{12}$ kcal
= $1.21504 * 10^{12}$ kcal * 1000 cal/kcal * 4.184 J / cal
(E) = $0.5084 * 10^{16}$ J = 5083.7516 TJ
= 5083.7516 TJ * 20.2 tones C / TJ * 0.99 * 44 / 12
(J) = 372771.1666 tones CO_2

Table B.8 Example of CO_2 emission calculations for households

Fuel type[(1)]	Unit	Fuel[(1)]	TOE Factor	Tons of Oil Equivalent (TOE)	Energy Kcal	Energy T joule[(2)]	Carbon Emission Factor tC/TJ	Carbon Oxidized	Convert to CO_2 emission tones
		A	B	C=A*B	D=C*10^7	E=D*4.184*10^{-9}	F	G	J=E*F*G*44/12
Natural gas	1000 m3	35320	2,70	95364,16	953641598139,20	3990,04	17,20	1,00	**250380,11**
LPG	tones	323	1,09	352,48	3524773810,73	14,75	17,20	1,00	**925,43**
Hard coal	tones	36080	0,61	22009,08	220090756489,53	920,86	26,80	0,98	**88680,02**
Imported coal	tones	114677	0,60	68806,11	688061083875,23	2878,85	25,80	0,98	**266892,20**
Coke	tones	8374	0,60	5024,36	50243645094,58	210,22	25,80	0,98	**19489,02**
Coal	tones	72807	0,72	52421,24	524212399032,38	2193,30	26,20	0,98	**206489,40**
Lignite	tones	79211	0,55	43566,14	435661408999,36	1822,81	27,60	0,98	**180778,74**
Wood	tones	103520	0,30	31055,85	310558529147,00	1299,38	13,00	0,95	**58840,12**
Wood dust	tones	585	0,30	175,50	1754999498,31	7,34	13,00	0,95	**332,51**
Fuel oil	tones	16493	1,00	16534,69	165346919925,06	691,81	20,00	0,99	**50225,52**
Diessel oil	tones	1450	1,02	1478,57	14785674542,18	61,86	20,20	0,99	**4536,19**
Plant waste	tones	1470	0,23	338,19	3381867981,19	14,15	13,00	0,90	**607,02**
Animal waste	tones	6056	0,23	1392,88	13928823865,78	58,28	13,00	0,90	**2500,13**
Other	tones	139762	0,30	41928,49	419284897905,56	1754,29	13,00	0,90	**75258,96**
Total CO_2 emission									**1205935,37**

[(1)] Source: [54]
[(2)] 1calorie=4.184 Joule; T=Tera ($1*10^{12}$)

Example CO_2 Emission calculation from Households for Hard Coal:

(D) = 36080.45 tones * 0.061 * 10000 kcal/kg = $0.22009 * 10^{12}$ kcal
= $0.22009 * 10^{12}$ kcal * 1000 cal/kcal * 4.184 J / cal
(E) = $0.92086 * 10^{15}$ J = 920.86 TJ
= 920.86 TJ * 26.8 tones C / TJ * 0.98 * 44 / 12
(J) = 88680.01935 tones CO_2

Table B.9 Number of manufacturing industries with respect to its size in Ankara's districts [57]

Distritcs	10-24 (1)	25-49 (1)	50-99 (1)	100-199 (1)	200-499 (1)	500-999 (1)	1000+ (1)	Total
Altındağ	62	47	14	7	-	-	-	**130**
Çankaya	46	25	13	7	5	-	-	**96**
Etimesgut	9	9	2	6	5	1	2	**34**
Gölbaşı	8	3	2	4	3	-	-	**20**
Keçiören	13	6	3	1	-	-	-	**23**
Mamak	5	8	3	2	2	-	-	**20**
Sincan	49	48	24	13	11	-	-	**145**
Yenimahalle	136	55	18	7	6	2	1	**225**
Akyurt	6	11	5	8	5	3	1	**39**
Ayas	-	1	-	-	-	-	-	**1**
Bala	2	-	-	-	-	-	-	**2**
Beypazarı	5	2	-	-	-	-	-	**7**
Çamlıdere	-	-	-	-	-	-	-	**-**
Çubuk	5	8	4	1	-	-	-	**18**
Elmadağ	10	8	-	4	2	1	-	**25**
Evren	-	-	-	-	-	-	-	**-**
Güdül	-	-	-	-	-	-	-	**-**
Haymana	-	-	-	-	-	-	-	**-**
Kalecik	-	-	-	-	-	-	-	**-**
Kazan	10	14	8	5	1	-	1	**39**
Kızılcahamam	-	2	-	-	-	-	-	**2**
Nallıhan	-	-	-	-	-	-	-	**-**
Polatlı	11	3	6	1	-	2	-	**23**
Şereflikoçhisar	-	1	-	-	-	-	-	**1**
Total	**377**	**251**	**102**	**66**	**40**	**9**	**5**	**850**

(1) Size of establishments (person): It represents the size of establishments by annual average numbers of persons engaged.

Table B.10 Example of CO_2 emission calculations for manufacturing industries

Fuel type[1]	Unit	Fuel[1]	TOE Factor	Tons of Oil Equivalent TOE	Energy Kcal	Energy T joule[3]	Carbon Emission Factor tC/TJ	Carbon Oxidized	Convert to CO_2 emission tones
		A	B	C=A*B	D=C*10^7	E=D*4.184*10^{-9}	F	G	J=E*F*G*44/12
Hard Coal	tones	2082	0,610	1270,08	12700760613,12	53,14	26,8	0,980	**5117,45**
Lignite (2000)	tones	918	0,200	183,61	1836092239,23	7,68	27,6	0,980	**761,89**
Lignite (3000)	tones	396	0,300	118,94	1189350358,58	4,98	27,6	0,980	**493,52**
Lignite (4500)	tones	6442	0,450	2898,88	28988790840,81	121,29	27,6	0,980	**12028,97**
Wood	tones	214	0,300	64,28	642795625,42	2,69	13,0	0,950	**121,79**
Acetylene	tones	150	1,423	213,37	2133656736,20	8,93	30,0	0,995	**977,08**
Propane	tones	180	1,020	183,28	1832848165,56	7,67	20,0	0,995	**559,55**
LPG	tones	715	1,090	779,45	7794497162,75	32,61	17,2	0,995	**2046,46**
Gasoline	tones	183	1,040	189,87	1898721794,77	7,94	18,9	0,995	**547,78**
Kerosene	tones	150	0,829	124,24	1242393751,22	5,20	19,6	0,990	**369,84**
Diesel Oil	tones	727	1,020	741,46	7414624406,66	31,02	20,2	0,990	**2274,78**
Fuel-Oil No:5	tones	654	1,003	656,15	6561491516,47	27,45	20,0	0,990	**1993,11**
Fuel-Oil No:6	tones	2023	0,986	1994,87	19948707391,07	83,47	20,0	0,990	**6059,59**
Petrocoke	tones	2307	0,760	1753,40	17534021033,31	73,36	27,5	0,990	**7323,40**
Coke Coal	tones	228	0,600	136,84	1368356439,60	5,73	25,8	0,980	**530,77**
Natural Gas	1000 m_3	1770	0,825	1459,91	14599130223,06	61,08	17,2	0,995	**3833,02**
Owen Gas	tones	5124	0,080	409,90	4098952893,68	17,15	0,0	0,995	**0,00**
Total CO_2 emission									**38666,14**

[1] Source: [56]

[2] 1calorie=4.184 Joule; T=Tera (1*10^{12})

Example CO_2 Emission calculation from Manufacturing Industries for Hard Coal:

(D) = 2082.09 tones * 0.061 * 10000 kcal/kg = 1.27007 * 10^{10} kcal

= 1.27007 * 10^{10} kcal * 1000 cal/kcal * 4.184 J / cal

(E) = 0.53140 * 10^{14} J = 53.14 TJ

=53.14 TJ * 26.8 tones C / TJ * 0.98 * 44 / 12

(J) = 5117.4512 tones CO_2

Table B.11 Forest biomass and its increment in Ankara

BROADLEAF												
Categories	High forest			Low forest			Standart coppice			Bad coppice		
	Area ha	Total Volume m^3	Increment m^3	Area ha	Total Volume m^3	Increment m^3	Area ha	Total Volume m^3	Increment m^3	Area ha	Total Volume m^3	Increment m^3
National Park	12	2836	80	95	2864	58	31	961	19	-	-	-
Protected characteristics	1584	81563	3708	30069	285081	4944	-	-	-	10697	99771	3812
Protected forest	43	4695	111	477	5853	52	-	-	-	-	-	-
Private ownership	-	-	-	-	-	-	12	1134	58	-	-	-
Commercial coppice forest	-	-	-	-	-	-	2082	32748	9923	10553	66484	3989
Commercial selected forest	0	140	12	-	-	-	-	-	-	-	-	-
Commercial age-categorized forest	784	117362	5200	15235	169900	1671	1263	39484	8599	35928	352029	18105
Total	**2424**	**206596**	**9111**	**45876**	**463698**	**6725**	**3387**	**74327**	**18599**	**57177**	**518284**	**25906**

CONIFEROUS												
Categories	High forest			Low forest			Standart coppice			Bad coppice		
	Area ha	Total Volume m^3	Increment m^3	Area ha	Total Volume m^3	Increment m^3	Area ha	Total Volume m^3	Increment m^3	Area ha	Total Volume m^3	Increment m^3
National Park	725	129336	3107	149	4295	81	-	-	-	-	-	-
Protected characteristics	55560	3893667	85216	48909	394765	9940	-	-	-	4295	23190	233
Protected forest	2302	220268	8212	939	11451	367	-	-	-	-	-	-
Commercial coppice forest	-	-	-	39	294	6	-	-	-	-	-	-
Commercial selected forest	3103	870508	26411	199	1515	48	-	-	-	-	-	-
Commercial age-categorized forest	97757	16686509	393757	37037	293416	8380	-	-	-	-	-	-
Total	**159447**	**21800288**	**516703**	**87272**	**705736**	**18822**	**-**	**-**	**-**	**4295**	**23190**	**233**

Source: The Ministry of Forestry

Table B.12 Calculation of CO_2 uptake by forest in Ankara

Type	[5] Broadleaf increment m^3	[5] Coniferous increment m^3	Estimation of Biomass Excluding roots[1]		Estimation of Biomass Including roots[2]		C Storage [3]		$C0_2$ Uptake [4]		Total CO_2 Uptake tones
			Broadleaf tones	Coniferous tones	Broadleaf tones	Coniferous tones	Broadleaf tones	Coniferous tones	Broadleaf tones	Coniferous tones	
High forest	9111	516703	5794,60	256801,39	6953,52	295321,60	3129,08	132894,72	11473,30	487280,64	498753,94
Low forest	6725	18822	4277,10	9354,53	5132,52	10757,71	2309,63	4840,97	8468,66	17750,23	26218,89
Standart coppice	18599	0	11828,96	0,00	14194,76	0,00	6387,64	0,00	23421,35	0,00	23421,35
Bad coppice	25906	233	16476,22	115,80	19771,46	133,17	8897,16	59,93	32622,91	219,73	32842,64
											581236,81

[5] Source: The Ministry of Forestry

Example CO_2 Uptake calculation for Coniferous Forest Area in Ankara:

[1] Biomass = Increment * Dry Density = 516703 m3 * 0,497 tones/m3 = 256801.39 tones
[2] Total Biomass (Including Roots) = Biomass * (1 + (Root Factor)) = 256801.39 tones * (1+0.15)
[3] Carbon Storage = Total Biomass * 0.45 tones C /ton dry biomass = 295321.60 tones* 0.45 = 132894.72 tones
[4] $C0_2$ Uptake = Carbon Storage * 44 / 12 = 132894.72 tones * 44 / 12 = 487280.64 tones

Table B.13 Land cover of Ankara's districts according to its types

Districts	Emtpy Land (0) km^2	Poor Forest (1) km^2	Intermediate Forest (2) km^2	Good Forest (3) km^2	Lake (4) km^2
Akyurt	212,16	-	-	-	-
Altındağ	166,97	-	-	-	7,56
Gölbaşı	734,75	-	-	-	3,55
Ayaş	1108,08	-	-	-	3,66
Bala	2350,84	179,13	-	-	33,17
Beypazarı	1255,82	303,57	239,99	-	14,90
Camlıdere	168,29	351,73	35,68	-	76,21
Çankaya	267,61	-	-	-	-
Çubuk	1186,82	163,63	-	-	11,18
Elmadağ	561,17	6,69	-	-	-
Etimesgut	49,19	-	-	-	-
Evren	145,31	-	-	-	34,43
Güdül	248,86	134,52	0,34	-	-
Haymana	2983,56	-	-	-	-
Kalecik	1340,46	-	-	-	-
Kazan	384,99	23,00	-	-	-
Keçiören	189,88	-	-	-	-
Kızılcahamam	871,93	873,06	-	-	16,59
Mamak	470,85	-	-	-	7,55
Nallıhan	911,27	966,00	-	-	95,28
Polatlı	3458,06	7,68	-	-	-
Şereflikoçhisar	1550,69	-	-	-	577,10
Sincan	344,26	-	-	-	-
Yenimahalle	274,16	-	-	-	-
Total	**21235,99**	**3009,00**	**276,00**	**-**	**881,19**

* Calculated by Intersection of Districts' map and Land cover map of Turkey (GIS techniques)

Table B.14 Total CO_2 uptake of forest in Ankara according to its types

Type	Categorize[(1)]	Total CO_2 Uptake tones	Total CO_2 Uptake wrt its type tones A	Forest Area km^2 [(2)] B	Factor C=A/B
High forest	**2 or 3**	498753,94	524972,83	3009,00	174,4673
Low forest	**2**	26218,89			
Standart coppice	**1 or 2**	23421,35	56263,99	276,00	203,8523
Bad coppice	**1**	32842,64			
Total		**581236,81**	**581236,81**	**3285,01**	**176,9362**

(1) 1:forest(poor), 2:forest(intermediate), 3:forest(good).
Forest area (low/high) assumed as (2) and Coppice area assumed as (1).
(2) Calculated by GIS techniques.

Table B.15 CO_2 uptake in forest area of Ankara's districts

Districts	Poor Forest (tones)	Intermediate Forest (tones)	Good Forest (tones)	Total CO_2 uptake (tones)
Akyurt	-	-	-	-
Altındağ	-	-	-	-
Gölbaşı	-	-	-	-
Ayaş	-	-	-	-
Bala	31252,94	-	-	**31252,94**
Beypazarı	52962,20	48922,31	-	**101884,51**
Çamlıdere	61366,20	7272,99	-	**68639,19**
Çankaya	-	-	-	-
Çubuk	28548,84	-	-	**28548,84**
Elmadağ	1166,76	-	-	**1166,76**
Etimesgut	-	-	-	-
Evren	-	-	-	-
Güdül	23469,71	68,70	-	**23538,41**
Haymana	-	-	-	-
Kalecik	-	-	-	-
Kazan	4012,08	-	-	**4012,08**
Keçiören	-	-	-	-
Kızılcahamam	152319,58	-	-	**152319,58**
Mamak	-	-	-	-
Nallıhan	168535,26	-	-	**168535,26**
Polatlı	1339,39	-	-	**1339,39**
Şereflikoçhisar	-	-	-	-
Sincan	-	-	-	-
Yenimahalle	-	-	-	-
Total	**524972,96**	**56264,00**	-	**581236,96**

APPENDIX C

In Appendix C, the following digitized maps are presented:

- Provinces in Turkey
- Districts in Turkey
- Lakes in Turkey
- Forests in Turkey
- Roads in Turkey
- Thermal power plants in Turkey

Figure C.1 Provinces in Turkey

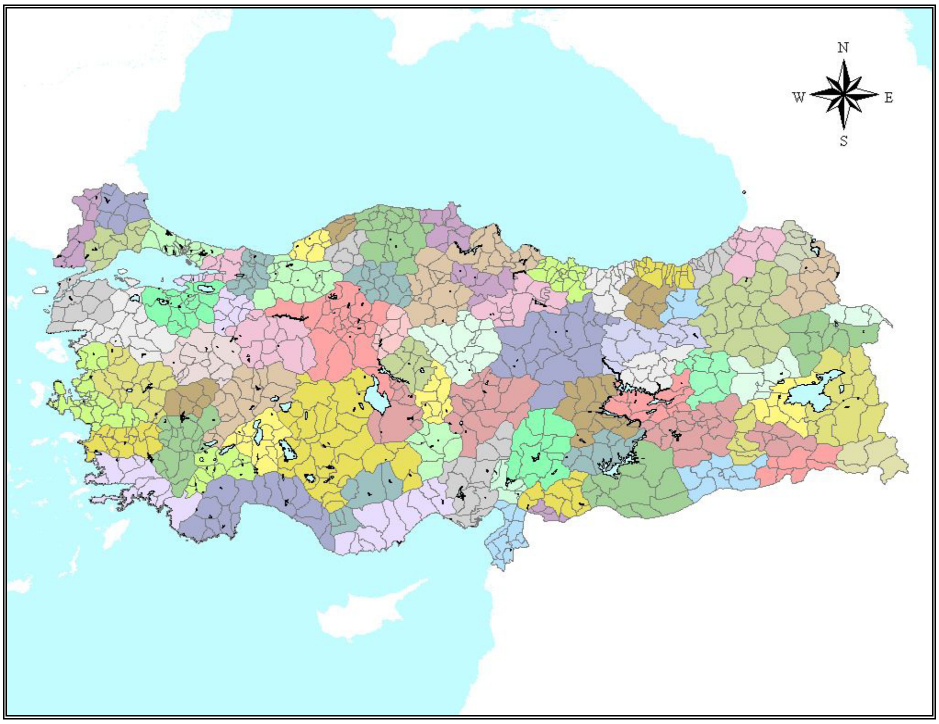

Figure C.2 Districts in Turkey

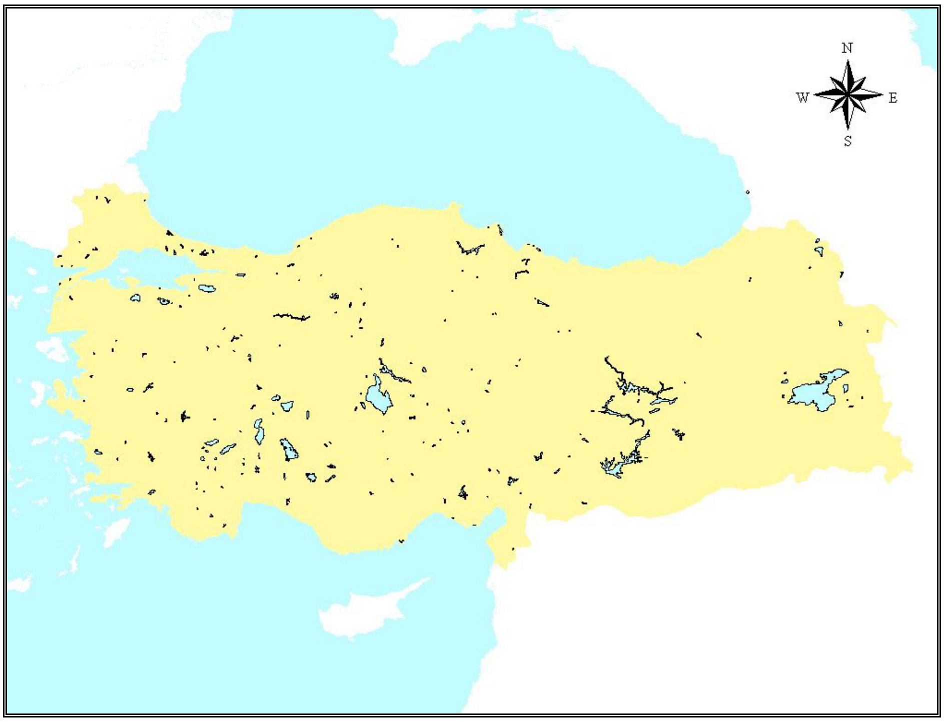

Figure C.3 Lakes in Turkey

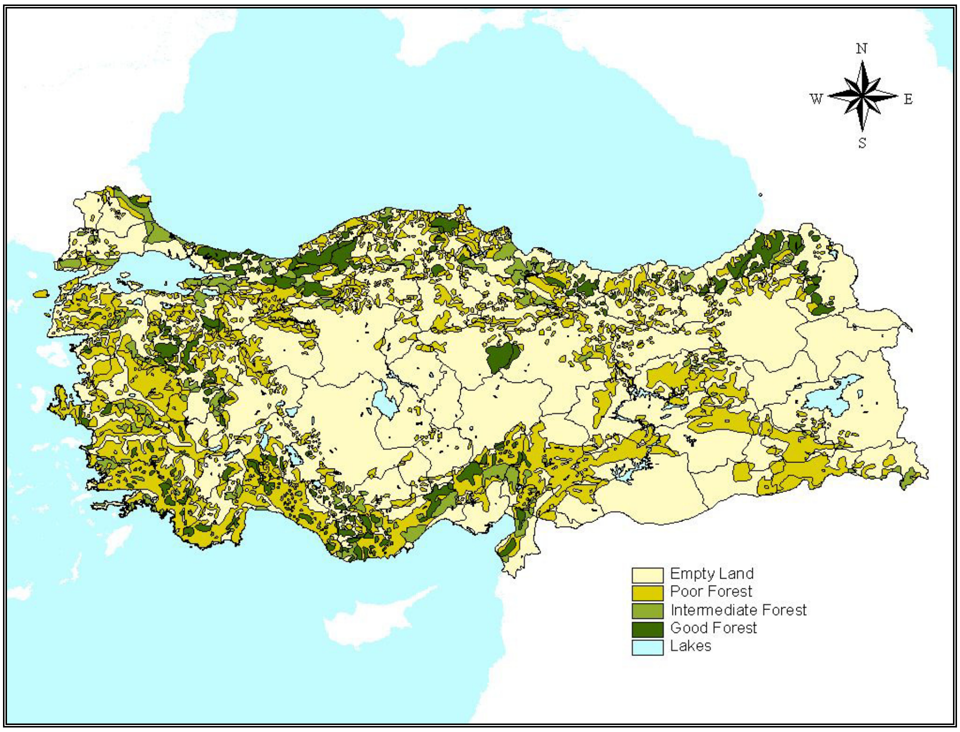

Figure C.4 Forests in Turkey

Figure C.5 Roads in Turkey

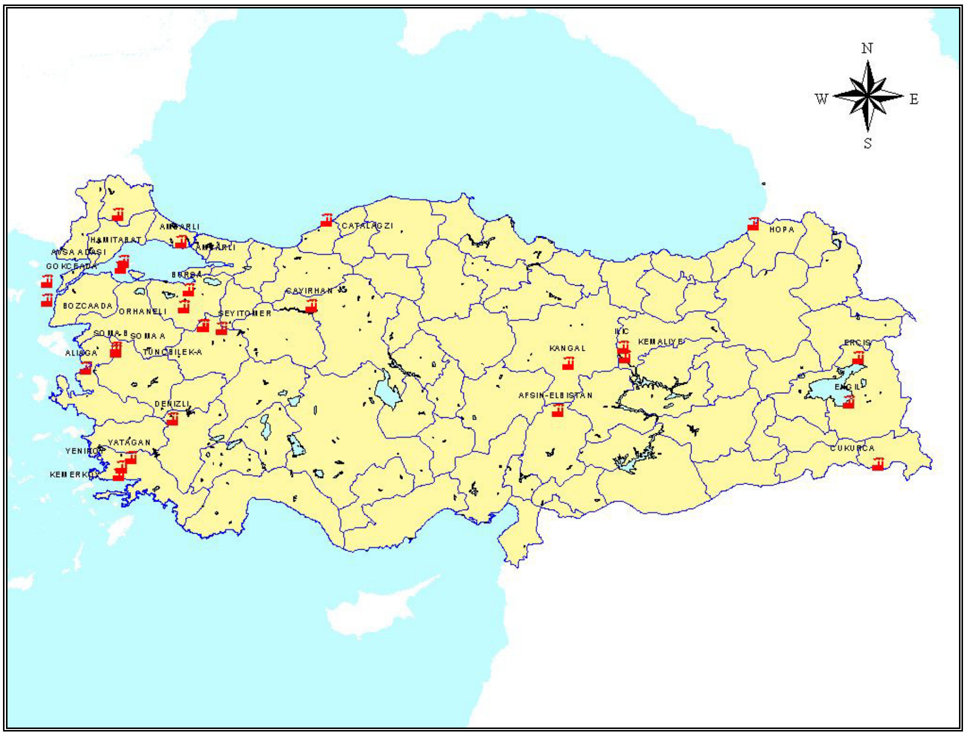

Figure C.6 Thermal power plants in Turkey

APPENDIX D

GAUSSIAN DISPERSION MODEL

The Industrial Source Complex (ISC) Model designed by EPA to support regulatory modeling options provides options to model emissions from a wide range of sources that might be present at a typical industrial source complex. The basis of the model is the straight line, steady state Gaussian Plume Equation [13].

In order to derive the Gaussian plume formula, firstly the material balances in a differential cube as shown in Figure D.1, have to be considered:

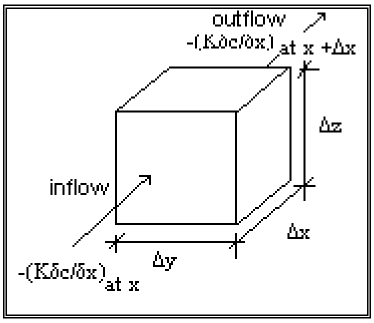

Figure D.1 Material Balance [8]

The general material balance is written as follows:

(Accumulation rate) = (all flow rates in) – (all flow rates out)

The volume of the cube is constant, $V = \Delta x \cdot \Delta y \cdot \Delta z$

$$\{\text{Accumulation Rate}\} = \frac{\delta}{\delta t}\left(cV\right) = V\frac{\delta c}{\delta t} = \Delta x \Delta y \Delta z \frac{\delta c}{\delta t}$$

$$\{\text{Net Flow into the cube in the x direction}\} = \left[\left(-K\frac{\delta c}{\delta t} \right)_X - \left(-K\frac{\delta c}{\delta t} \right)_{X+\Delta X} \right] \Delta y \Delta z$$

where, Flux: mass/time area; δc/δt: mass/lenght^4; K: lenght^2/time

$$\Delta x \Delta y \Delta z \frac{\delta c}{\delta t} = \left[\left(-K\frac{\delta c}{\delta x} \right)_X - \left(-K\frac{\delta c}{\delta x} \right)_{X+\Delta X} \right] \Delta y \Delta z + \left[\left(-K\frac{\delta c}{\delta y} \right)_Y - \left(-K\frac{\delta c}{\delta y} \right)_{y+\Delta y} \right] \Delta x \Delta z$$

$$+ \left[\left(-K\frac{\delta c}{\delta z} \right)_Z - \left(-K\frac{\delta c}{\delta z} \right)_{Z+\Delta Z} \right] \Delta x \Delta y$$

$$\frac{\delta c}{\delta t} = \frac{\left[\left(K\frac{\delta c}{\delta x} \right)_{X+\Delta X} - \left(K\frac{\delta c}{\delta x} \right)_X \right]}{\Delta x} + \frac{\left[\left(K\frac{\delta c}{\delta y} \right)_{Y+\Delta Y} - \left(K\frac{\delta c}{\delta y} \right)_Y \right]}{\Delta y} + \frac{\left[\left(K\frac{\delta c}{\delta z} \right)_{Z+\Delta Z} - \left(K\frac{\delta c}{\delta z} \right)_Z \right]}{\Delta z}$$

Since;

$$Limit_{\Delta X \to 0} \frac{\left[\left(K\frac{\delta c}{\delta x} \right)_{X+\Delta X} - \left(K\frac{\delta c}{\delta x} \right)_X \right]}{\Delta x} = K\frac{\delta^2 c}{\delta x^2}$$

$$Limit_{\Delta Y \to 0} \frac{\left[\left(K\frac{\delta c}{\delta y} \right)_{Y+\Delta Y} - \left(K\frac{\delta c}{\delta y} \right)_Y \right]}{\Delta y} = K\frac{\delta^2 c}{\delta y^2}$$

$$Limit_{\Delta Z \to 0} \frac{\left[\left(K\frac{\delta c}{\delta z} \right)_{Z+\Delta Z} - \left(K\frac{\delta c}{\delta z} \right)_Z \right]}{\Delta z} = K\frac{\delta^2 c}{\delta z^2}$$

Then equation becomes

$$\frac{\delta c}{\delta t} = K\frac{\delta^2 c}{\delta x^2} + K\frac{\delta^2 c}{\delta y^2} + K\frac{\delta^2 c}{\delta z^2}$$

This equation is similar to heat conduction equation.

Experimental data indicates that for turbulent diffusion in the atmosphere the values of K in the three directions are not the same. So three K's are written as K_x, K_y and K_z [8].

The Statistical Approach to the Turbulent Process:

Since the pollutant follows the wind fluctuations which are distributed in a Gaussian manner, the following Gaussian formula can be written:

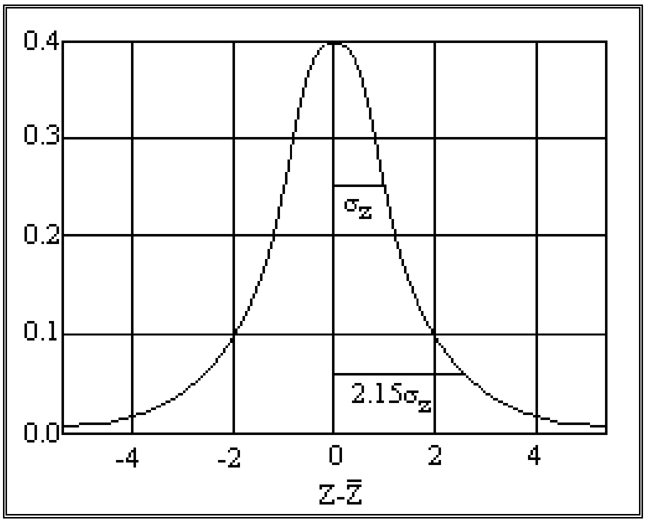

Figure D.2 Profile of pollution across a plume [52]

$$P(z) = \frac{1}{(2\pi)^{1/2}\sigma_z}\exp\left[-\frac{1}{2}\left(\frac{z-\bar{z}}{\sigma_z}\right)^2\right]$$

where;

$\bar{z}$: mean value of z

σ_z: standard deviation

σ_z: 1.000 for normalized curve

Thus the statistical approach can be used to define turbulent dispersion of the pollutant gaseous [52].

Gaussian Plume Equation:

The Gaussian plume equation is regularly applied to pollutant spreading in two dimensions, since the wind in x direction spreads the plume in y and z directions

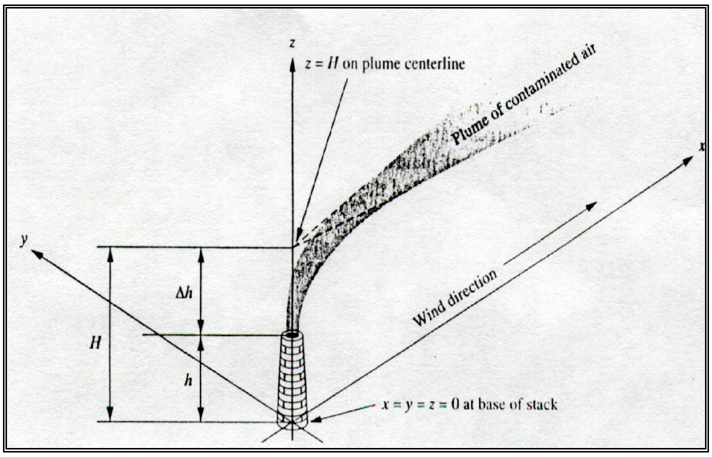

Figure D.3 Coordinate system and nomenclature for the Gaussian plume idea [8]

The integration with respect to shape (shape like the Gaussian normal distribution), one can get the following equation.

$$C = \frac{X}{4(\pi t)(K_y K_z)^{1/2}} \exp\left[-(\frac{1}{4t})\left\{ \frac{y^2}{K_y} + \frac{z^2}{K_z} \right\} \right] \text{ For two dimensional case}$$

Adding a spreading dimension multiplies the denominator of the leading fraction by $2(\pi t)^{1/2}K^{1/2}$ and adds a (dimension^2/K) to the exponential term on the right. Exp(0)=1 (instantaneous concentration at the origin, multiplied by an exponential term (always less than 1) that shows how much the instantaneous concentration decreases as it moves from the origin. By the way, the concentration at the origin is proportional to 1/t for two-dimensional cases ($1/\sqrt{t}$) for one dimension).

Assuming negligible net transfer of material in the x direction makes this a two-dimensional spreading problem.

At the origin x=y=0, but z=H which is the effective plume height (Figure D.3.)

And also substitute the equations:

$K_y=0.5\ \sigma_y^2\ u/x$

$K_z=0.5\ \sigma_z^2\ u/x$

$t=x/u$

$$C=\frac{Q/u}{4\pi(x/u)((0.5)^2\sigma_y^2\sigma_z^2(u/x)^2)^{1/2}}\exp\left[-(\frac{1}{4(x/u)})(\frac{y^2}{0.5\sigma_y^2(u/x)}+\frac{(z-H)^2}{0.5\sigma_z^2(u/x)})\right]$$

$$C=\frac{Q/u}{4\pi(0.5)\sigma_y\sigma_z}\exp\left[-(\frac{1}{4(x/u)})(\frac{1}{0.5(u/x)})(\frac{y^2}{\sigma_y^2}+\frac{(z-H)^2}{\sigma_z^2})\right]$$

$$C=\frac{Q}{2\pi u\sigma_y\sigma_z}\exp\left[-(\frac{1}{2})(\frac{y^2}{\sigma_y^2}+\frac{(z-H)^2}{\sigma_z^2})\right]$$

$$C=\frac{Q}{2\pi u\sigma_y\sigma_z}\exp\left[-\frac{y^2}{2\sigma_y^2}\right]\exp\left[-\frac{(z-H)^2}{2\sigma_z^2})\right]$$

The concentration due to the mirror image plume are exactly the same as shown above equation, except that $(z-H)^2$ is replaced by $(z+H)^2$.Then the corrected from of the equation is:

$$C=\frac{Q}{2\pi u\sigma_y\sigma_z}\exp\left[-\frac{y^2}{2\sigma_y^2}\right]\left\{\exp\left[-\frac{(z-H)^2}{2\sigma_z^2})\right]+\exp\left[-\frac{(z+H)^2}{2\sigma_z^2})\right]\right\}$$

which is the basic Gaussian Equation, where;

C (x, y, z)=Concentration of pollutant at location x, y, z in $\mu g/m^3$,.

Q=Pollutant emission rate at source in g/sec, u=Horizontal wind speed at the source at stack height in m/sec,

H=Effective stack height in m,

$H=h+\Delta h$

h=Physical height of stack (m)

Δh= Plume rise (m)

σ_y, σ_z= Standard deviations of the concentration of pollutant "x" in the horizontal crosswind and vertical directions respectively.

Assumptions made in the model:

- Pollutant concentrations are homogenous through the region of interest.
- The source is continuous.
- The emitted pollutants are instantaneously and uniformly mixed.
- A wind of constant speed across the cell cross-section characterizes the transport.
- In the x direction, there is only wind advection. However, advection and dispersion are in the y and z directions.

Advantages:

- ISC3 model is a EPA approved model.

Disadvantages:

- Flows over surfaces markedly different from the basic experiments, including dispersion over forest, cities, water and rough terrain.
- Chemical reaction, dry deposition, resuspension, or precipitation scavenging, produce additional uncertainties in model predictions [52].

Uses of models

- It is applied to estimate single source or multi-source (e.g., Thermal power plants, industries, transportation vehicles and residential area) pollutant concentration at the receptor points for meteorological conditions [8].

APPENDIX E

COMPUTER PROGRAM

This program was used to obtain the STARDATA file according to the Pasquill Stability Classes.

```
REM     ***************************************************
REM     *              S T A R D A T A   P R O G R A M              *
REM     *                                                           *
REM     *                       LANGUAGE IS QBASIC                  *
REM     ***************************************************

REM *** DEGISKEN TANIMI ***
  DIM AY(24), AH(24), DATY(12, 31, 24), DATH(12, 31, 24)
  DIM BU21(12, 31)
  DIM GU(16), GUDAT(12, 31, 16)
  DIM STAR(6, 16, 6)

REM **********  DOSYA OKUMA  **********
REM *** DOSYA TANITIM ***
   INPUT "RUZGAR DOSYASININ ADINI GIRINIZ : "; n$
   OPEN n$ FOR INPUT AS #1
   INPUT "SAAT 21  BULUTLULUK DOSYASININ ADINI GIRINIZ : "; n$
   OPEN n$ FOR INPUT AS #4
   INPUT "GUNESLENME DOSYASININ ADINI GIRINIZ : "; n$
   OPEN n$ FOR INPUT AS #5
5  REM *** ISTASYON NOSU VE YILI ***
  INPUT "ISTASYON NOSUNU GIRINIZ : "; ISTNO
  INPUT "YILINI GIRINIZ : "; YIL

REM *** RUZGAR VERILERININ OKUNMASI ***
10 INPUT #1, ISTNOR, YILR, AY, GUN
  IF ISTNOR = 99999 THEN GOTO 20
  FOR I = 1 TO 24
  INPUT #1, AY(I), AH(I)
  NEXT I
  INPUT #1, MAR, MAH, MSA
  IF ISTNO = ISTNOR AND YIL = YILR THEN
   FOR I = 1 TO 24
     DATY(AY, GUN, I) = AY(I): DATH(AY, GUN, I) = AH(I)
     NEXT
   END IF
  GOTO 10
20 REM *** RUZGAR OKUMA SON ***
```

```
REM *** BULUT OKUMA ***
REM *** SAAT 21 ***
70 INPUT #4, ISTNOR, YILR, AY, GUN, BUL
  IF ISTNOR = 99999 THEN GOTO 80
  IF ISTNO = ISTNOR AND YIL = YILR THEN
     BU21(AY, GUN) = BUL
   END IF
  GOTO 70
80 REM *** BULUT OKUMA SON ***

REM *** GUNESLENME OKUMA ***
90 INPUT #5, ISTNOR, YILR, AY, GUN
  IF ISTNOR = 99999 THEN GOTO 100
  FOR I = 1 TO 16
  INPUT #5, GU(I)
  NEXT I
  IF ISTNO = ISTNOR AND YIL = YILR THEN
    FOR I = 1 TO 16
    GUDAT(AY, GUN, I) = GU(I)
    NEXT I
  END IF
  GOTO 90
100 REM *** GUNESLENME OKUMA SON ***

REM ********** STARDATA OLUSTURMA  **********
  FOR I = 1 TO 12
  FOR J = 1 TO 31
  FOR K = 1 TO 24
  STAB = 0
     IF DATH(I, J, K) < 20 THEN
          IF K >= 5 AND K < 20 THEN
                IF GUDAT(I, J, K - 4) > 6 AND GUDAT(I, J, K - 4) < 11 THEN
                     STAB = 1
                ELSEIF GUDAT(I, J, K - 4) <= 6 THEN
                     STAB = 2
                END IF
                     GOTO 110
          ELSE
                STAB = 2
110            END IF
     ELSEIF DATH(I, J, K) >= 20 AND DATH(I, J, K) < 30 THEN
          IF K >= 5 AND K <= 20 THEN
                IF GUDAT(I, J, K - 4) > 6 AND GUDAT(I, J, K - 4) < 11 THEN
                     STAB = 1
                ELSEIF GUDAT(I, J, K - 4) > 3 AND GUDAT(I, J, K - 4) <= 6 THEN
                     STAB = 2
                ELSEIF GUDAT(I, J, K - 4) <= 3 THEN
                     STAB = 3
                END IF
                GOTO 120
          ELSEIF K < 5 AND K > 20 THEN
                IF BU21(I, J) < 4 THEN
                     STAB = 6
                ELSEIF BU21(I, J) >= 4 AND BU21(I, J) < 11 THEN
                     STAB = 5
```

```
                END IF
120            END IF
        ELSEIF DATH(I, J, K) >= 30 AND DATH(I, J, K) < 50 THEN
            IF K >= 5 AND K <= 20 THEN
                IF GUDAT(I, J, K - 4) > 6 AND GUDAT(I, J, K - 4) < 11 THEN
                    STAB = 2
                ELSEIF GUDAT(I, J, K - 4) > 0 AND GUDAT(I, J, K - 4) <= 6 THEN
                    STAB = 3
                END IF
                GOTO 130
            ELSEIF K < 5 AND K > 20 THEN
                IF BU21(I, J) < 4 THEN
                    STAB = 4
                ELSEIF BU21(I, J) >= 4 AND BU21(I, J) < 11 THEN
                    STAB = 5
                END IF
130            END IF
        ELSEIF DATH(I, J, K) >= 50 AND DATH(I, J, K) < 500 THEN
            IF K >= 5 AND K <= 20 THEN
                IF GUDAT(I, J, K - 4) > 6 AND GUDAT(I, J, K - 4) < 11 THEN
                    STAB = 3
                ELSEIF GUDAT(I, J, K - 4) > 0 AND GUDAT(I, J, K - 4) <= 6 THEN
                    STAB = 4
                END IF
                GOTO 140
            ELSEIF K < 5 AND K > 20 THEN
                IF BU21(I, J) < 11 THEN
                    STAB = 4
                END IF
140            END IF
        END IF
      YO = DATY(I, J, K)
      ST = STAB
      IF DATH(I, J, K) < 30 THEN
        HIZ = 1
      ELSEIF DATH(I, J, K) >= 30 AND DATH(I, J, K) < 60 THEN
        HIZ = 2
      ELSEIF DATH(I, J, K) >= 60 AND DATH(I, J, K) < 100 THEN
        HIZ = 3
      ELSEIF DATH(I, J, K) >= 100 AND DATH(I, J, K) < 160 THEN
        HIZ = 4
      ELSEIF DATH(I, J, K) >= 160 AND DATH(I, J, K) < 210 THEN
        HIZ = 5
      ELSEIF DATH(I, J, K) >= 210 THEN
        HIZ = 6
      END IF
      IF DATH(I, J, K) = 999 THEN GOTO 150
      STAR(ST, YO, HIZ) = STAR(ST, YO, HIZ) + 1
150 NEXT K: NEXT J: NEXT I
REM *** YAZDIRMA ***
    INPUT "STAR DOSYA ADINI GIRINIZ : ", STD$
    OPEN STD$ FOR OUTPUT AS #6
    FOR I = 1 TO 6
    FOR J = 1 TO 16
    FOR K = 1 TO 6
```

```
   PRINT #6, STAR(I, J, K), ",";
   NEXT K
   PRINT #6,
   NEXT J: NEXT I
   CLOSE #6
REM *** YAZDIRMA SON ***
   INPUT "DEVAM ETMEK ISTIYORMUSUNUZ (E/H) ", E$
   IF E$ = "E" THEN GOTO 5
   CLOSE ALL
   END
```

APPENDIX F

ISCLT3 MODEL INPUTS

The inputs of the model have been divided into two parts: "Runstream File" and "Meteorological File (STARDATA)".

D.1. Runstream File

Modeling options, source locations, source properties, receptor information, meteorological properties and output options are defined in this file.

Runstream file for "Point" type source:

```
********************************************************
**   This is a programe for the ISC Long Term Model, ISCLT3      **
**    THERMAL POWER PLANT-1  PROVINCE:ANKARA        **
**                                                GRID 1        **
********************************************************
CO STARTING
  TITLEONE MATHEMATICAL MODELING OF CO2
  TITLETWO SOURCE:THERMAL POWER PLANT-1  PROVINCE:ANKARA
  MODELOPT  DFAULT  CONC  URBAN
  AVERTIME ANNUAL
  POLLUTID CO2
  TERRHGTS  ELEV
  RUNORNOT RUN
  ERRORFIL ERR06T01.LST DEBUG
CO FINISHED

SO STARTING
SO LOCATION 6221 POINT 634034.1 4775652.8 734.0
SO SRCPARAM 6221 11627.90 120.00 433.00 2.074 5.10
```

```
SO LOCATION 6222 POINT 634034.1 4775652.8 734.0
SO SRCPARAM 6222 11627.90 120.00 433.00 2.074 5.10
SO LOCATION 6223 POINT 634034.1 4775652.8 734.0
SO SRCPARAM 6223 13724.73 120.00 433.00 1.132 7.50
SO SRCGROUP ALL
SO FINISHED

RE STARTING
RE GRIDCART GRID1 STA
RE GRIDCART XYINC 100000.  35.  25000.  4250000.  33.  25000.
RE GRIDCART  GRID1 ELEV  1    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
      0.00    0.00    0.00
RE GRIDCART  GRID1 ELEV  1    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
      0.00    0.00    0.00
RE GRIDCART  GRID1 ELEV  1    0.00    0.00    0.00    0.00    0.00  115.55    0.00    0.00    0.00
      0.00    0.00
RE GRIDCART  GRID1 ELEV  2   17.24    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
      0.00    0.00    0.00
RE GRIDCART  GRID1 ELEV  2    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
      0.00    0.00    0.00
RE GRIDCART  GRID1 ELEV  2    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
      0.00    0.00
RE GRIDCART  GRID1 ELEV  3    0.00    0.00    0.00    0.00  175.57    0.00    0.00    0.00    0.00
      0.00    0.00    0.00
RE GRIDCART  GRID1 ELEV  3    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
      0.00    0.00    0.00
RE GRIDCART  GRID1 ELEV  3    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
      0.00    0.00
RE GRIDCART  GRID1 ELEV  4    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
      0.00    0.00    0.00
RE GRIDCART  GRID1 ELEV  4    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
      0.00    0.00    0.00
RE GRIDCART  GRID1 ELEV  4  146.35    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
      0.00    0.00
RE GRIDCART  GRID1 ELEV  5    0.00    0.00    0.00    0.00    0.00    0.00    0.00   39.06    0.00
      0.00    0.00    0.00
```

RE GRIDCART GRID1 ELEV 5 0.00 0.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 299.22
RE GRIDCART GRID1 ELEV 5 2185.30 1494.68 1416.74 769.42 733.33 21.59 0.00 0.00
0.00 0.00 0.00
RE GRIDCART GRID1 ELEV 6 0.00 0.00 0.00 0.00 0.00 0.00 0.00 847.60 0.46
0.00 0.00 0.00
RE GRIDCART GRID1 ELEV 6 28.41 1669.73 413.17 168.22 308.61 0.00 0.00 0.00
0.00 0.00 0.00 1542.49
RE GRIDCART GRID1 ELEV 6 1802.97 575.16 198.36 141.87 1278.79 784.22 0.00 0.00
0.00 0.00 0.00
RE GRIDCART GRID1 ELEV 7 0.00 0.00 0.00 0.00 0.00 211.23 0.00 0.00 0.00
0.00 0.00 0.00
RE GRIDCART GRID1 ELEV 7 193.91 1762.28 1070.00 1775.62 1775.98 0.00 0.00 0.00
0.00 505.27 1671.77 2143.35
RE GRIDCART GRID1 ELEV 7 1797.67 1979.27 292.92 1676.67 1720.26 1372.87 1084.16
6.83 13.09 12.25 5.09
RE GRIDCART GRID1 ELEV 8 0.00 0.00 0.00 0.00 0.00 0.00 581.18 0.00 364.22
0.00 118.72 859.37
RE GRIDCART GRID1 ELEV 8 602.09 1117.42 1925.49 1936.78 1026.72 70.56 42.20
62.37 491.81 1084.42 2295.23 1739.11
RE GRIDCART GRID1 ELEV 8 1893.73 1191.33 1477.26 1509.88 1910.36 2195.81 1347.38
826.80 209.67 23.62 43.79
RE GRIDCART GRID1 ELEV 9 0.00 0.00 0.00 0.00 0.00 23.04 0.00 0.00 0.00
342.94 55.47 939.12
RE GRIDCART GRID1 ELEV 9 1119.31 1160.43 1374.58 1122.68 825.30 329.08 141.18
290.53 1048.84 1365.10 1757.75 1625.24
RE GRIDCART GRID1 ELEV 9 1421.80 1832.08 1008.09 1138.48 1448.00 1764.30 2991.26
2089.64 1090.44 156.71 86.60
RE GRIDCART GRID1 ELEV 10 0.00 0.00 0.00 0.00 0.00 99.89 0.00 124.79
892.61 589.15 1018.11 756.23
RE GRIDCART GRID1 ELEV 10 1348.01 991.11 1119.44 1826.46 837.98 1242.04 379.11
465.43 1220.19 2052.20 1099.88 1541.43
RE GRIDCART GRID1 ELEV 10 1037.79 1045.67 1165.40 991.71 1230.56 1160.14 1781.63
1947.54 1010.28 912.65 569.48
RE GRIDCART GRID1 ELEV 11 0.00 0.00 0.00 0.00 0.00 114.15 480.63 522.26
317.41 951.18 660.16 1010.86

RE GRIDCART GRID1 ELEV 11 1584.93 914.51 1230.05 1235.21 1385.54 1068.88 1133.36 1406.94 1107.77 1243.74 1974.39 1214.36

RE GRIDCART GRID1 ELEV 11 1018.00 1010.59 994.09 1026.93 1051.49 1010.59 1052.58 1398.19 1658.40 1797.33 1350.58

RE GRIDCART GRID1 ELEV 12 0.00 0.00 0.00 0.00 0.00 0.71 160.02 326.35 135.71 111.94 775.21 1376.11

RE GRIDCART GRID1 ELEV 12 1370.36 1248.49 876.40 1637.49 873.53 959.89 918.01 2181.34 1144.23 1205.20 1612.82 1289.69

RE GRIDCART GRID1 ELEV 12 1005.42 1007.92 1426.65 1042.71 1028.49 1098.48 1170.43 1136.42 2052.54 2116.51 1980.62

RE GRIDCART GRID1 ELEV 13 0.00 0.00 0.00 360.56 0.00 0.00 448.78 53.83 127.86 77.59 102.81 148.25

RE GRIDCART GRID1 ELEV 13 818.02 857.27 1224.06 908.91 1210.62 1386.04 917.00 1996.56 1235.24 1425.62 1842.24 1709.80

RE GRIDCART GRID1 ELEV 13 1044.34 1009.42 1113.17 1040.00 1023.41 1107.76 1875.64 1970.64 1343.92 1293.95 1273.58

RE GRIDCART GRID1 ELEV 14 0.00 0.00 0.00 0.00 0.00 316.19 41.25 555.40 582.69 687.31 634.87 525.11

RE GRIDCART GRID1 ELEV 14 780.91 790.15 826.46 836.09 1429.74 1527.11 917.00 1049.70 1642.91 1112.58 1003.43 1022.00

RE GRIDCART GRID1 ELEV 14 1012.63 959.79 971.09 949.17 911.96 949.46 1163.68 1284.00 1510.41 1108.42 1151.66

RE GRIDCART GRID1 ELEV 15 0.00 0.00 0.00 336.04 175.60 144.42 191.58 563.58 1079.20 1163.76 140.43 706.47

RE GRIDCART GRID1 ELEV 15 687.66 739.34 945.75 1278.59 1107.47 1137.25 1025.51 1915.65 954.00 1048.32 1485.04 986.00

RE GRIDCART GRID1 ELEV 15 1055.07 1018.34 937.75 892.00 904.00 1176.25 1131.17 1319.93 1304.36 1290.10 2081.62

RE GRIDCART GRID1 ELEV 16 0.00 0.00 0.00 201.30 0.00 32.00 368.62 48.12 62.04 102.71 752.82 470.58

RE GRIDCART GRID1 ELEV 16 801.29 893.60 912.60 1305.43 1536.50 1220.68 985.54 973.09 1362.90 1027.31 951.00 1051.96

RE GRIDCART GRID1 ELEV 16 1091.76 1078.79 914.13 892.00 1181.19 1248.45 995.76 1056.37 1187.89 986.57 1346.54

RE GRIDCART GRID1 ELEV 17 0.00 0.00 0.00 32.42 199.81 396.21 38.49 44.00 131.58 477.08 303.17 613.66

RE GRIDCART GRID1 ELEV 17 1041.90 917.81 1397.05 1398.00 1380.17 1065.91 1299.73
1135.59 1205.87 1011.83 946.66 1134.17
RE GRIDCART GRID1 ELEV 17 1184.53 1041.59 967.02 892.00 1253.89 859.98 998.00
1181.83 1185.00 1169.74 1358.09
RE GRIDCART GRID1 ELEV 18 0.00 0.00 0.00 0.00 0.00 8.24 689.79 197.41
416.76 998.80 990.45 1254.39
RE GRIDCART GRID1 ELEV 18 941.81 1253.76 1319.98 1176.96 1311.65 1248.25 1573.18
1019.58 903.64 839.60 914.40 817.32
RE GRIDCART GRID1 ELEV 18 1186.27 1119.55 1048.83 893.30 1006.10 1491.32 1184.31
1117.92 1032.98 1240.67 1217.49
RE GRIDCART GRID1 ELEV 19 0.00 0.00 127.24 0.00 0.00 365.21 45.09 124.74
532.52 259.61 770.53 1560.87
RE GRIDCART GRID1 ELEV 19 1228.13 1259.34 1151.92 1339.51 1082.13 1081.98 991.94
871.17 905.09 1171.53 717.51 993.95
RE GRIDCART GRID1 ELEV 19 1281.30 1085.59 1018.94 748.42 980.92 1111.70 1341.07
1202.32 1031.81 1107.42 1125.68
RE GRIDCART GRID1 ELEV 20 0.00 0.00 116.54 5.05 0.00 342.95 834.72 338.18
260.16 215.47 566.56 718.52
RE GRIDCART GRID1 ELEV 20 711.84 855.77 961.99 1152.77 984.63 1001.20 913.96
933.38 990.81 954.17 744.09 853.17
RE GRIDCART GRID1 ELEV 20 1104.48 1009.88 933.50 1009.25 1235.12 776.79 757.10
799.25 1161.11 1073.51 1166.47
RE GRIDCART GRID1 ELEV 21 0.00 0.00 67.90 272.38 169.49 19.00 683.45 314.23
272.42 89.42 965.09 644.21
RE GRIDCART GRID1 ELEV 21 923.75 985.19 807.09 1393.29 1127.77 823.17 788.51
881.68 1027.24 1416.66 764.81 749.72
RE GRIDCART GRID1 ELEV 21 831.41 889.85 1275.98 891.44 882.75 794.61 1202.64
1428.47 1335.98 1337.34 1253.43
RE GRIDCART GRID1 ELEV 22 0.00 0.00 0.00 41.96 322.43 540.07 238.48 321.59
253.52 144.66 251.85 637.11
RE GRIDCART GRID1 ELEV 22 546.00 1188.59 420.69 782.10 653.29 306.24 314.42
837.10 471.32 478.22 485.49 787.41
RE GRIDCART GRID1 ELEV 22 1100.32 1199.01 1028.87 1089.35 1162.84 1057.17 697.75
860.30 923.17 1053.27 925.43
RE GRIDCART GRID1 ELEV 23 0.00 0.00 0.00 95.00 290.47 234.91 308.84 502.66
166.07 17.59 6.09 2.00

RE GRIDCART GRID1 ELEV 23 229.32 277.32 243.00 492.47 161.15 944.29 729.98 1018.95 806.26 868.76 1685.81 1343.42

RE GRIDCART GRID1 ELEV 23 904.56 1135.32 1292.45 785.34 809.41 540.83 741.26 1304.23 1138.70 1118.27 1102.51

RE GRIDCART GRID1 ELEV 24 0.00 30.03 0.00 59.79 33.09 449.37 55.50 5.33 0.00 106.85 555.37 0.00

RE GRIDCART GRID1 ELEV 24 0.00 140.89 69.00 892.34 68.17 721.19 1246.32 1453.66 856.03 1401.82 1803.40 1736.21

RE GRIDCART GRID1 ELEV 24 1513.89 1390.77 1315.85 1484.35 861.44 890.43 935.82 497.21 1084.33 1065.38 1085.94

RE GRIDCART GRID1 ELEV 25 0.00 0.00 0.00 0.00 257.07 0.00 0.00 0.00 0.00 0.00 0.00 0.00

RE GRIDCART GRID1 ELEV 25 0.00 50.74 34.00 401.23 83.32 52.00 45.00 796.06 656.15 937.21 820.68 1291.66

RE GRIDCART GRID1 ELEV 25 1406.03 1415.10 1261.75 1181.04 1507.54 1379.83 1399.42 846.64 540.55 1512.36 643.68

RE GRIDCART GRID1 ELEV 26 0.00 0.00 0.00 81.43 79.55 344.80 290.48 0.00 0.00 0.00 0.00 0.00

RE GRIDCART GRID1 ELEV 26 0.00 0.00 285.71 193.82 264.71 110.82 345.70 374.20 610.29 633.81 472.66 1072.02

RE GRIDCART GRID1 ELEV 26 1239.41 1198.06 864.22 1011.49 1892.65 1380.13 525.87 762.05 1155.14 1386.99 858.32

RE GRIDCART GRID1 ELEV 27 0.00 0.00 20.66 6.00 39.34 158.76 142.73 198.68 9.02 0.00 0.00 0.59

RE GRIDCART GRID1 ELEV 27 136.34 149.81 89.26 126.83 0.00 34.13 0.00 0.00 0.00 156.72 703.86 326.76

RE GRIDCART GRID1 ELEV 27 390.25 544.49 718.32 886.66 1121.11 1187.06 1217.88 1266.33 994.71 898.30 252.85

RE GRIDCART GRID1 ELEV 28 25.03 32.45 539.67 237.57 59.09 96.35 84.76 83.92 77.99 198.84 205.55 92.82

RE GRIDCART GRID1 ELEV 28 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 150.06 265.88

RE GRIDCART GRID1 ELEV 28 385.25 766.24 1024.78 1350.02 918.87 708.10 577.48 1050.04 351.41 1316.01 785.07

RE GRIDCART GRID1 ELEV 29 630.28 594.37 815.43 227.96 32.09 73.36 68.24 123.49 145.09 186.91 182.64 0.00

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RE GRIDCART  GRID1 ELEV 29    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         0.00    0.00    0.00
RE GRIDCART  GRID1 ELEV 29  237.17  682.43  919.79 1014.55 1236.51 1265.85 1413.03
         1506.84  956.19  766.44    0.00
RE GRIDCART  GRID1 ELEV 30  605.52  482.90  646.64  255.94   98.11   93.22  131.62  158.49
         310.44  161.26    0.00    0.00
RE GRIDCART  GRID1 ELEV 30    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         0.00    0.00    0.00
RE GRIDCART  GRID1 ELEV 30    0.00    0.00    0.00  393.07  284.66  432.16   19.06   99.14
         14.27    6.22    0.00
RE GRIDCART  GRID1 ELEV 31  832.33  351.26  241.94   96.83  187.07  156.25  224.70
         388.97  304.07  108.85    0.00    0.00
RE GRIDCART  GRID1 ELEV 31    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         0.00    0.00    0.00
RE GRIDCART  GRID1 ELEV 31    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         0.00    0.00
RE GRIDCART  GRID1 ELEV 32  332.15  264.29  231.31  277.01  524.85  311.15  323.50
         525.48  280.65   72.51    0.00    0.00
RE GRIDCART  GRID1 ELEV 32    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         0.00    0.00    0.00
RE GRIDCART  GRID1 ELEV 32    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         0.00    0.00
RE GRIDCART  GRID1 ELEV 33  126.00  161.83  141.92  112.74  185.00  105.57  123.73
         87.21  133.58    0.00    0.00    0.00
RE GRIDCART  GRID1 ELEV 33    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         0.00    0.00    0.00
RE GRIDCART  GRID1 ELEV 33    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
         0.00    0.00
RE GRIDCART GRID1 END
RE FINISHED

ME STARTING
   INPUTFIL  ANKARA.TXT
   ANEMHGHT  19
   SURFDATA  17130  1995  ANKARA
   UAIRDATA  17130  1995  ANKARA
   STARDATA  ANNUAL
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   AVETEMPS  ANNUAL  285.1 285.1 285.1 285.1 285.1 285.1
   AVEMIXHT  ANNUAL 1 2556.3 2556.3 2556.3 2556.3 2556.3 2556.3
   AVEMIXHT  ANNUAL 2 1704.2 1704.2 1704.2 1704.2 1704.2 1704.2
   AVEMIXHT  ANNUAL 3 1704.2 1704.2 1704.2 1704.2 1704.2 1704.2
   AVEMIXHT  ANNUAL 4 1157.1 1157.1 1157.1 1157.1 1157.1 1157.1
   AVEMIXHT  ANNUAL 5  609.9  609.9  609.9  609.9  609.9  609.9
   AVEMIXHT  ANNUAL 6  609.9  609.9  609.9  609.9  609.9  609.9
ME FINISHED

OU STARTING
   RECTABLE  SRCGRP INDSRC
   MAXTABLE  10 INDSRC SRCGRP SOCONT
   PLOTFILE  ANNUAL  ALL 06T01.DAT
OU FINISHED

*********************************************************
**    This is a programe for the ISC Long Term Model, ISCLT3        **
**     THERMAL POWER PLANT-2  PROVINCE:ANKARA          **
**                                                  GRID 2          **
*********************************************************
CO STARTING
   TITLEONE  MATHEMATICAL MODELING OF CO2
   TITLETWO SOURCE:THERMAL POWER PLANT-2  PROVINCE:ANKARA
   MODELOPT  DFAULT  CONC  URBAN
   AVERTIME ANNUAL
   POLLUTID CO2
   TERRHGTS  ELEV
   RUNORNOT RUN
   ERRORFIL ERR06T02.LST DEBUG
CO FINISHED

SO STARTING
⇩
NOTE: This part is the same as Point type source (Thermal Power Plant "GRID 1 Programme")
⇩
SO FINISHED
```

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RE STARTING
RE GRIDCART GRID2 STA
RE GRIDCART XYINC 975000.  34.  25000.  4250000.  33.  25000.
RE GRIDCART  GRID2 ELEV  1    0.00  132.80  165.76  301.83  337.17  412.32  305.83  366.83
         426.42  422.17  365.42  393.58
RE  GRIDCART   GRID2  ELEV   1   457.32   696.85   597.36   364.68   190.10   227.92   222.00
         213.00  206.59  256.66  269.42  246.75
RE  GRIDCART   GRID2  ELEV   1   246.83   235.92   184.76   153.49   118.74   198.92   177.91
         184.92  257.55  605.26
RE GRIDCART  GRID2 ELEV  2    0.00  190.98  173.24  654.37  453.60  308.21  280.44  322.42
         366.33  371.76  348.26  280.42
RE  GRIDCART   GRID2  ELEV   2   345.63   349.67   356.77   209.80   286.21   249.66   209.55
         257.33  203.09  275.04  207.38  203.33
RE  GRIDCART   GRID2  ELEV   2   193.53   200.13   178.84   199.54   167.29   178.92   213.50
         260.04  373.92  660.61
RE GRIDCART  GRID2 ELEV  3    0.00  448.37  490.33  630.45  315.76  245.09  508.66  311.00
         350.15  355.83  286.12  246.09
RE  GRIDCART   GRID2  ELEV   3   324.64   217.43   251.91   284.15   337.59   293.00   279.00
         255.43  269.34  261.51  232.64  246.32
RE  GRIDCART   GRID2  ELEV   3   247.83   211.49   244.08   193.17   209.00   229.17   231.27
         329.34  512.30  705.00
RE GRIDCART  GRID2 ELEV  4    0.00   19.04  159.46  809.70  277.92  355.84  331.49  325.46
         383.23  380.00  378.31  262.67
RE  GRIDCART   GRID2  ELEV   4   268.89   294.67   335.39   344.16   334.88   313.83   295.92
         277.82  310.12  286.50  287.66  311.83
RE  GRIDCART   GRID2  ELEV   4   266.88   251.58   256.59   233.99   227.25   321.29   380.55
         409.95  532.85  529.49
RE GRIDCART  GRID2 ELEV  5    0.00  803.70   68.59   87.75  462.91  489.98  505.40  455.98
         395.76  335.15  441.27  337.45
RE  GRIDCART   GRID2  ELEV   5   302.25   417.34   435.59   525.07   520.15   412.00   275.59
         345.60  400.76  384.68  356.59  317.17
RE  GRIDCART   GRID2  ELEV   5   248.68   254.58   291.42   292.92   256.06   283.00   420.23
         611.26  445.93  712.99
RE GRIDCART  GRID2 ELEV  6    0.00    0.00 1519.67  350.05  317.44  507.82  476.05  524.36
         446.94  355.78  506.64  376.96
RE  GRIDCART   GRID2  ELEV   6   317.21   360.74   382.67   500.30   438.28   400.08   319.76
         334.97  498.60  536.09 1107.67  465.40
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RE GRIDCART GRID2 ELEV 6 383.12 355.93 320.35 250.56 280.57 309.35 500.38 844.24 674.03 508.69

RE GRIDCART GRID2 ELEV 7 32.42 0.00 848.27 339.58 699.63 944.09 648.25 531.13 446.51 497.75 489.59 384.22

RE GRIDCART GRID2 ELEV 7 355.83 406.00 402.17 419.92 345.08 388.75 333.42 355.92 344.08 360.92 371.59 392.66

RE GRIDCART GRID2 ELEV 7 382.66 326.90 317.81 344.51 328.08 361.37 570.80 727.28 2305.78 1481.05

RE GRIDCART GRID2 ELEV 8 20.09 331.62 902.13 1097.93 1032.21 813.17 852.29 629.33 328.81 625.11 487.66 423.54

RE GRIDCART GRID2 ELEV 8 371.01 574.91 464.24 406.35 354.93 433.99 414.59 389.67 390.99 360.28 381.17 428.33

RE GRIDCART GRID2 ELEV 8 370.54 360.08 534.87 977.02 450.70 642.59 1120.36 1329.71 1264.95 2229.02

RE GRIDCART GRID2 ELEV 9 50.76 29.26 159.81 1021.75 485.25 981.04 856.68 756.52 622.27 645.00 724.57 712.15

RE GRIDCART GRID2 ELEV 9 497.02 653.60 537.25 504.60 436.08 455.09 501.59 544.32 517.19 514.83 483.40 594.14

RE GRIDCART GRID2 ELEV 9 517.63 1041.42 955.66 1486.16 1031.86 1658.53 629.28 738.73 1890.67 2354.35

RE GRIDCART GRID2 ELEV 10 183.01 125.09 232.05 812.00 665.20 697.14 1043.26 547.49 567.12 484.19 491.79 818.38

RE GRIDCART GRID2 ELEV 10 714.91 700.31 814.69 765.89 893.98 1058.49 1086.46 939.18 892.81 937.32 776.90 318.68

RE GRIDCART GRID2 ELEV 10 698.27 755.25 1490.92 1294.33 1375.31 1729.41 1011.54 2305.13 1849.46 2174.68

RE GRIDCART GRID2 ELEV 11 730.69 963.50 1560.65 1107.67 543.82 2038.57 978.06 925.83 652.72 630.39 637.08 568.26

RE GRIDCART GRID2 ELEV 11 603.08 777.17 1128.81 1156.44 833.32 901.92 1083.71 1230.40 1090.28 937.36 845.94 848.42

RE GRIDCART GRID2 ELEV 11 1547.28 1024.17 1575.05 2867.96 2219.08 1762.03 2232.02 1326.21 2614.41 1956.86

RE GRIDCART GRID2 ELEV 12 1565.20 1306.22 1181.23 1630.52 1886.41 2026.41 1296.71 1181.05 2127.80 1121.89 819.57 735.76

RE GRIDCART GRID2 ELEV 12 827.27 966.63 1050.16 907.07 605.68 547.16 524.26 854.24 981.55 616.48 863.98 1405.19

RE GRIDCART GRID2 ELEV 12 1714.45 1419.15 3155.61 2540.09 2810.18 2999.03 2014.39 2963.75 1658.81 1362.54
RE GRIDCART GRID2 ELEV 13 1573.21 1777.08 1343.32 1478.66 1268.04 2038.12 1544.96 2513.30 1999.87 1507.57 1653.57 1403.70
RE GRIDCART GRID2 ELEV 13 1017.21 752.22 781.76 722.43 677.47 716.26 671.38 586.79 603.15 747.30 1032.57 754.93
RE GRIDCART GRID2 ELEV 13 671.53 1853.67 2577.39 2058.67 2531.30 2335.75 2159.38 2041.94 2350.13 1283.60
RE GRIDCART GRID2 ELEV 14 1440.47 1498.48 1858.79 2683.16 1255.76 1608.35 1622.29 1710.16 965.63 979.92 974.35 1577.12
RE GRIDCART GRID2 ELEV 14 1000.69 1441.30 1089.17 867.17 810.00 858.74 921.12 755.85 1051.78 1529.86 1396.79 2217.18
RE GRIDCART GRID2 ELEV 14 2066.67 2520.25 2705.68 2191.16 2355.60 2944.67 2559.89 1698.68 2087.35 1255.54
RE GRIDCART GRID2 ELEV 15 1627.10 1578.49 1606.25 1738.68 1715.51 2069.15 1440.48 1522.78 1458.00 692.92 1427.06 1344.43
RE GRIDCART GRID2 ELEV 15 999.68 1440.96 1570.16 1223.60 930.72 1508.55 912.84 1013.33 1645.35 1677.00 2035.79 1889.94
RE GRIDCART GRID2 ELEV 15 1884.08 2251.13 1689.42 1792.34 2036.06 2681.03 2254.36 2144.43 1381.64 1257.00
RE GRIDCART GRID2 ELEV 16 1292.38 1679.99 1751.84 1738.17 1988.36 1771.77 1636.09 1745.92 1252.23 1127.92 1044.38 1258.15
RE GRIDCART GRID2 ELEV 16 1064.10 747.24 1430.15 1357.34 1033.83 1235.66 2601.17 1599.52 2024.35 1268.42 1263.08 1931.70
RE GRIDCART GRID2 ELEV 16 1634.00 1634.00 1632.29 1835.81 2117.87 2415.69 2192.81 2413.55 1196.92 1769.44
RE GRIDCART GRID2 ELEV 17 1260.63 1257.60 1564.70 1631.41 1718.91 1614.00 1666.49 1478.53 1894.74 1399.51 1068.82 890.04
RE GRIDCART GRID2 ELEV 17 1397.87 1211.47 1362.15 1153.39 1340.66 1272.38 1485.59 1381.09 1302.61 1576.49 1832.42 1903.54
RE GRIDCART GRID2 ELEV 17 2329.85 1796.43 1634.00 1942.62 2201.57 2160.43 2345.40 1831.73 1446.72 1010.66
RE GRIDCART GRID2 ELEV 18 1888.90 1223.91 1380.77 1546.55 1839.94 1543.55 1512.01 1686.34 1349.51 1492.87 1577.01 2209.90
RE GRIDCART GRID2 ELEV 18 1665.11 1253.95 1831.14 1592.06 1556.04 1653.70 1933.57 1904.01 1713.46 1982.73 1509.26 1577.07

RE GRIDCART GRID2 ELEV 18 1805.03 1801.16 1808.49 1867.36 2276.38 2192.72 2421.24 2136.97 1387.31 1595.23
RE GRIDCART GRID2 ELEV 19 1575.14 1809.56 1450.27 1531.34 1602.27 1757.33 1641.25 1321.56 1408.85 1338.25 1161.08 2224.78
RE GRIDCART GRID2 ELEV 19 2453.15 2564.59 2149.70 2107.26 2171.01 2112.96 1903.78 2460.58 2502.85 1656.07 1529.76 1935.45
RE GRIDCART GRID2 ELEV 19 1972.01 1987.99 2481.16 3168.85 2276.34 2444.88 2036.08 1337.79 974.42 852.26
RE GRIDCART GRID2 ELEV 20 1236.50 1537.87 1670.87 1469.05 1321.64 1493.02 1411.00 1481.77 2012.07 1268.24 1657.69 1525.26
RE GRIDCART GRID2 ELEV 20 1387.72 1194.64 1454.69 1652.21 1978.29 1772.38 1895.85 2312.80 2192.26 2092.96 2050.68 2044.99
RE GRIDCART GRID2 ELEV 20 1631.33 2016.87 2370.00 2178.44 2307.64 2247.42 1324.61 1551.07 804.38 1011.86
RE GRIDCART GRID2 ELEV 21 899.83 1177.21 1314.87 1575.47 1456.79 1993.60 1430.45 1528.15 1728.26 2742.93 1841.23 1742.83
RE GRIDCART GRID2 ELEV 21 2184.74 2420.47 1901.42 1486.02 1748.66 1943.25 2244.93 2406.81 2684.31 2376.58 2343.47 2371.66
RE GRIDCART GRID2 ELEV 21 1716.59 1665.98 1956.34 2648.58 1942.57 1783.90 1929.39 933.21 851.49 2233.08
RE GRIDCART GRID2 ELEV 22 819.83 983.44 1307.06 1533.45 1554.75 1483.58 2243.30 1777.12 1364.72 975.44 1008.97 1347.19
RE GRIDCART GRID2 ELEV 22 1465.87 1561.98 1855.99 2038.89 2320.43 2160.97 2545.92 1772.64 1827.76 1921.47 1587.30 2305.69
RE GRIDCART GRID2 ELEV 22 2410.15 2317.25 2320.83 1724.27 1105.84 1070.32 855.96 1019.59 1883.76 1669.17
RE GRIDCART GRID2 ELEV 23 766.23 643.55 1372.02 1289.41 1059.91 1307.87 1182.70 1563.00 1675.63 2004.20 1441.36 2088.94
RE GRIDCART GRID2 ELEV 23 1767.00 1466.47 2095.66 1544.60 1800.81 2125.38 2249.92 2364.15 1998.61 2042.85 2047.19 2700.96
RE GRIDCART GRID2 ELEV 23 2201.77 1403.04 1399.15 1007.76 913.93 848.09 1034.76 1547.68 2386.29 3038.89
RE GRIDCART GRID2 ELEV 24 539.82 866.20 1549.09 453.56 272.42 1650.23 1147.90 1233.27 1974.58 1393.73 1965.39 2053.72
RE GRIDCART GRID2 ELEV 24 1455.36 2199.80 1932.63 1967.23 2794.56 2089.11 1198.47 2224.54 1821.09 1874.41 1925.67 2419.12

RE GRIDCART GRID2 ELEV 24 1878.60 2021.56 1963.43 1427.83 1653.44 1387.70 1365.96 2490.05 2028.57 1875.00

RE GRIDCART GRID2 ELEV 25 736.98 1813.11 1099.23 1275.90 1192.96 987.11 643.09 230.28 945.15 630.05 919.91 955.93

RE GRIDCART GRID2 ELEV 25 1291.37 838.46 1055.01 1090.05 2025.79 2324.41 3128.03 1421.24 2163.81 2183.14 1178.12 1919.40

RE GRIDCART GRID2 ELEV 25 2248.27 1839.66 1774.61 1430.41 2291.34 2961.12 2179.29 1944.22 1875.00 2280.83

RE GRIDCART GRID2 ELEV 26 568.15 591.64 947.00 257.61 205.42 339.45 0.29 0.00 0.00 0.00 0.00 56.97

RE GRIDCART GRID2 ELEV 26 199.19 92.35 0.00 0.00 396.03 1370.51 1728.86 1534.55 2081.87 2533.27 1979.64 1979.06

RE GRIDCART GRID2 ELEV 26 2136.04 2219.57 1751.07 1626.12 2071.35 2143.43 1939.97 1675.40 2316.03 1549.66

RE GRIDCART GRID2 ELEV 27 1019.00 895.18 151.06 9.00 10.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

RE GRIDCART GRID2 ELEV 27 0.00 0.00 0.00 0.00 0.00 0.00 265.12 2130.42 1650.12 859.68 2651.80 1796.00

RE GRIDCART GRID2 ELEV 27 1883.68 1972.83 2653.72 2023.36 2284.27 1593.09 1172.52 1532.11 1510.76 1107.45

RE GRIDCART GRID2 ELEV 28 345.23 32.02 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

RE GRIDCART GRID2 ELEV 28 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 223.96 2823.04 923.99 2583.49

RE GRIDCART GRID2 ELEV 28 2044.31 1733.91 1807.59 2195.29 1941.03 1842.86 1141.27 922.75 451.93 296.86

RE GRIDCART GRID2 ELEV 29 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

RE GRIDCART GRID2 ELEV 29 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 353.39 773.32 1290.23 2371.68

RE GRIDCART GRID2 ELEV 29 2114.41 1836.92 1668.83 2119.59 1319.27 719.53 419.34 305.34 422.64 517.34

RE GRIDCART GRID2 ELEV 30 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

RE GRIDCART GRID2 ELEV 30 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 653.10 2455.61 1849.37

RE GRIDCART GRID2 ELEV 30 1962.98 1131.28 1745.24 1861.97 1735.62 1207.73 1205.69 467.50 833.78 466.31

RE GRIDCART GRID2 ELEV 31 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

RE GRIDCART GRID2 ELEV 31 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 2.42 323.37 428.29 532.65

RE GRIDCART GRID2 ELEV 31 1029.73 580.77 768.49 1305.98 933.02 485.45 820.47 1551.96 1655.06 846.26

RE GRIDCART GRID2 ELEV 32 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

RE GRIDCART GRID2 ELEV 32 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 11.00 37.30 69.12 122.42

RE GRIDCART GRID2 ELEV 32 206.27 708.58 1057.77 787.61 830.00 841.92 687.17 1155.56 430.29 665.01

RE GRIDCART GRID2 ELEV 33 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

RE GRIDCART GRID2 ELEV 33 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 60.42 123.92 485.42 1052.69

RE GRIDCART GRID2 ELEV 33 1733.70 1404.68 1179.60 1225.10 2248.11 1926.73 1704.15 1465.99 2866.53 2066.54

RE GRIDCART GRID2 END

RE FINISHED

ME STARTING

⇩

NOTE: This part is the same as Point type source (Thermal Power Plant “GRID 1 Programme”)

⇩

ME FINISHED

OU STARTING

⇩

NOTE: This part is the same as Point type source (Thermal Power Plant “GRID 1 Programme”)

⇩

OU FINISHED

Runstream file for "Area" type source:

```
*********************************************************
**    This is a programe for the ISC Long Term Model, ISCLT3        **
**     HOUSEHOLDS –1   PROVINCE:ANKARA districts: 1,4,9      **
**                                                   GRID 1         **
*********************************************************
CO STARTING
   TITLEONE MATHEMATICAL MODELING OF CO2
   TITLETWO SOURCE:HOUSEHOLDS-1  PROVINCE:ANKARA
   MODELOPT  DFAULT  CONC  URBAN
   AVERTIME ANNUAL
   POLLUTID CO2
   TERRHGTS  ELEV
   RUNORNOT RUN
   ERRORFIL 06P011.LST DEBUG
CO FINISHED

SO STARTING
SO LOCATION 609 AREA 754619.0 4770062.0 1233.1
SO SRCPARAM 609 0.7446464 20.0 1000.0 1000.0
SO LOCATION 601 AREA 741795.5 4760414.0 1181.1
SO SRCPARAM 601 20.4262100 20.0 1000.0 1000.0
SO LOCATION 604 AREA 723875.4 4721351.0 1044.0
SO SRCPARAM 604 2.5529740 20.0 1000.0 1000.0
SO SRCGROUP ALL
SO FINISHED

RE STARTING
⇩
NOTE: This part is the same as Point type source (Thermal Power Plant "GRID 1 Programme")
⇩
RE FINISHED

ME STARTING
⇩
NOTE: This part is the same as Point type source (Thermal Power Plant "GRID 1 Programme")
⇩
```

ME FINISHED

OU STARTING

⇩

NOTE: This part is the same as Point type source (Thermal Power Plant “GRID 1 Programme”)

⇩

OU FINISHED

```
*******************************************************
**     This is a programe for the ISC Long Term Model, ISCLT3        **
**      HOUSEHOLDS –1    PROVINCE:ANKARA districts: 1,4,9      **
**                                                    GRID 2          **
*******************************************************
CO STARTING
   TITLEONE  MATHEMATICAL MODELING OF CO2
   TITLETWO SOURCE:HOUSEHOLDS-2  PROVINCE:ANKARA
   MODELOPT  DFAULT  CONC  URBAN
   AVERTIME ANNUAL
   POLLUTID CO2
   TERRHGTS  ELEV
   RUNORNOT RUN
   ERRORFIL 06P021.LST DEBUG
CO FINISHED
```

SO STARTING

⇩

NOTE: This part is the same as Area type source (Households “GRID 1 Programme”)

⇩

SO FINISHED

RE STARTING

⇩

NOTE: This part is the same as Point type source (Thermal Power Plant “GRID 2 Programme”)

⇩

RE FINISHED

ME STARTING

⇩

NOTE: This part is the same as Point type source (Thermal Power Plant “GRID 1 Programme”)

⇩

ME FINISHED

OU STARTING

⇩

NOTE: This part is the same as Point type source (Thermal Power Plant “GRID 1 Programme”)

⇩

OU FINISHED

D.2. Meteorological Input File (STARDATA)

The following Table F.1 shows the frequency distributions of wind speeds according to the wind directions and stability classes.

Table F.1 STARDATA input file of ISCLT3 Model for province Ankara

SC(1)	WD(2)	WIND SPEED (m/s)						SC(1)	WD(2)	WIND SPEED (m/s)					
		0-3	3-6	6-10	10-16	16-21	>21			0-3	3-6	6-10	10-16	16-21	>21
A	1	0.014267	0.000000	0.000000	0.000000	0.000000	0.000000	D	1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
A	2	0.045396	0.000000	0.000000	0.000000	0.000000	0.000000	D	2	0.000000	0.041237	0.020619	0.000000	0.000000	0.000000
A	3	0.101816	0.000000	0.000000	0.000000	0.000000	0.000000	D	3	0.000000	0.206186	0.164948	0.000000	0.000000	0.000000
A	4	0.169909	0.000000	0.000000	0.000000	0.000000	0.000000	D	4	0.000000	0.051546	0.092784	0.000000	0.000000	0.000000
A	5	0.103761	0.000000	0.000000	0.000000	0.000000	0.000000	D	5	0.000000	0.000000	0.010309	0.000000	0.000000	0.000000
A	6	0.039559	0.000000	0.000000	0.000000	0.000000	0.000000	D	6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
A	7	0.027886	0.000000	0.000000	0.000000	0.000000	0.000000	D	7	0.000000	0.020619	0.010309	0.000000	0.000000	0.000000
A	8	0.016861	0.000000	0.000000	0.000000	0.000000	0.000000	D	8	0.000000	0.010309	0.010309	0.000000	0.000000	0.000000
A	9	0.011025	0.000000	0.000000	0.000000	0.000000	0.000000	D	9	0.000000	0.030928	0.030928	0.000000	0.000000	0.000000
A	10	0.016861	0.000000	0.000000	0.000000	0.000000	0.000000	D	10	0.000000	0.030928	0.020619	0.000000	0.000000	0.000000
A	11	0.109598	0.000000	0.000000	0.000000	0.000000	0.000000	D	11	0.000000	0.041237	0.061856	0.000000	0.000000	0.000000
A	12	0.187419	0.000000	0.000000	0.000000	0.000000	0.000000	D	12	0.000000	0.030928	0.010309	0.000000	0.000000	0.000000
A	13	0.103113	0.000000	0.000000	0.000000	0.000000	0.000000	D	13	0.000000	0.041237	0.000000	0.000000	0.000000	0.000000
A	14	0.025292	0.000000	0.000000	0.000000	0.000000	0.000000	D	14	0.000000	0.020619	0.010309	0.000000	0.000000	0.000000
A	15	0.015564	0.000000	0.000000	0.000000	0.000000	0.000000	D	15	0.000000	0.010309	0.000000	0.000000	0.000000	0.000000
A	16	0.011673	0.000000	0.000000	0.000000	0.000000	0.000000	D	16	0.000000	0.020619	0.000000	0.000000	0.000000	0.000000
B	1	0.023013	0.005645	0.000000	0.000000	0.000000	0.000000	E	1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
B	2	0.055580	0.011724	0.000000	0.000000	0.000000	0.000000	E	2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
B	3	0.121581	0.049501	0.000000	0.000000	0.000000	0.000000	E	3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
B	4	0.130699	0.033435	0.000000	0.000000	0.000000	0.000000	E	4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
B	5	0.032132	0.004776	0.000000	0.000000	0.000000	0.000000	E	5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
B	6	0.014329	0.000434	0.000000	0.000000	0.000000	0.000000	E	6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
B	7	0.019974	0.004776	0.000000	0.000000	0.000000	0.000000	E	7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
B	8	0.016500	0.002171	0.000000	0.000000	0.000000	0.000000	E	8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
B	9	0.009119	0.003474	0.000000	0.000000	0.000000	0.000000	E	9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
B	10	0.016500	0.002171	0.000000	0.000000	0.000000	0.000000	E	10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
B	11	0.061224	0.015198	0.000000	0.000000	0.000000	0.000000	E	11	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
B	12	0.122883	0.072080	0.000000	0.000000	0.000000	0.000000	E	12	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
B	13	0.051672	0.045158	0.000000	0.000000	0.000000	0.000000	E	13	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
B	14	0.017369	0.009987	0.000000	0.000000	0.000000	0.000000	E	14	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
B	15	0.021711	0.004776	0.000000	0.000000	0.000000	0.000000	E	15	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
B	16	0.015632	0.004776	0.000000	0.000000	0.000000	0.000000	E	16	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	1	0.003861	0.017375	0.000000	0.000000	0.000000	0.000000	F	1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	2	0.001931	0.036680	0.001931	0.000000	0.000000	0.000000	F	2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	3	0.034749	0.175676	0.034749	0.000000	0.000000	0.000000	F	3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	4	0.040541	0.073359	0.032819	0.001931	0.000000	0.000000	F	4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	5	0.000000	0.017375	0.003861	0.000000	0.000000	0.000000	F	5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	6	0.003861	0.000000	0.000000	0.000000	0.000000	0.000000	F	6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	7	0.005792	0.013514	0.000000	0.000000	0.000000	0.000000	F	7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	8	0.007722	0.011583	0.001931	0.000000	0.000000	0.000000	F	8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	9	0.003861	0.007722	0.001931	0.000000	0.000000	0.000000	F	9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	10	0.000000	0.003861	0.000000	0.000000	0.000000	0.000000	F	10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	11	0.021236	0.055985	0.011583	0.000000	0.000000	0.000000	F	11	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	12	0.046332	0.137066	0.000000	0.000000	0.000000	0.000000	F	12	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	13	0.032819	0.071429	0.007722	0.000000	0.000000	0.000000	F	13	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	14	0.007722	0.030888	0.000000	0.000000	0.000000	0.000000	F	14	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	15	0.005792	0.009653	0.000000	0.000000	0.000000	0.000000	F	15	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C	16	0.001931	0.021236	0.000000	0.000000	0.000000	0.000000	F	16	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Note: This is the output of QBasic Programs (Appendix E).
(1) SC: Stability Class; (2) WD: Wind Direction

APPENDIX G

In Appendix G, the following figures are presented for the provinces of Turkey:

- Annual frequency distributions of wind speeds in provinces (wind roses), 1990
- Annual frequency distributions of wind speeds in selected provinces (wind roses), 1995
- Annual frequency distributions of wind speeds in selected provinces (wind roses), 1996
- Annual frequency distributions of wind speeds in selected provinces (wind roses), 1997
- Annual frequency distributions of wind speeds in selected provinces (wind roses), 1998
- Annual frequency distributions of wind speeds in selected provinces (wind roses), 1999
- Annual frequency distributions of wind speeds in selected provinces (wind roses), 2000
- Annual frequency distributions of wind speeds in selected provinces (wind roses), 2001
- Annual frequency distributions of wind speeds in selected provinces (wind roses), 2002
- Annual frequency distributions of wind speeds in selected provinces (wind roses), 2004

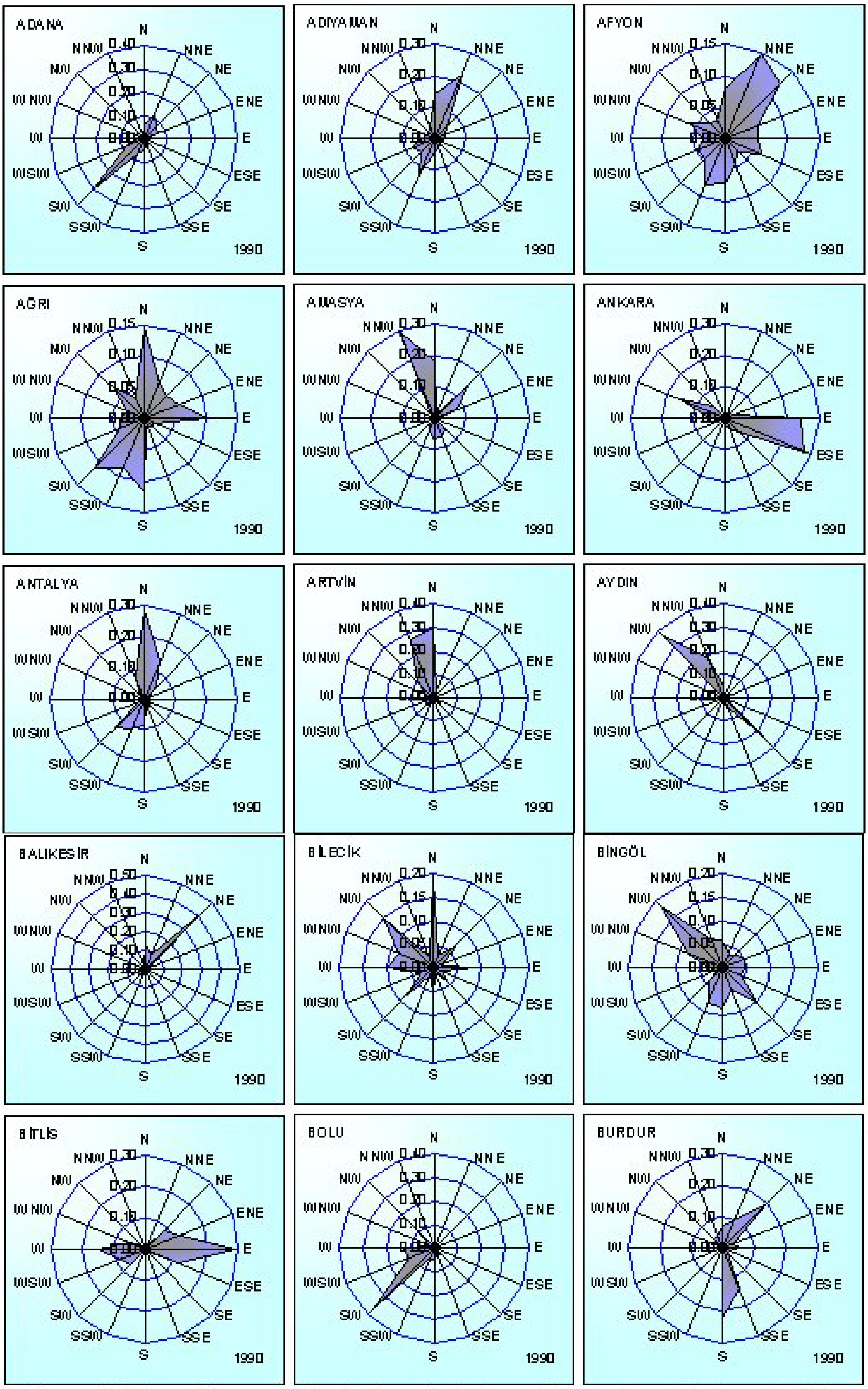


Figure G.1 Annual frequency distributions of wind speeds in provinces (wind roses), 1990

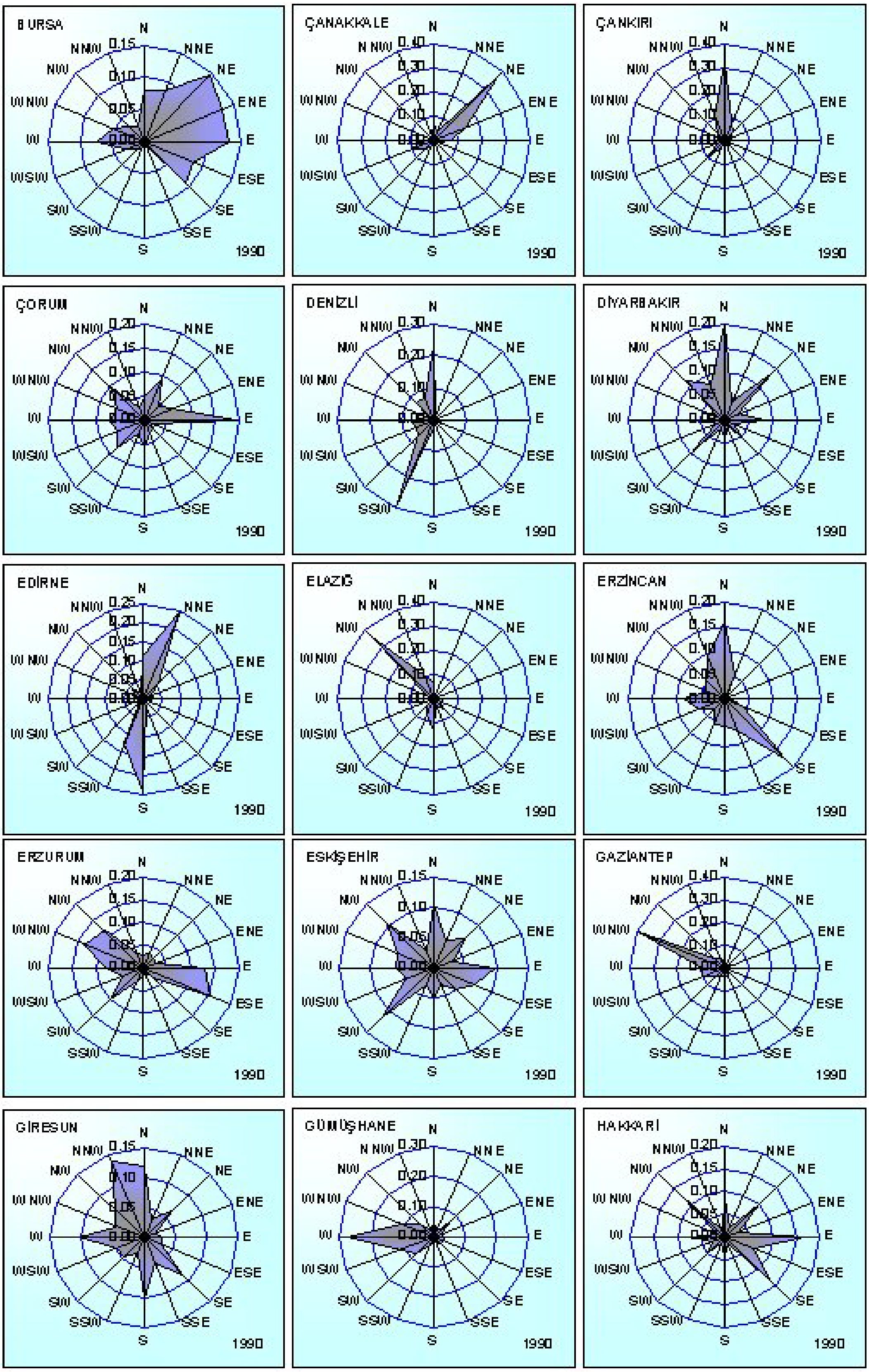


Figure G.1 Annual frequency distributions of wind speeds in provinces (wind roses), 1990 (continued)

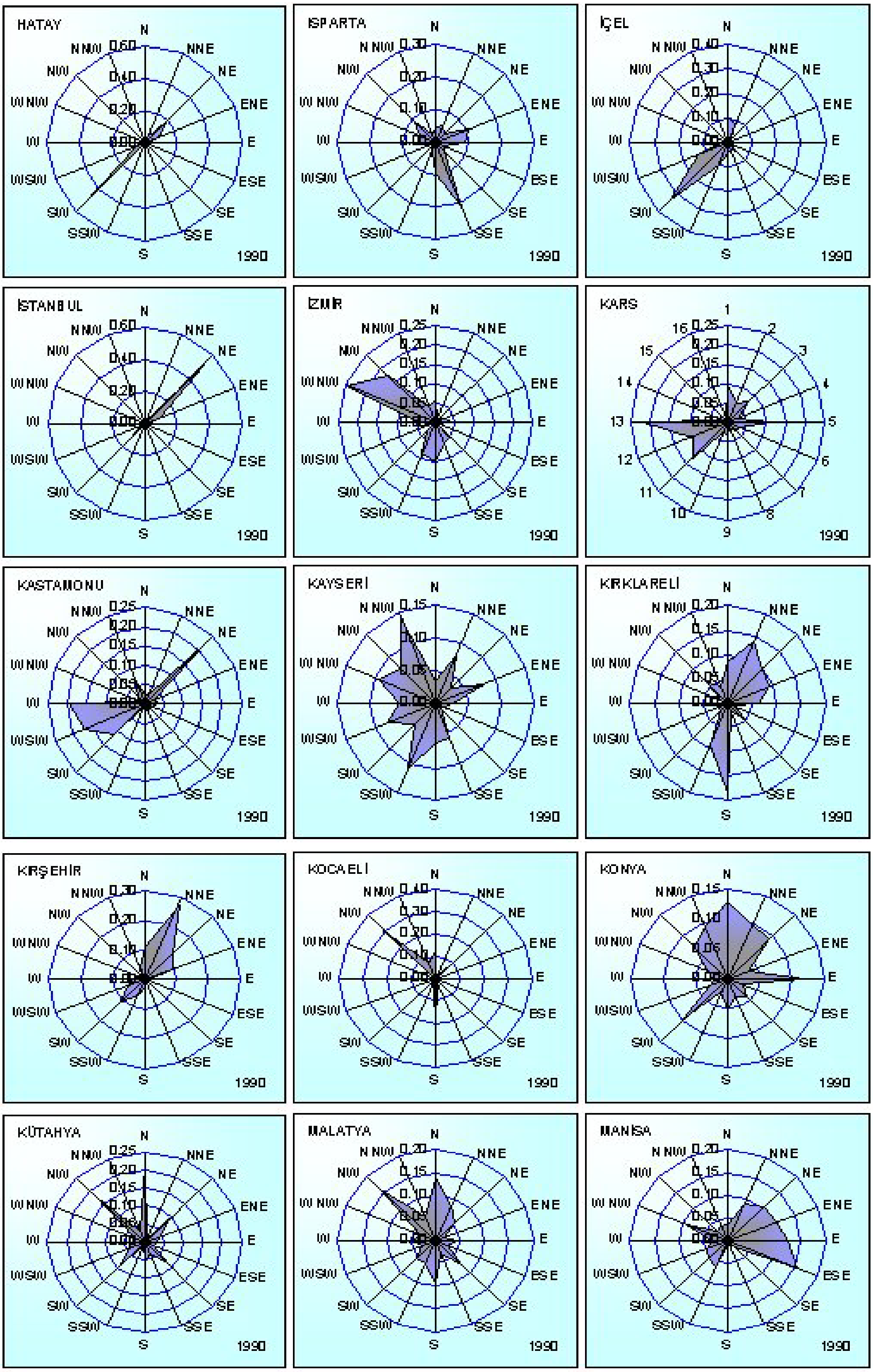


Figure G.1 Annual frequency distributions of wind speeds in provinces (wind roses), 1990 (continued)

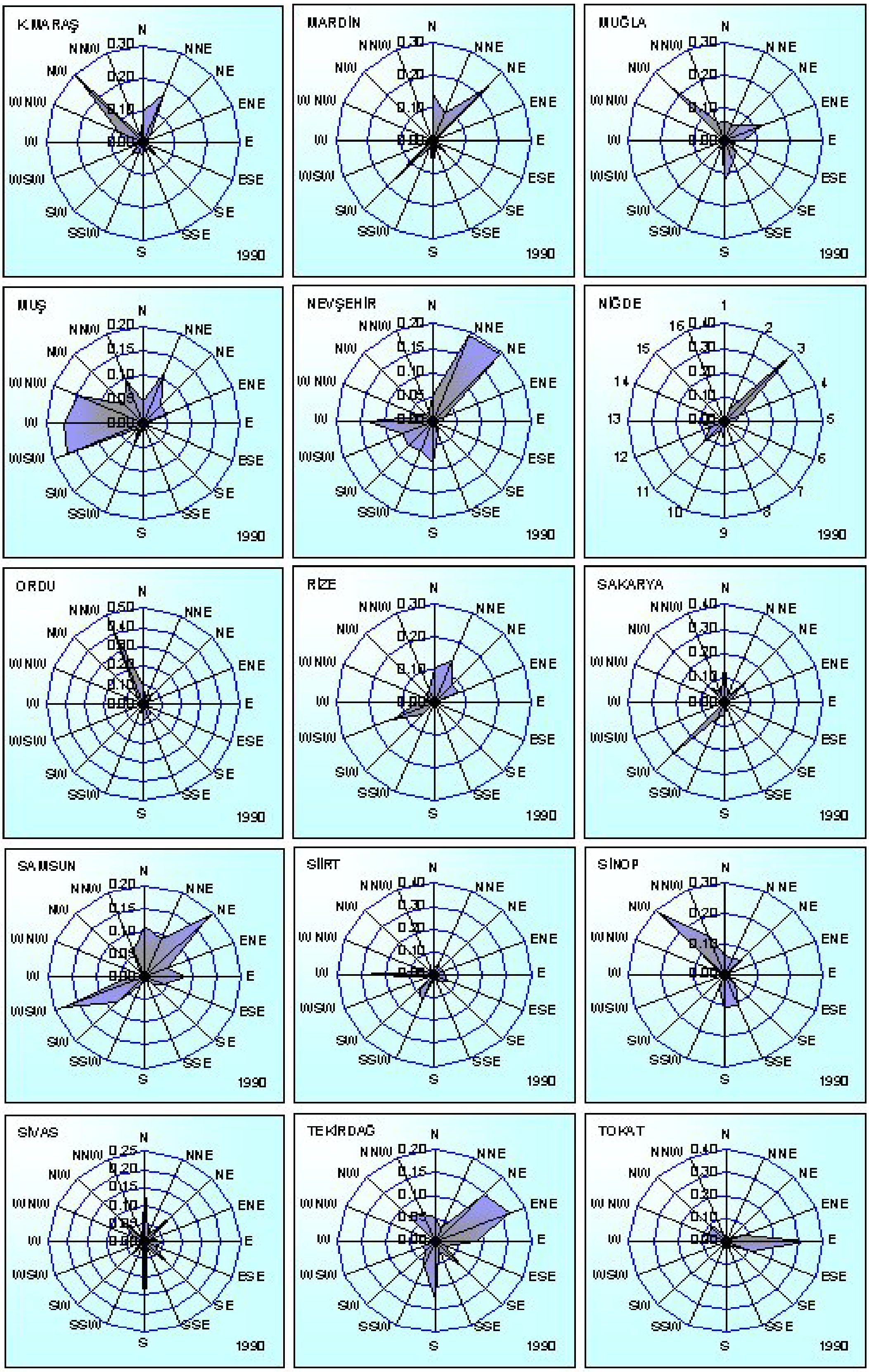


Figure G.1 Annual frequency distributions of wind speeds in provinces (wind roses), 1990 (continued

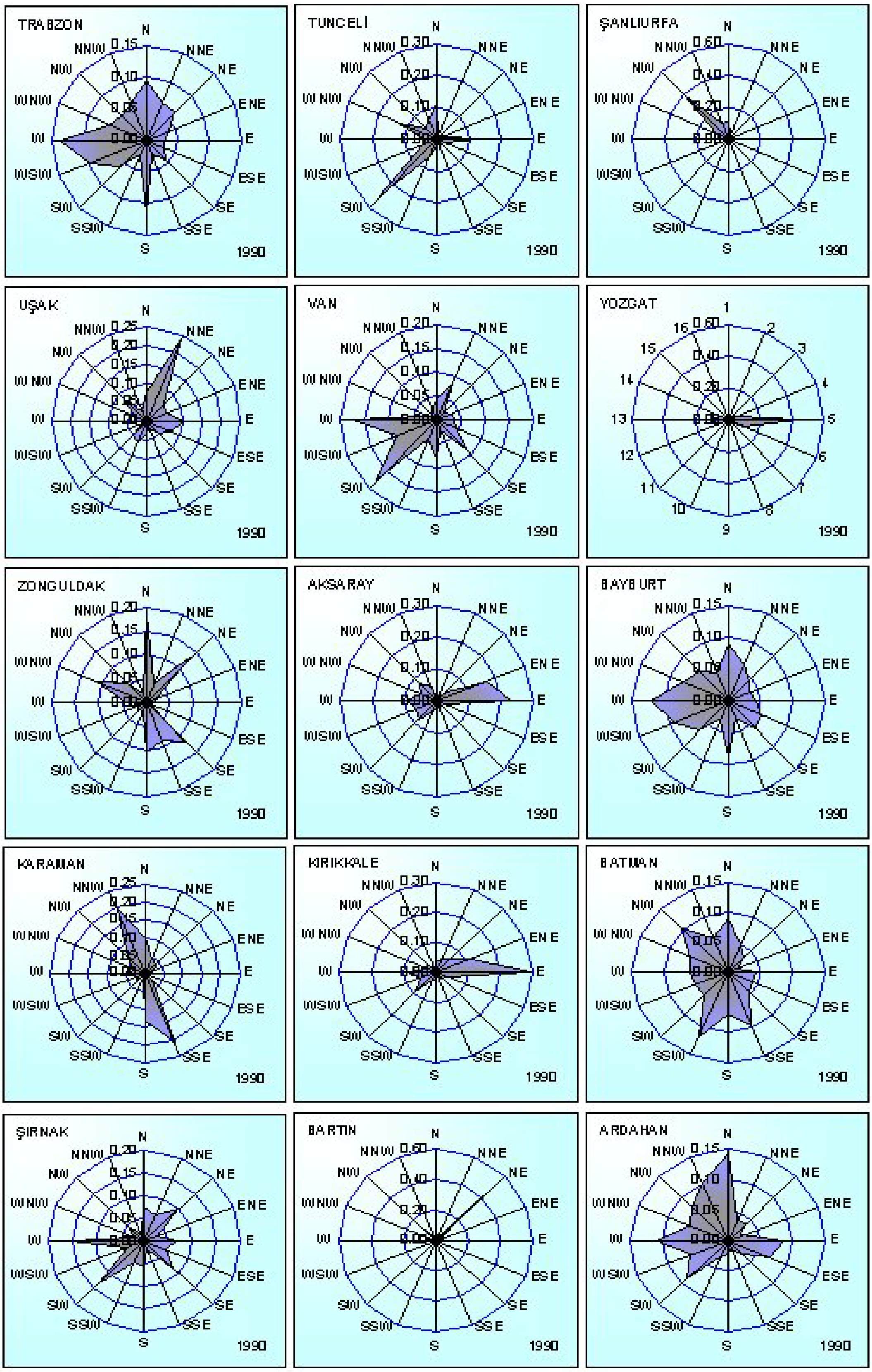


Figure G.1 Annual frequency distributions of wind speeds in provinces (wind roses), 1990 (continued)

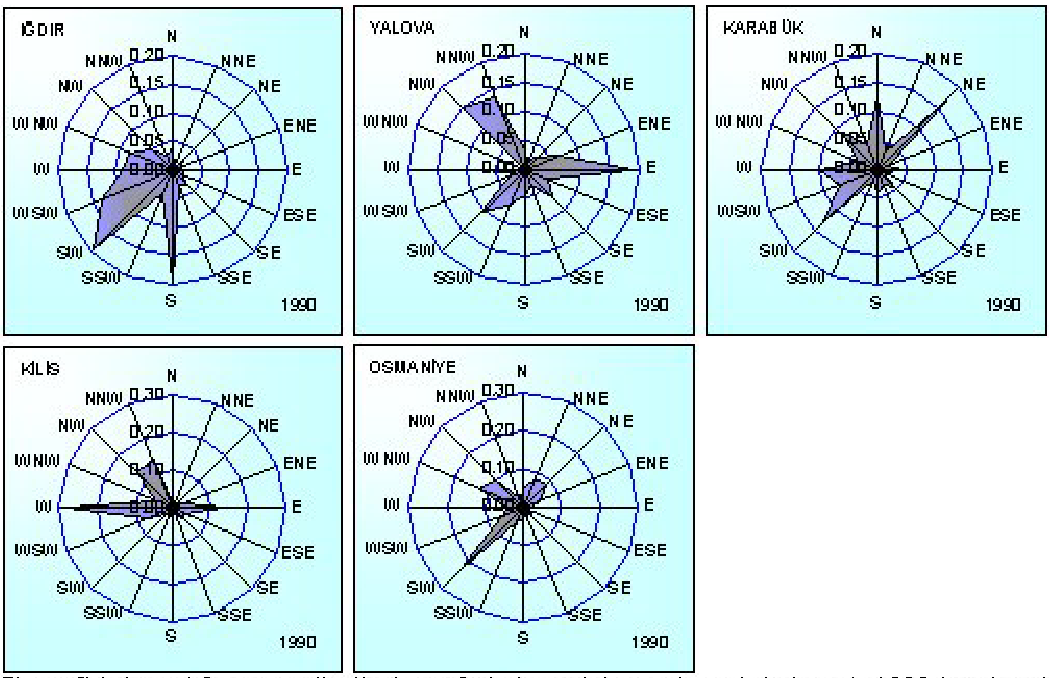


Figure G.1 Annual frequency distributions of wind speeds in provinces (wind roses), 1990 (continued)

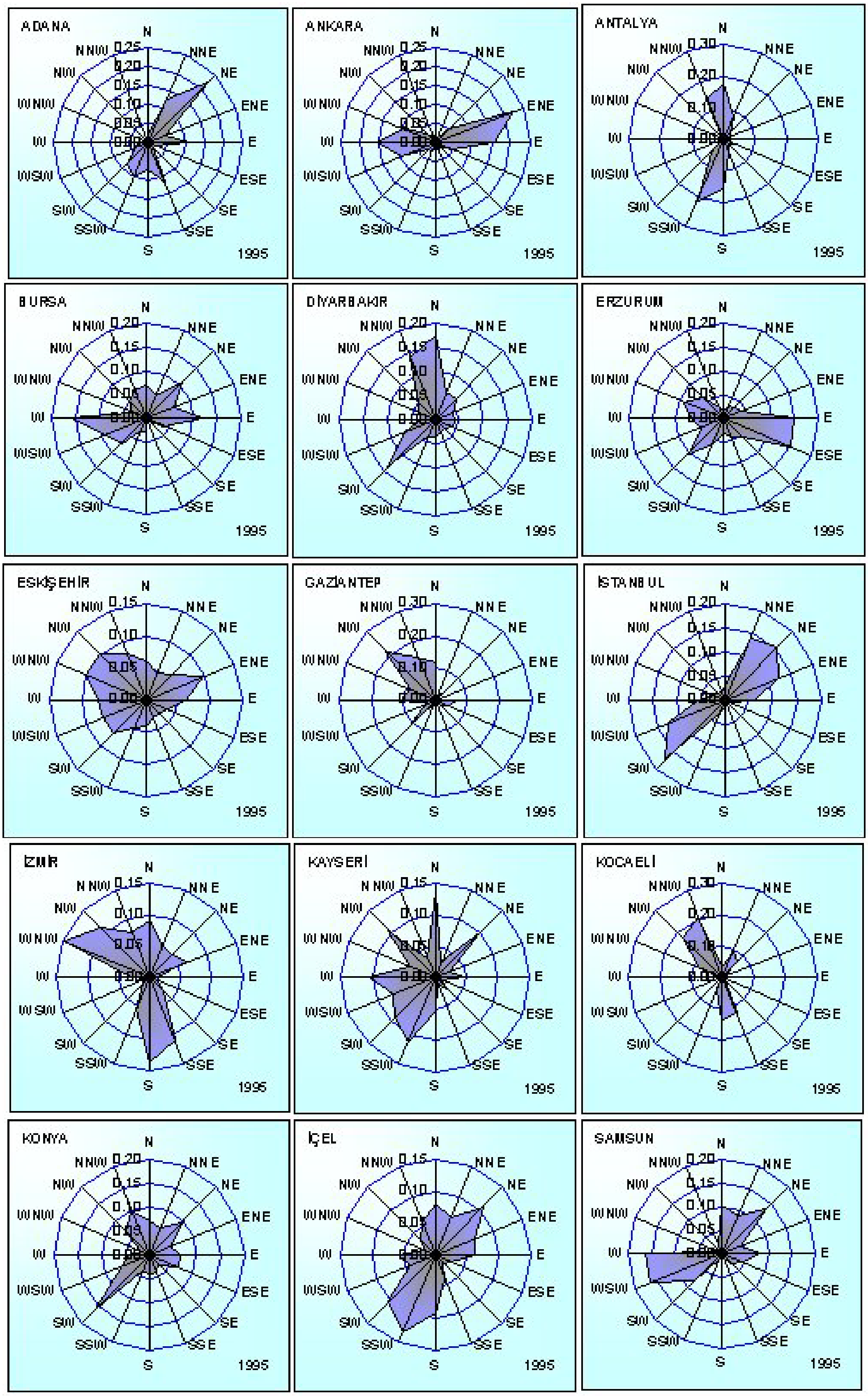


Figure G.2 Annual frequency distributions of wind speeds in selected provinces (wind roses), 1995

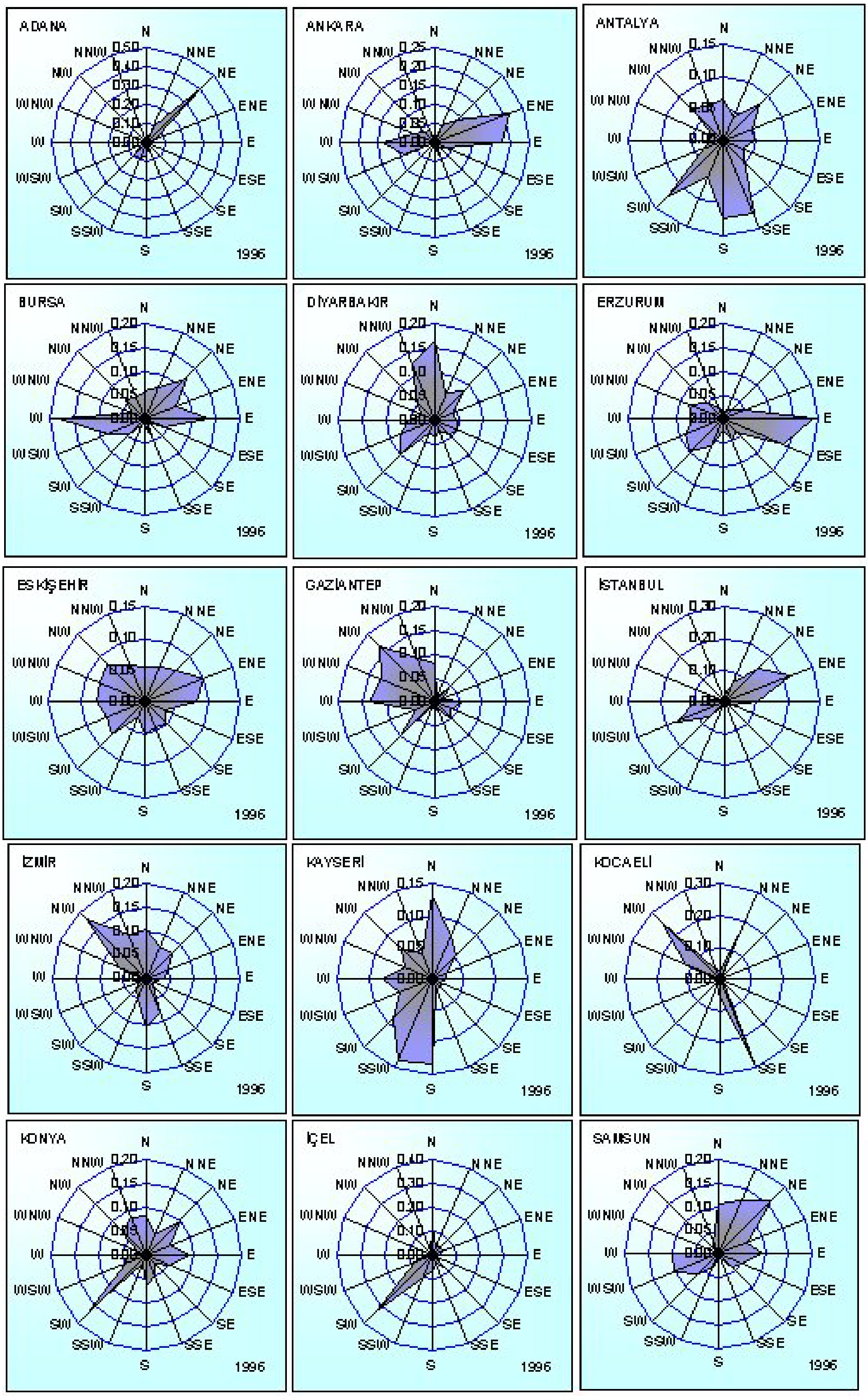


Figure G.3 Annual frequency distributions of wind speeds in selected provinces (wind roses), 1996

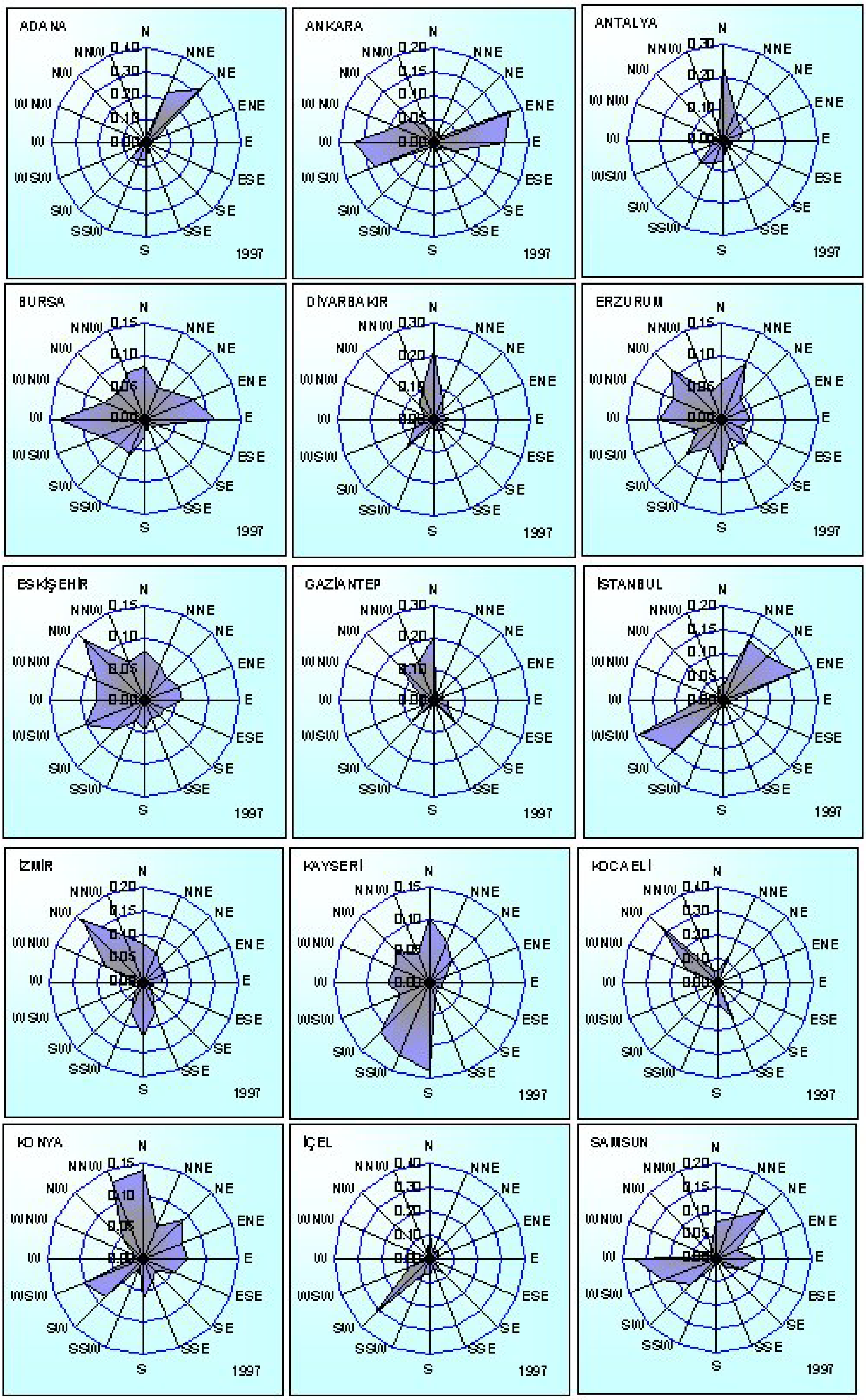


Figure G.4 Annual frequency distributions of wind speeds in selected provinces (wind roses), 1997

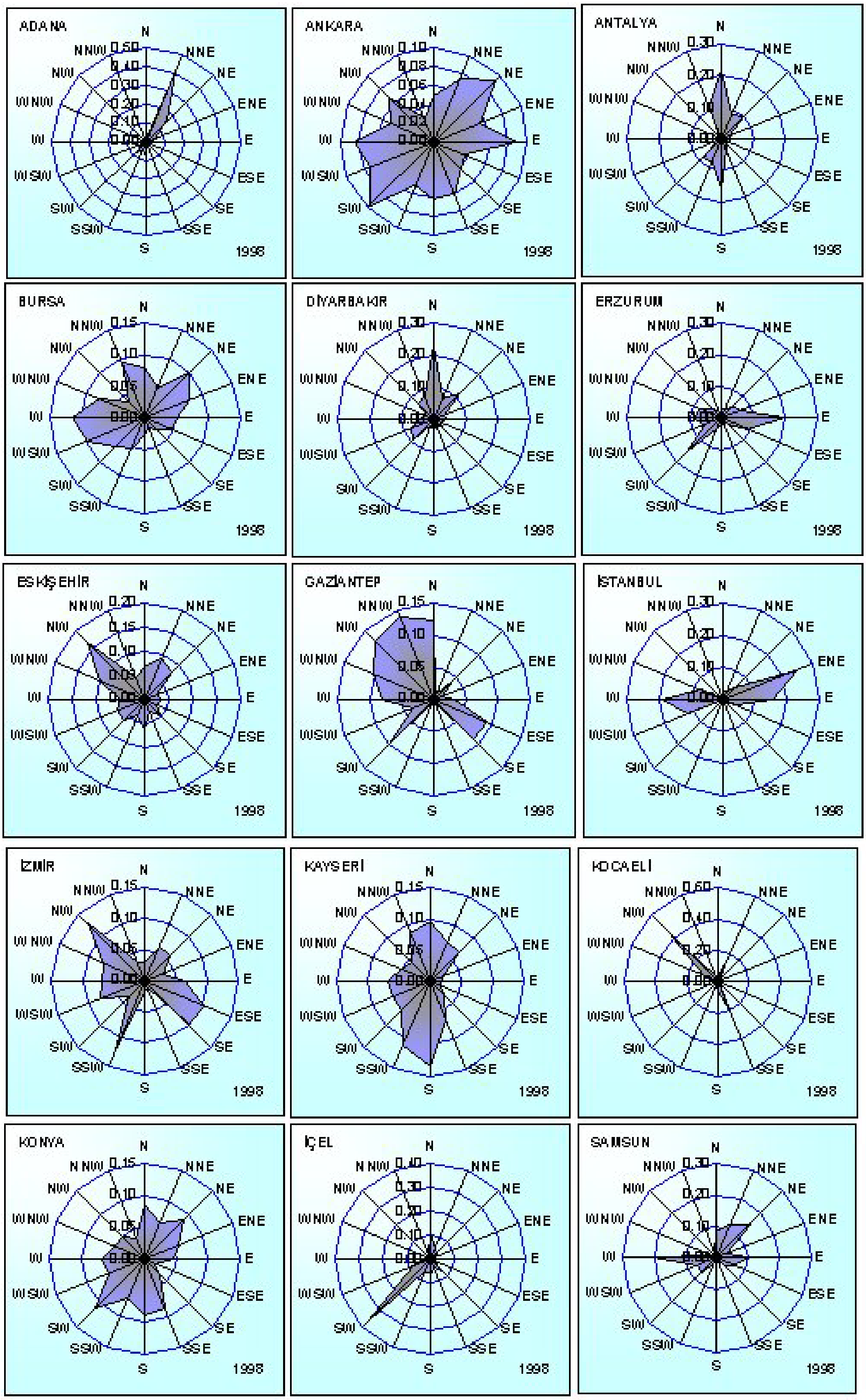


Figure G.5 Annual frequency distributions of wind speeds in selected provinces (wind roses), 1998

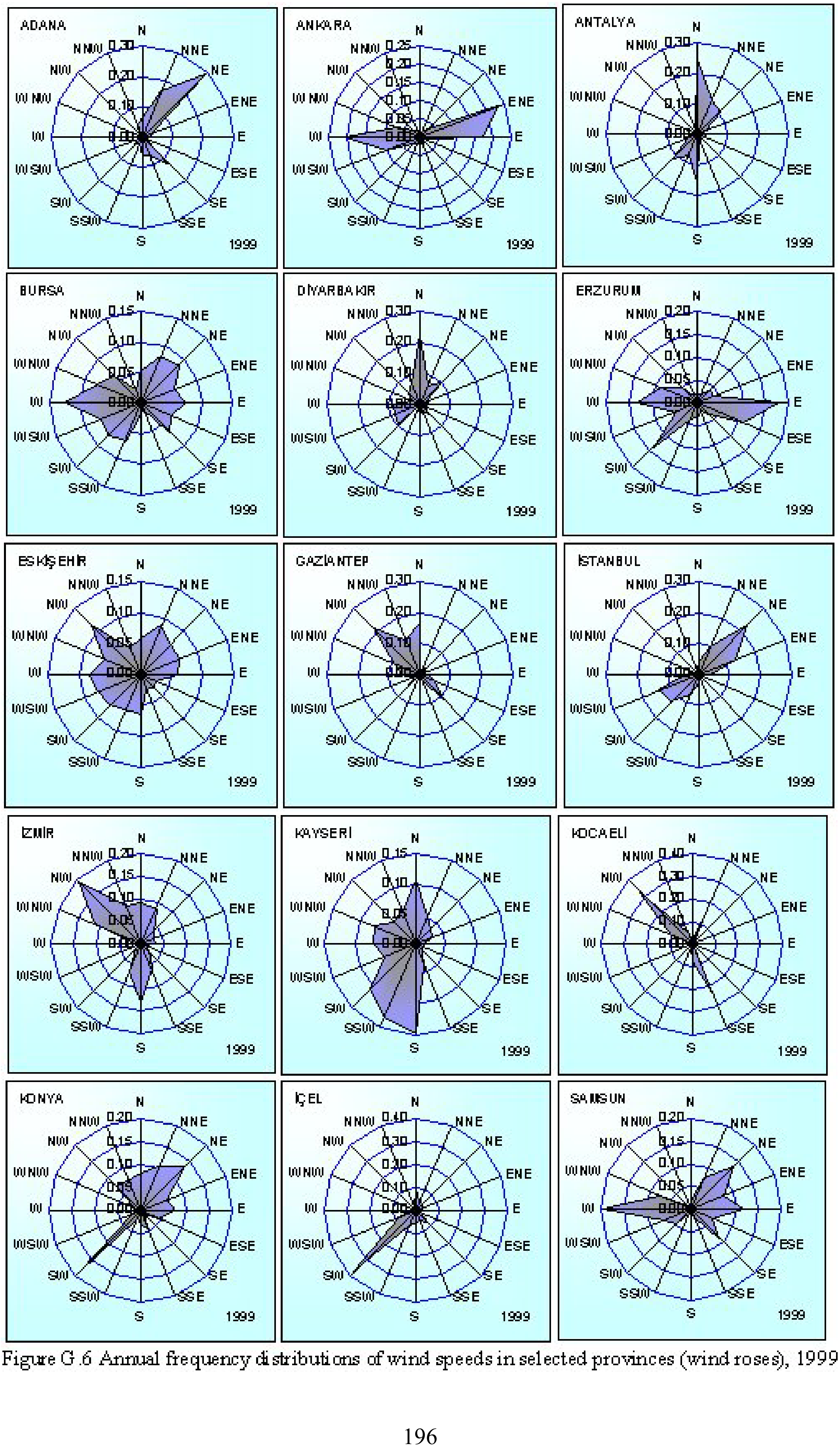


Figure G.6 Annual frequency distributions of wind speeds in selected provinces (wind roses), 1999

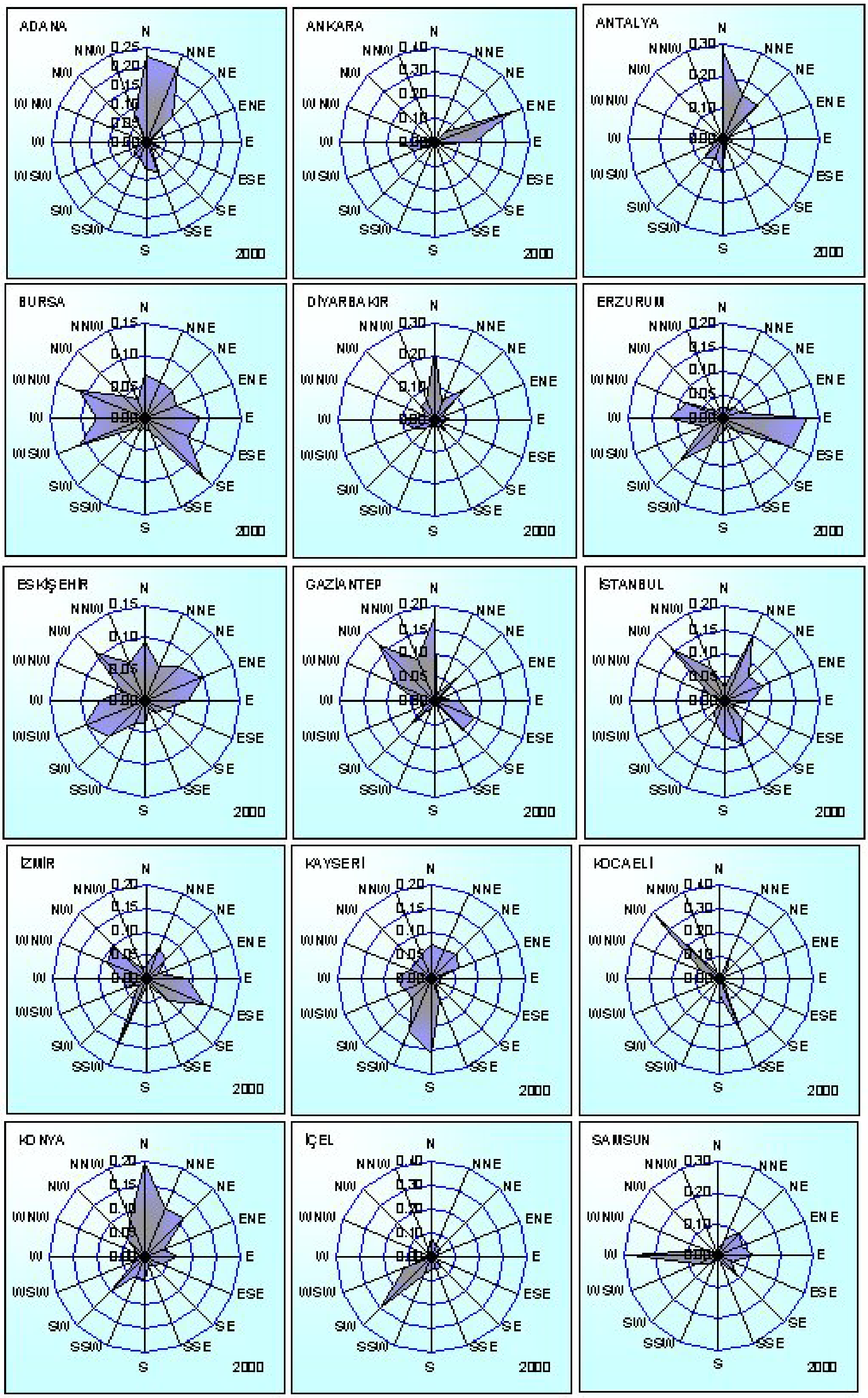


Figure G.7 Annual frequency distributions of wind speeds in selected provinces (wind roses), 2000

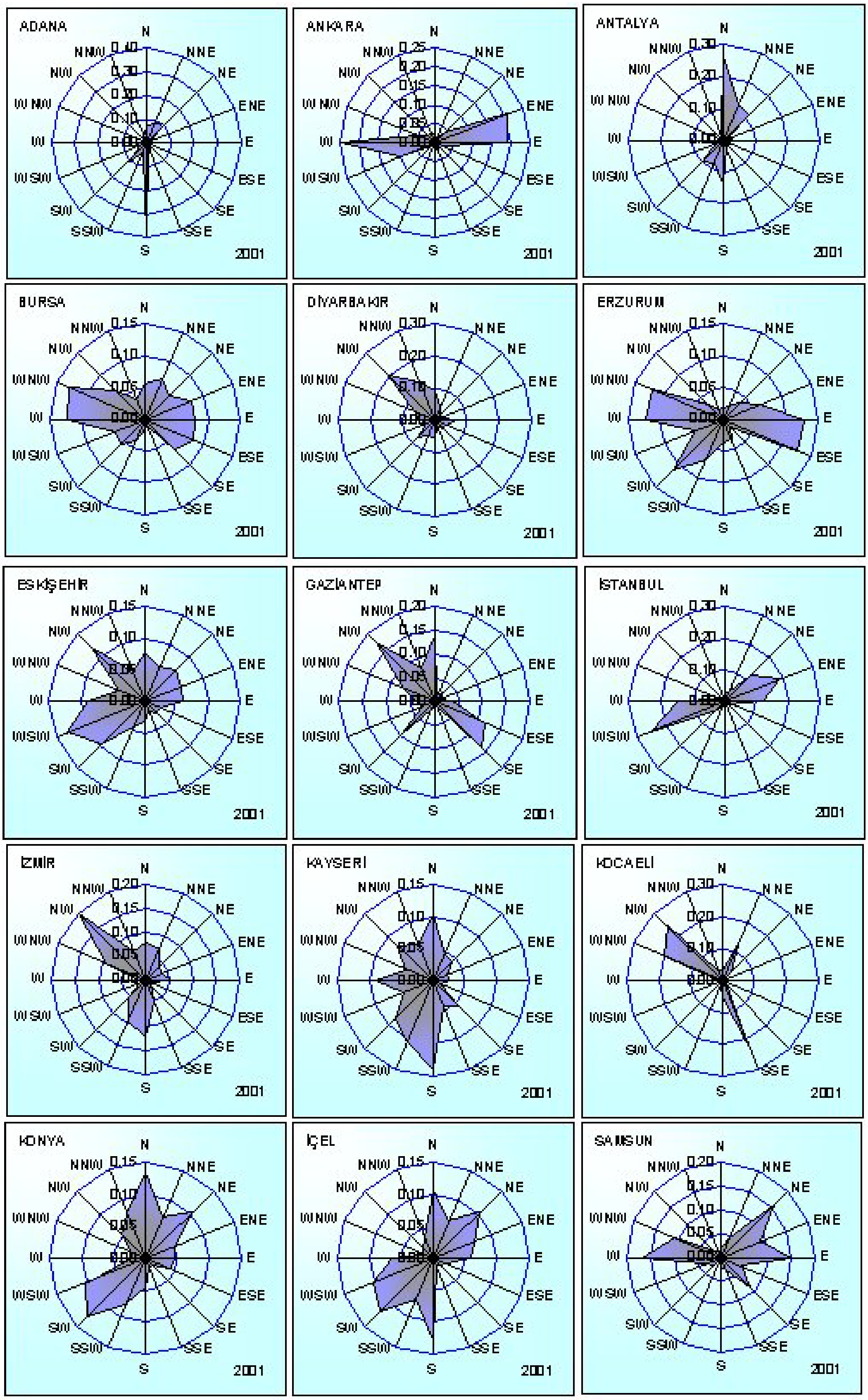


Figure G.8 Annual frequency distributions of wind speeds in selected provinces (wind roses), 2001

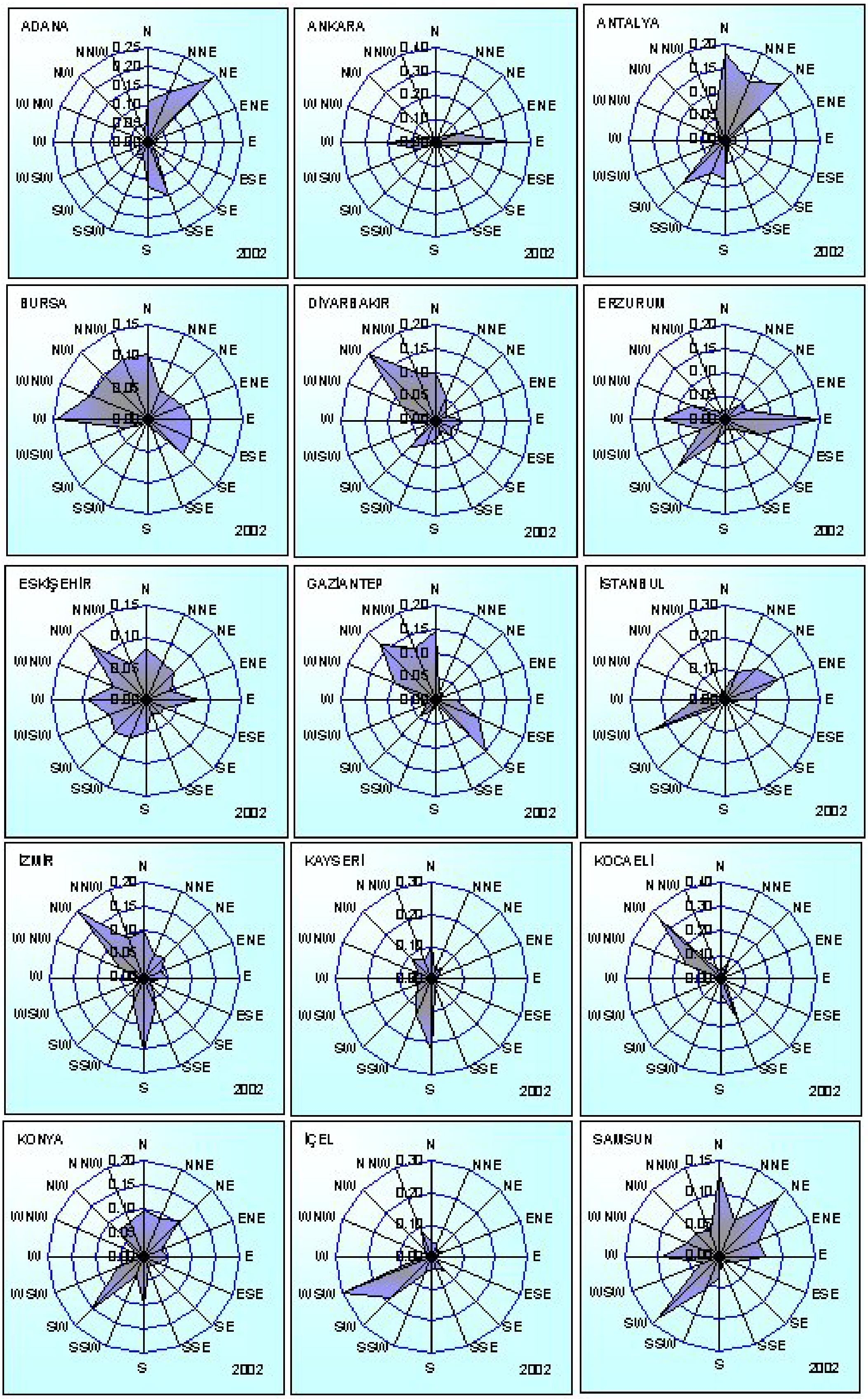


Figure G.9 Annual frequency distributions of wind speeds in selected provinces (wind roses), 2002

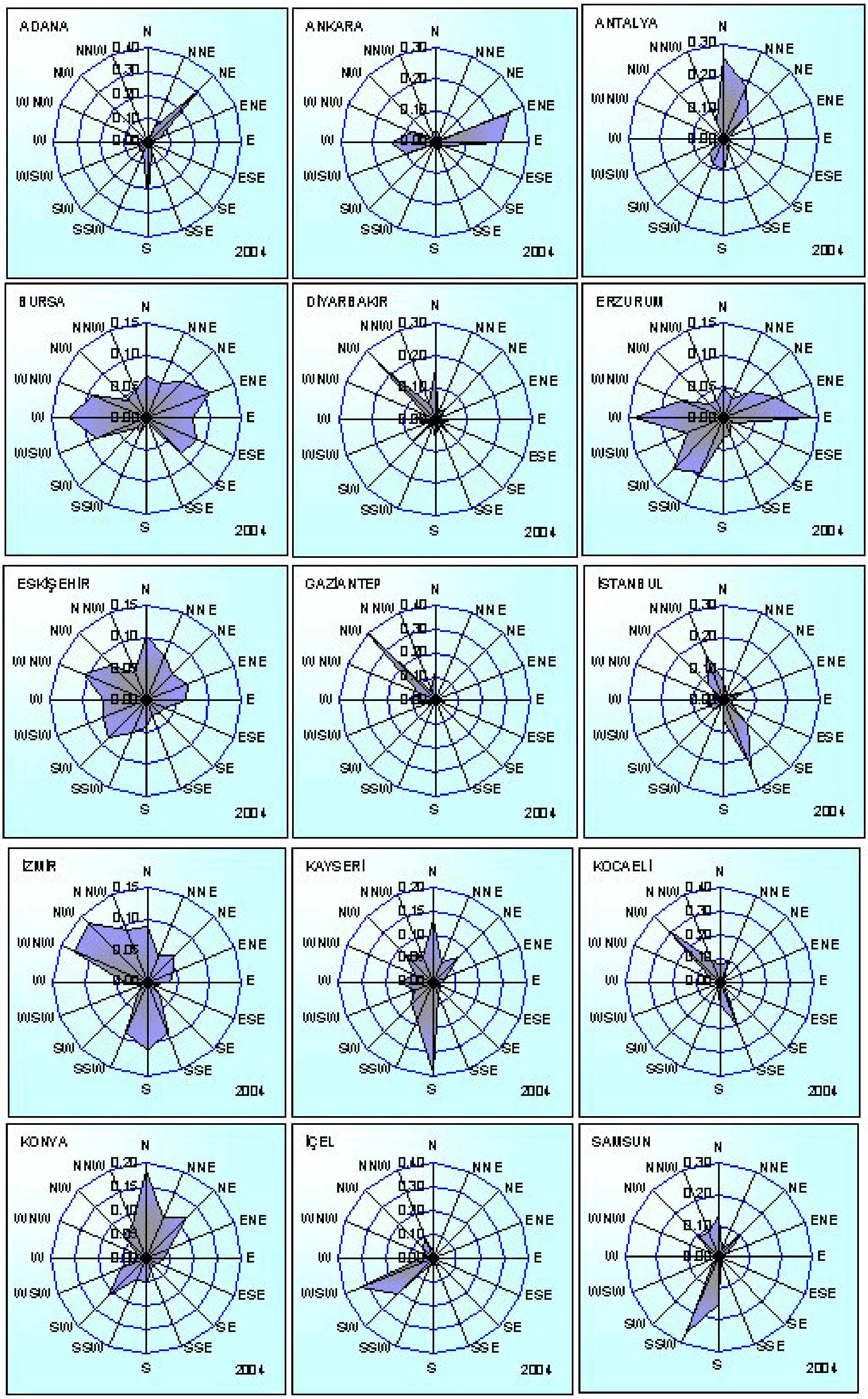
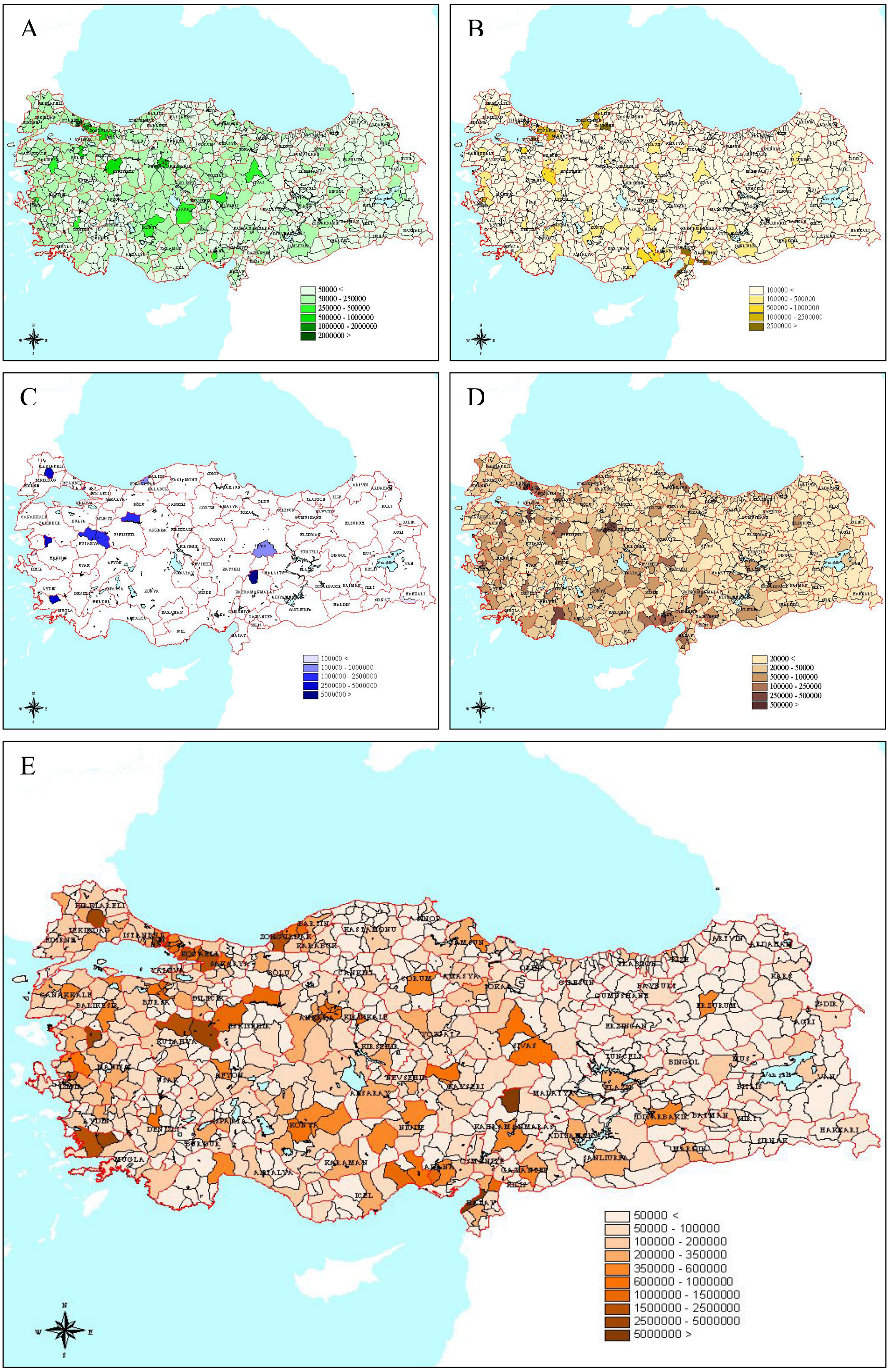


Figure G.10 Annual frequency distributions of wind speeds in selected provinces (wind roses), 2004

APPENDIX H

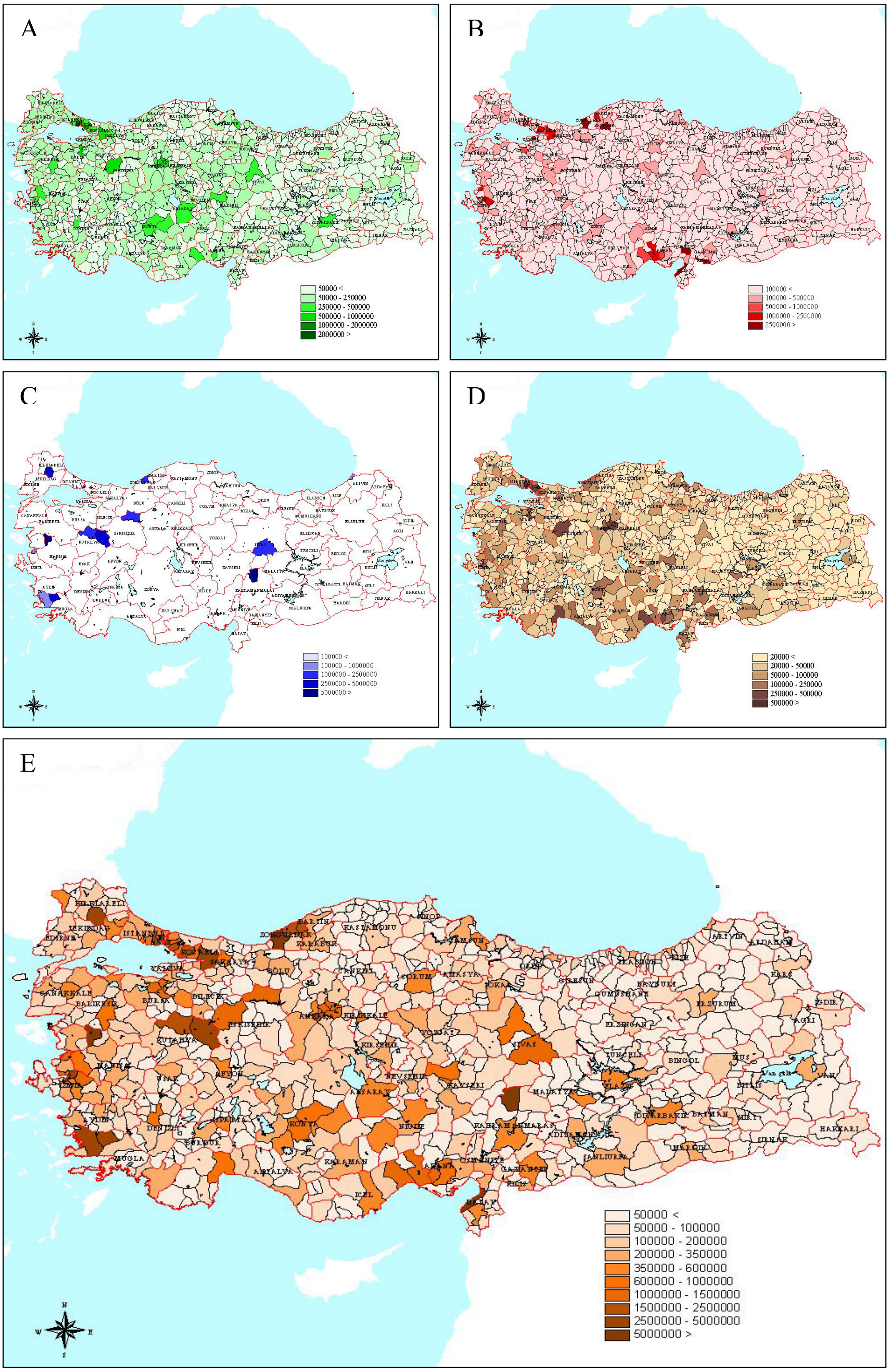
In Appendix H, the following CO_2 emission maps are presented according to its sources:

- CO_2 emissions of districts for 1990
- CO_2 emissions of districts for 1995
- CO_2 emissions of districts for 2000
- CO_2 emissions of districts for 2005
- CO_2 emissions of districts for 2010
- CO_2 emissions of provinces for 1990
- CO_2 emissions of provinces for 1995
- CO_2 emissions of provinces for 2000
- CO_2 emissions of provinces for 2005
- CO_2 emissions of provinces for 2010



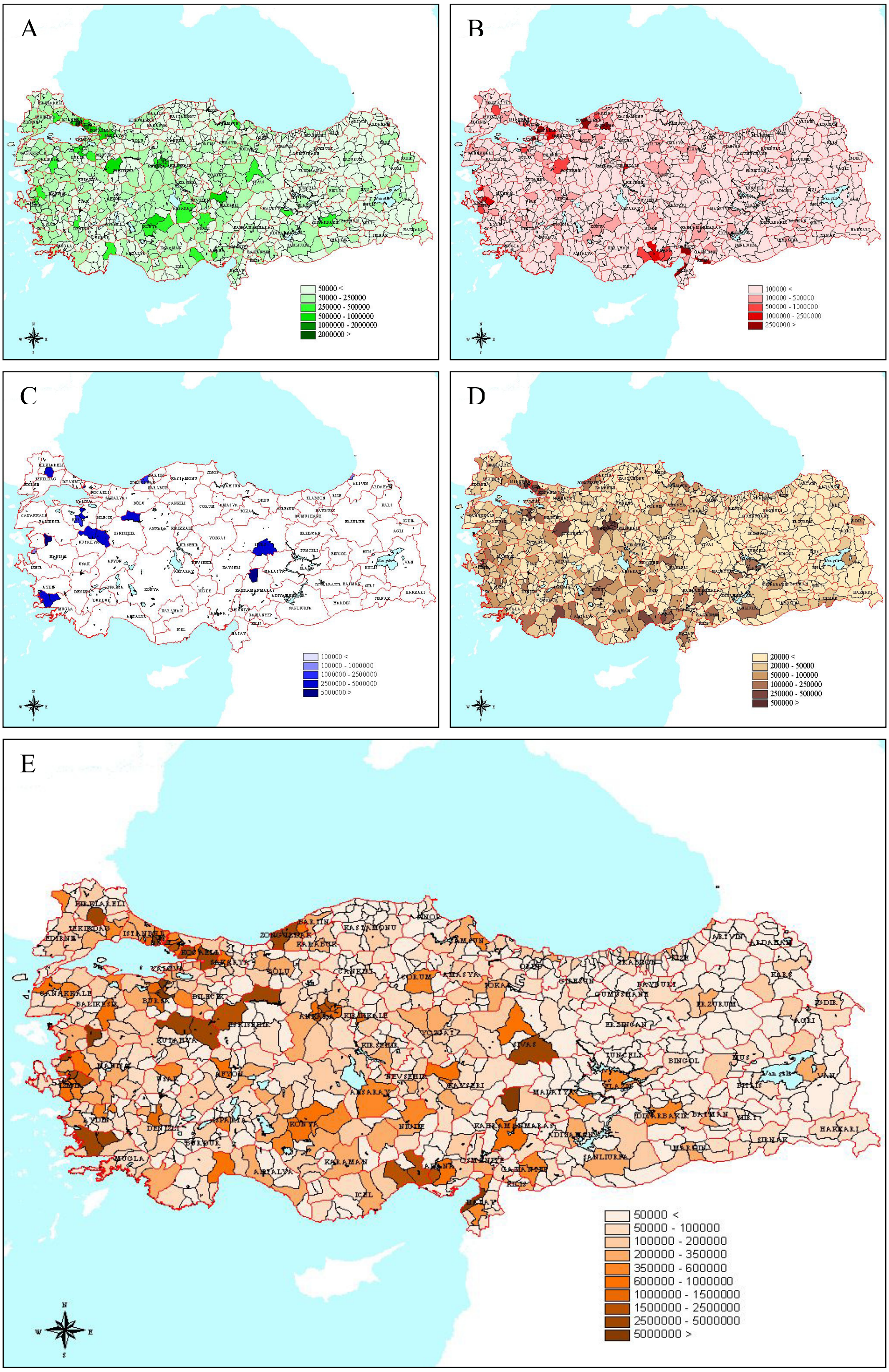
A-Households, B-Industries, C-Thermal Power Plants, D-Road Vehicles, E-Total

Figure H.1 CO_2 emissions of districts for 1990 in tones



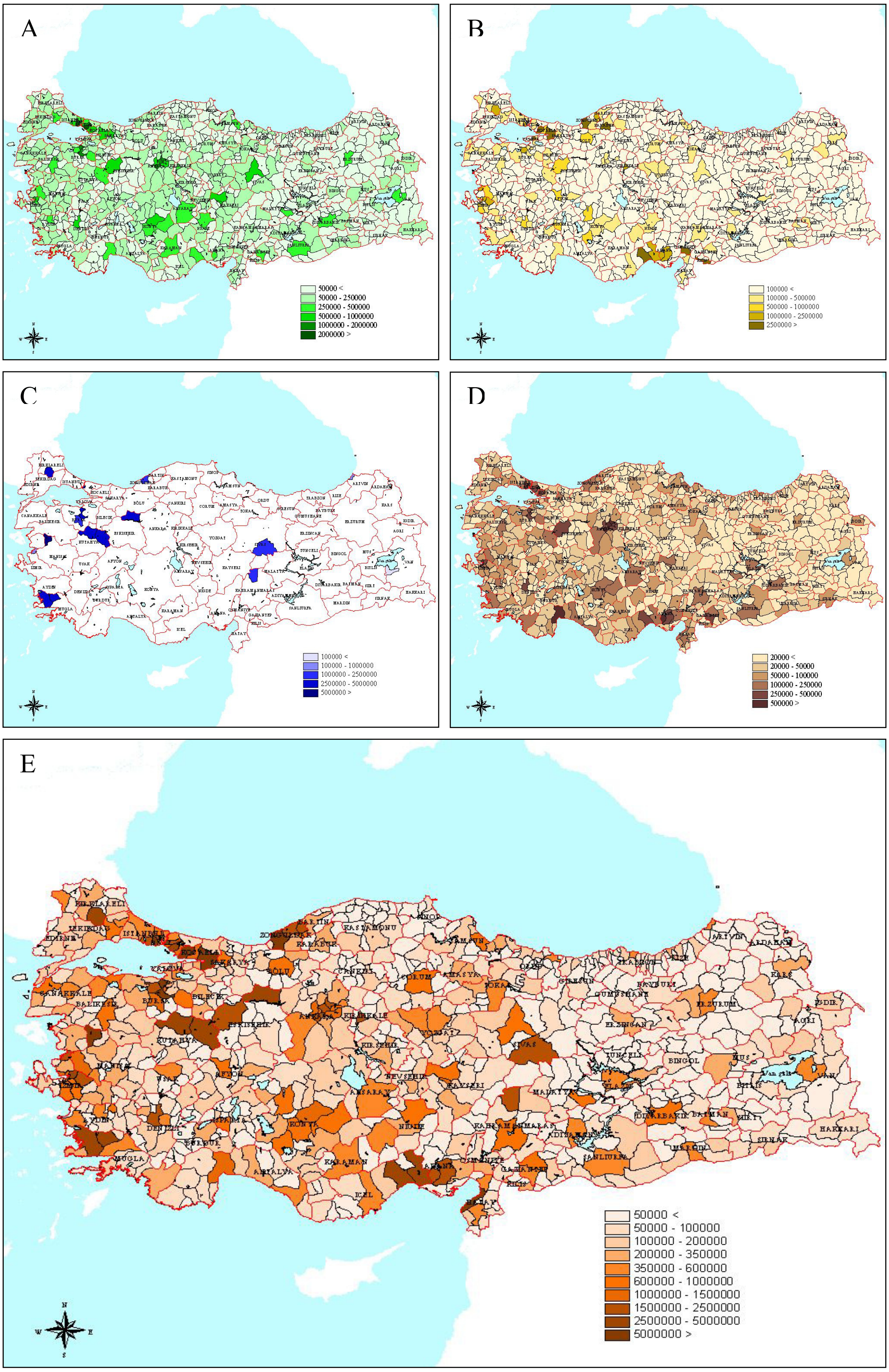
A-Households, B-Industries, C-Thermal Power Plants, D-Road Vehicles, E-Total

Figure H.2 CO_2 emissions of districts for 1995 in tones



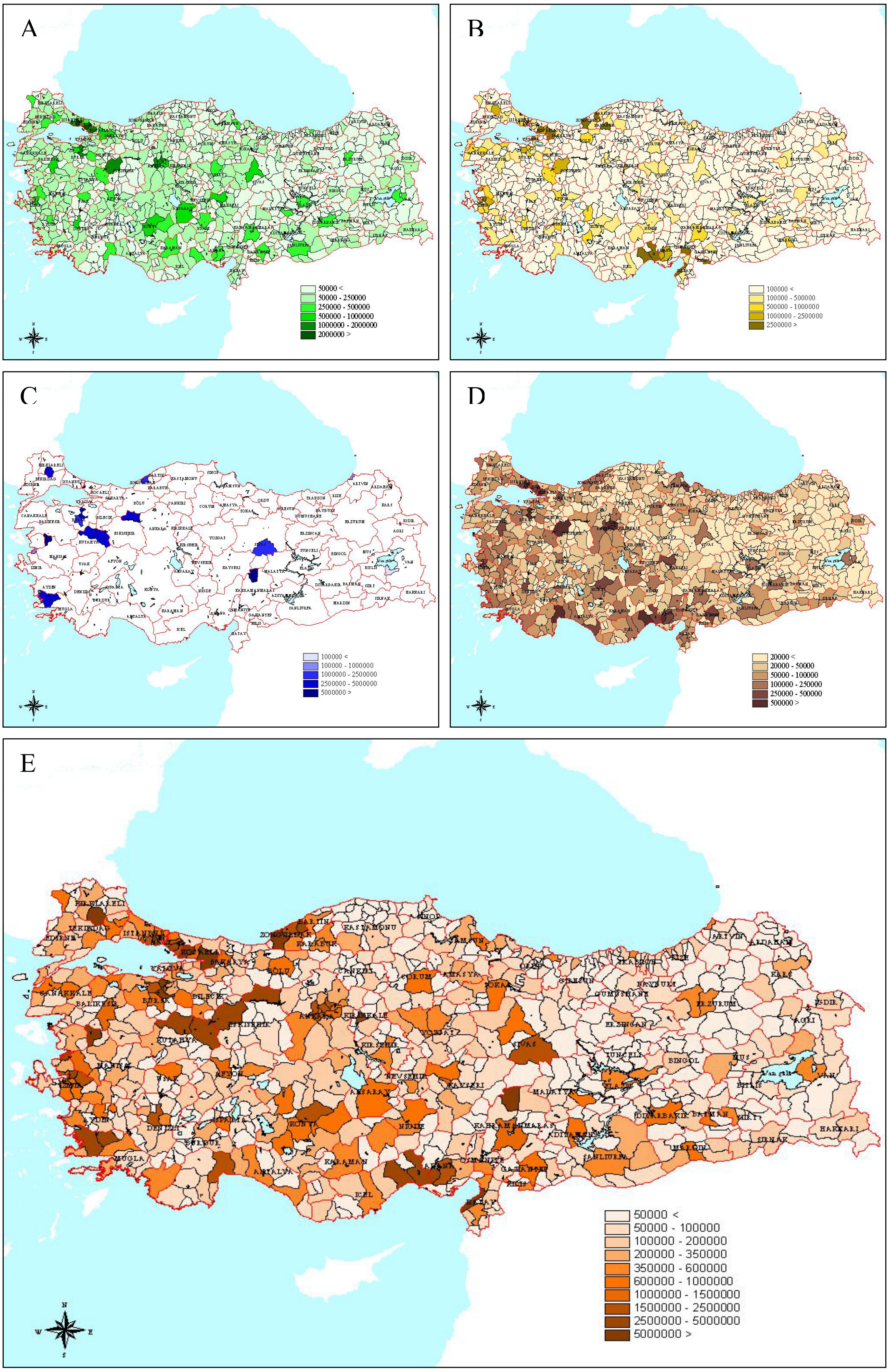
A-Households, B-Industries, C-Thermal Power Plants, D-Road Vehicles, E-Total

Figure H.3 CO_2 emissions of districts for 2000 in tones



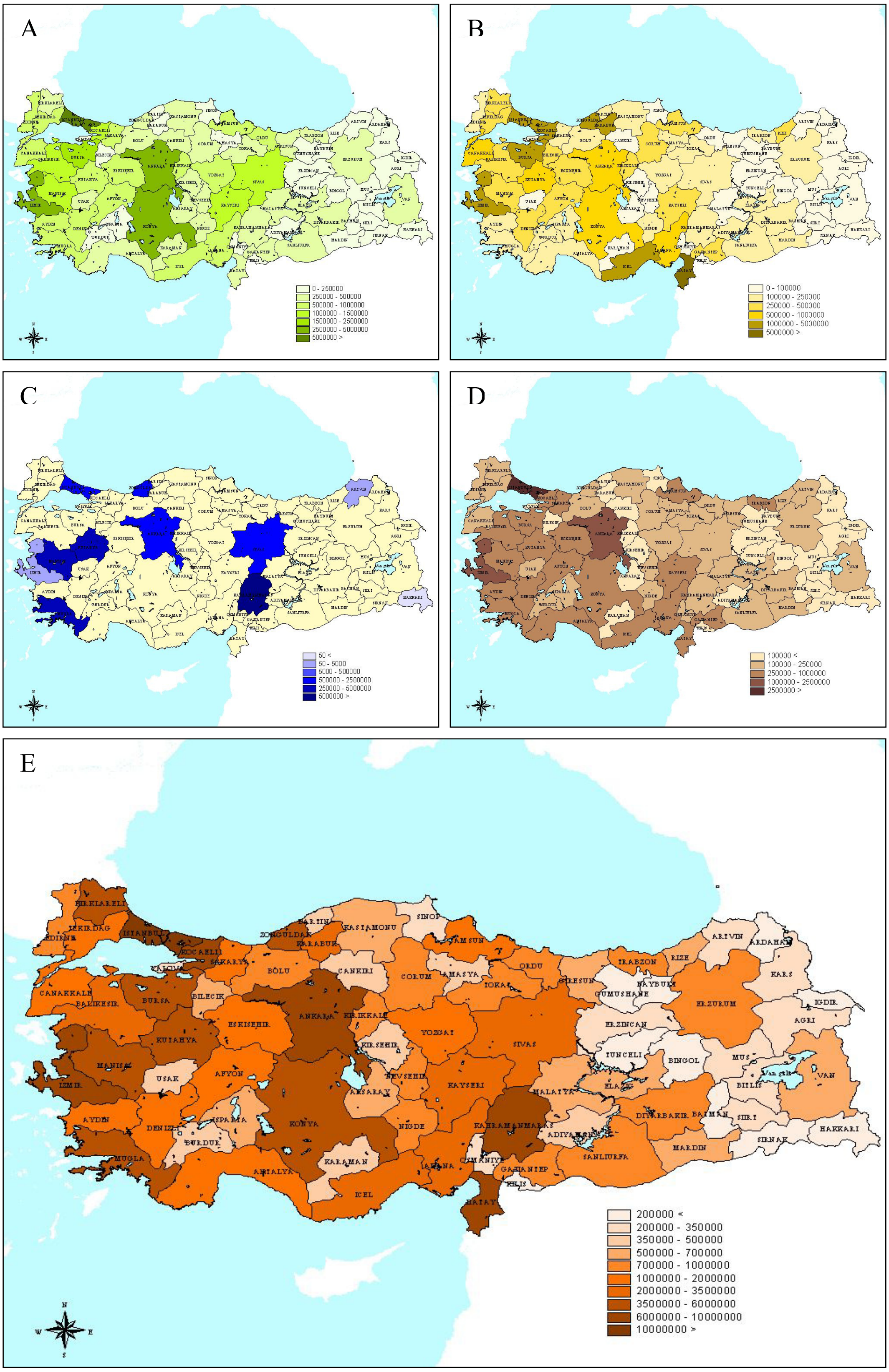
A-Households, B-Industries, C-Thermal Power Plants, D-Road Vehicles, E-Total

Figure H.4 CO_2 emissions of districts for 2005 in tones



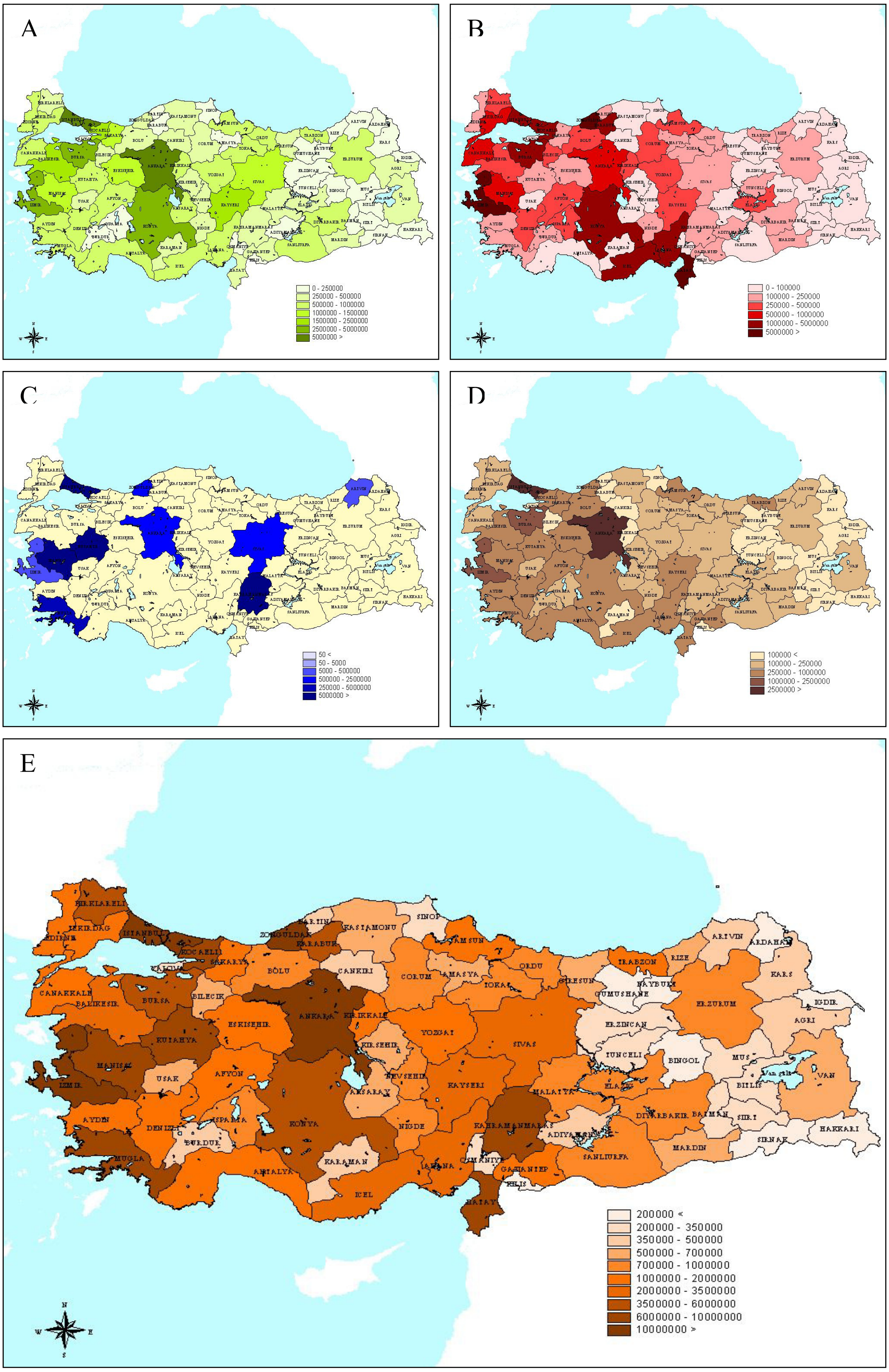
A-Households, B-Industries, C-Thermal Power Plants, D-Road Vehicles, E-Total

Figure H.5 CO_2 emissions of districts for 2010 in tones



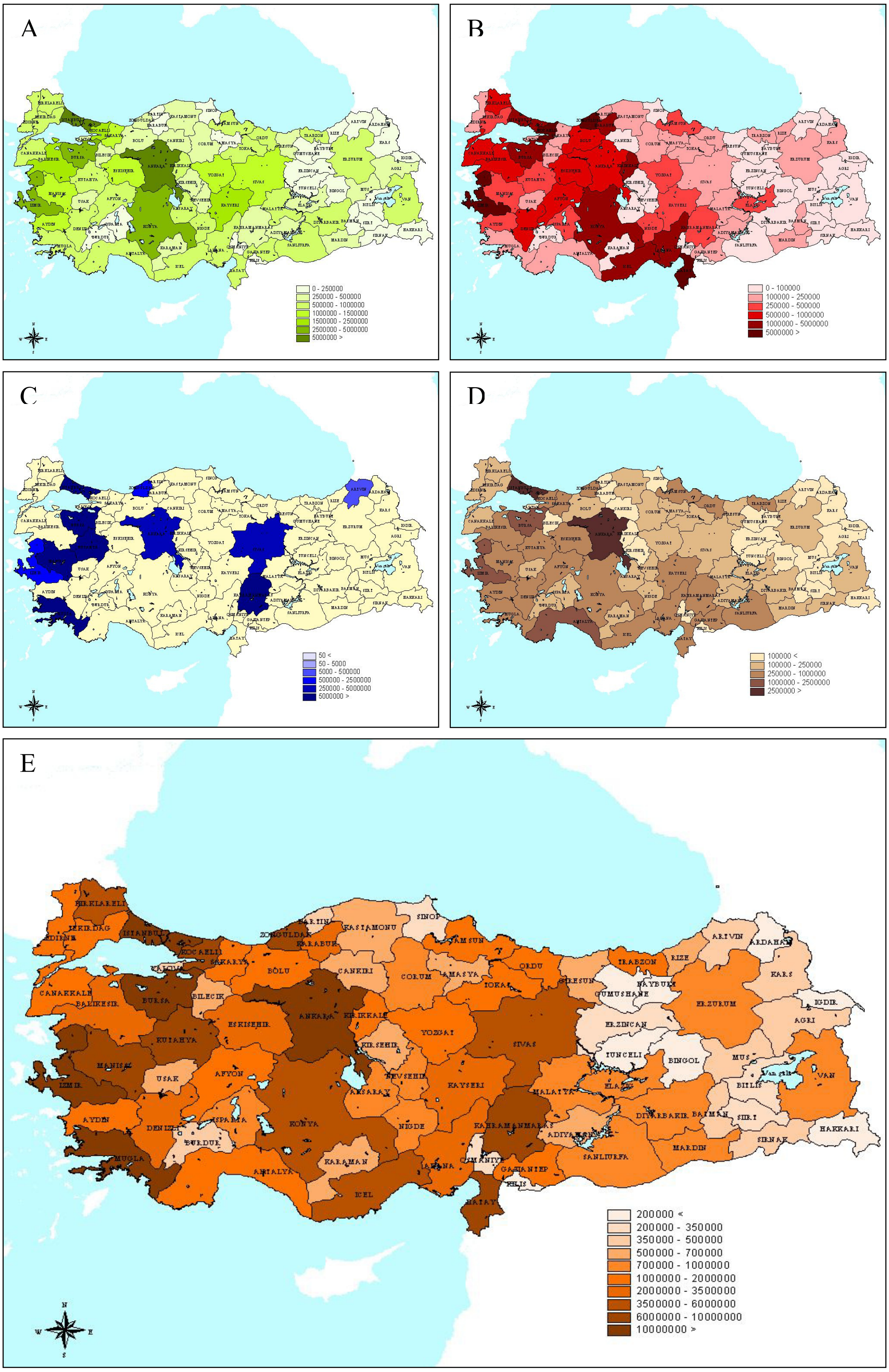
A-Households, B-Industries, C-Thermal Power Plants, D-Road Vehicles, E-Total

Figure H.6 CO_2 emissions of provinces for 1990 in tones



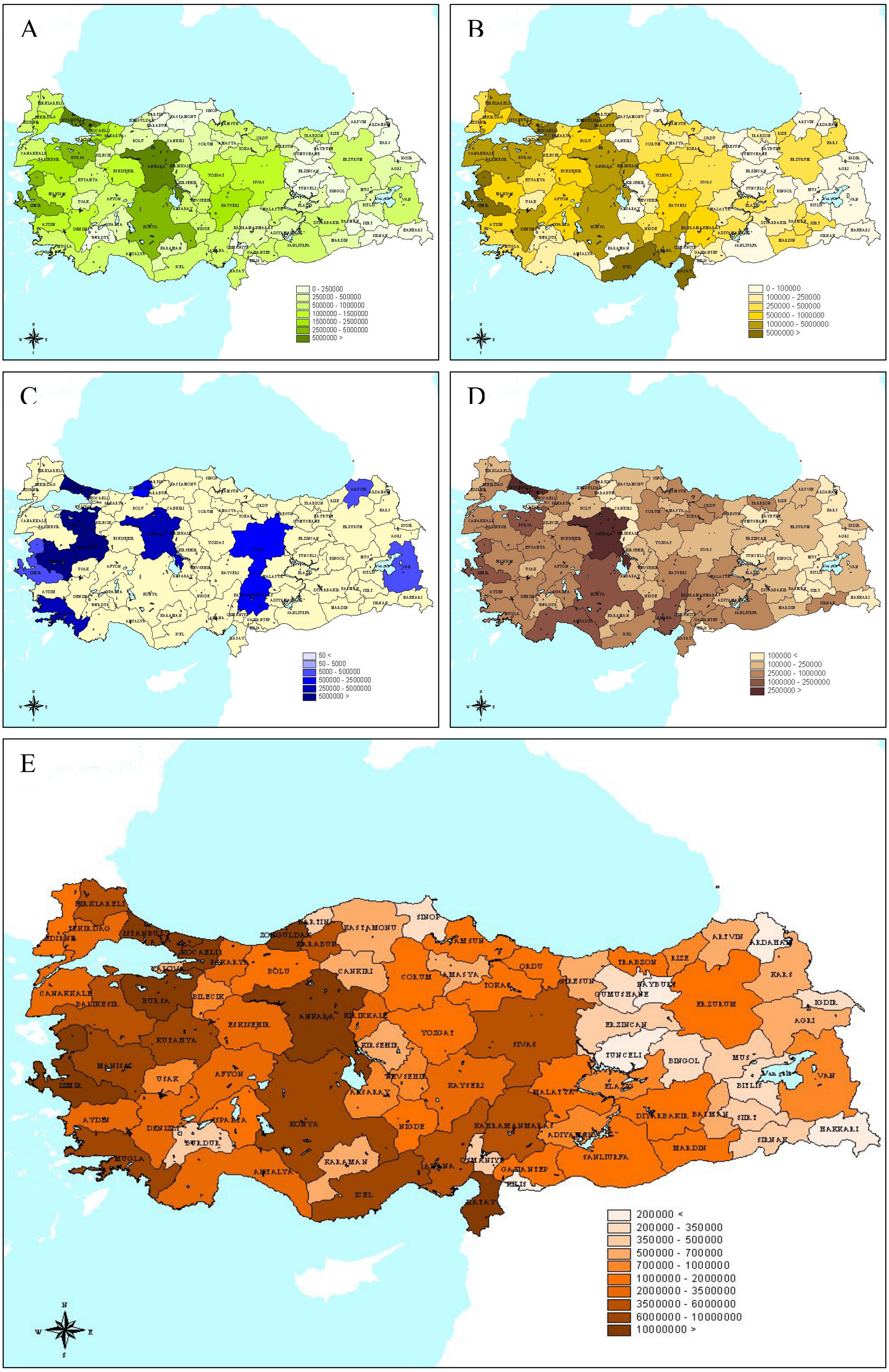
A-Households, B-Industries, C-Thermal Power Plants, D-Road Vehicles, E-Total

Figure H.7 CO_2 emissions of provinces for 1995 in tones



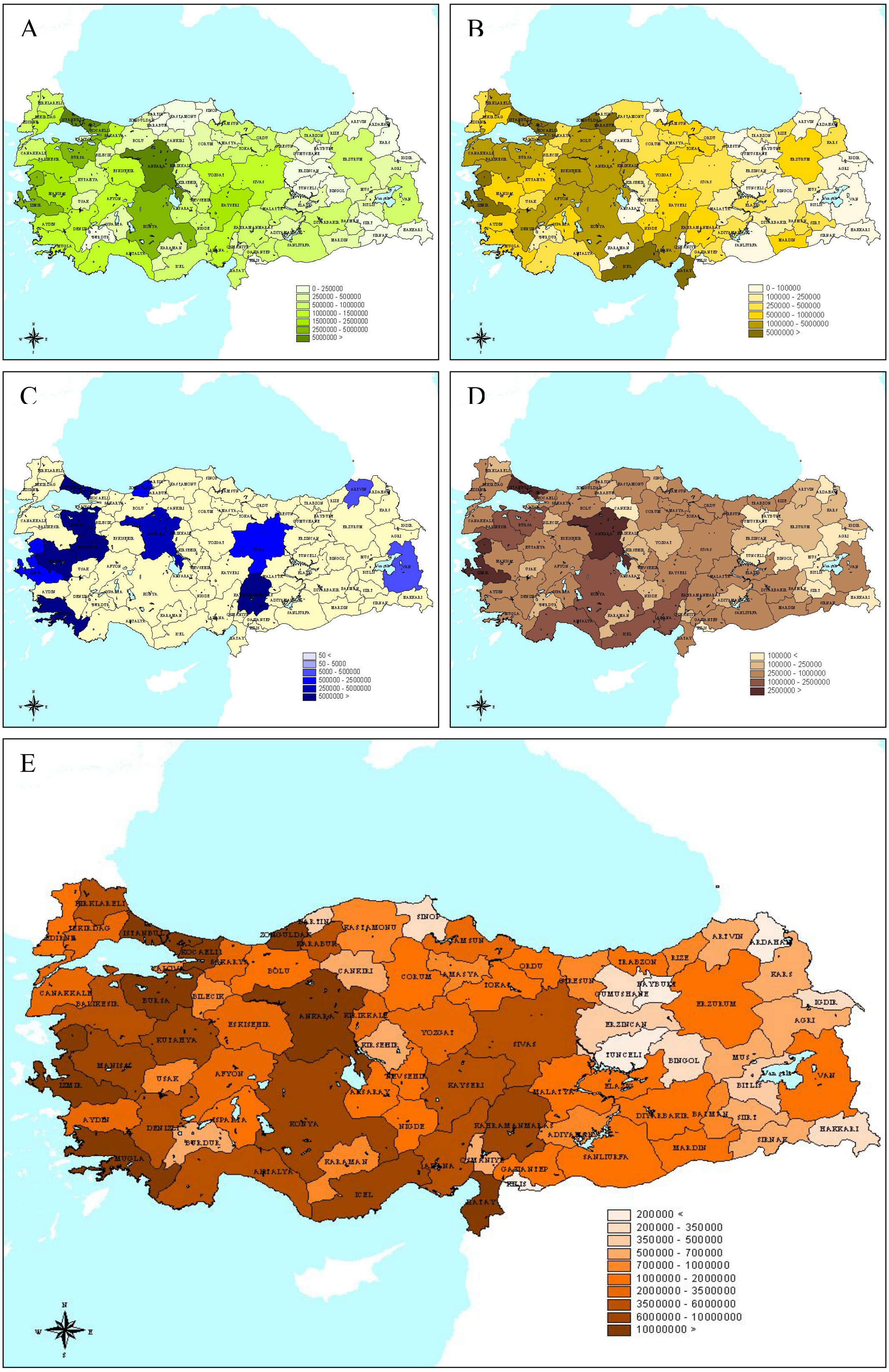
A-Households, B-Industries, C-Thermal Power Plants, D-Road Vehicles, E-Total

Figure H.8 CO_2 emissions of provinces for 2000 in tones



A-Households, B-Industries, C-Thermal Power Plants, D-Road Vehicles, E-Total

Figure H.9 CO_2 emissions of provinces for 2005 in tones



A-Households, B-Industries, C-Thermal Power Plants, D-Road Vehicles, E-Total

Figure H.10 CO_2 emissions of provinces for 2010 in tones

APPENDIX I

In Appendix I, the following regional figures are presented for the years of 1990-2010:

- CO_2 emissions from different sources

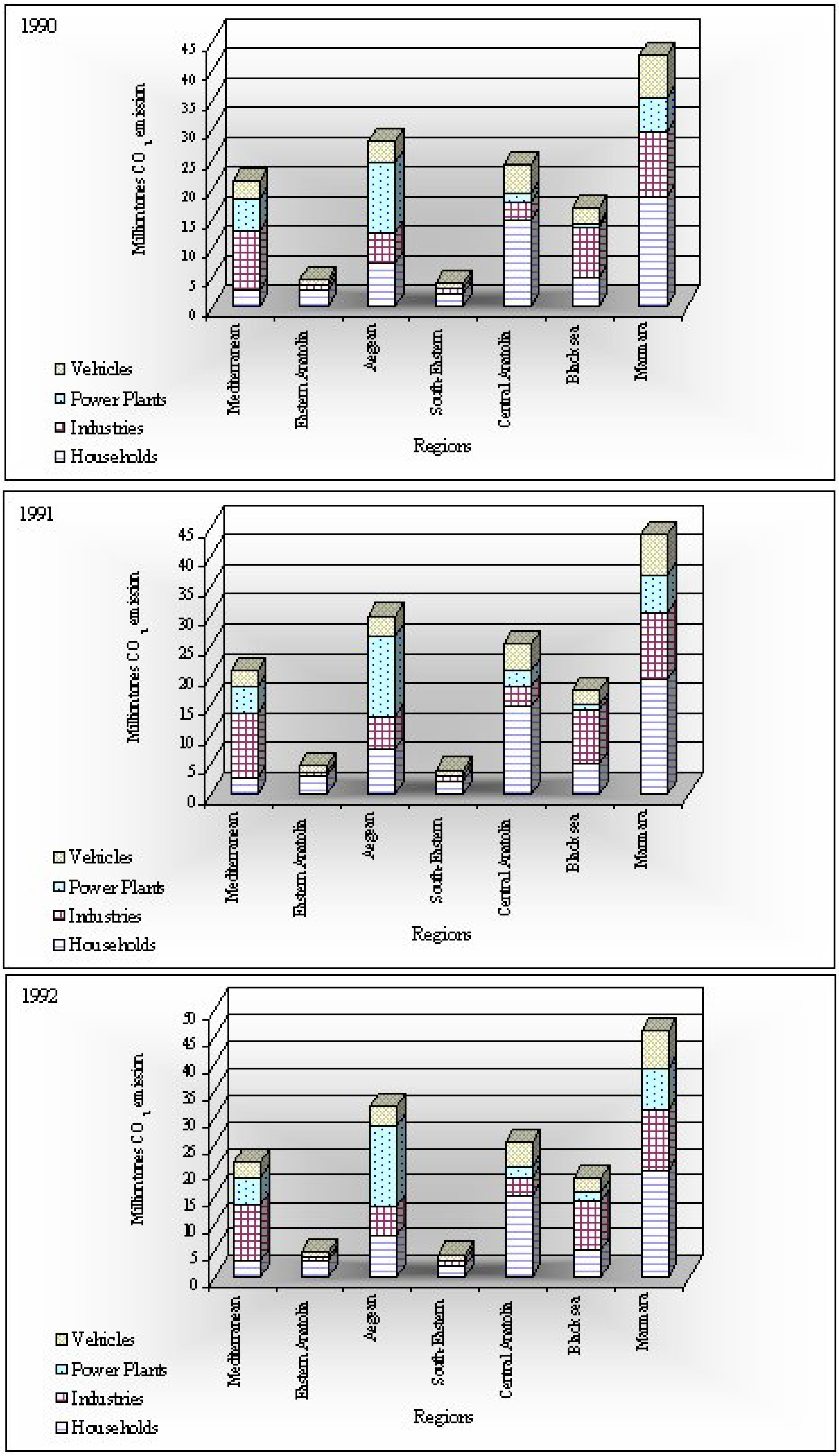


Figure I.1 CO_2 emission from different sources between 1990-2010

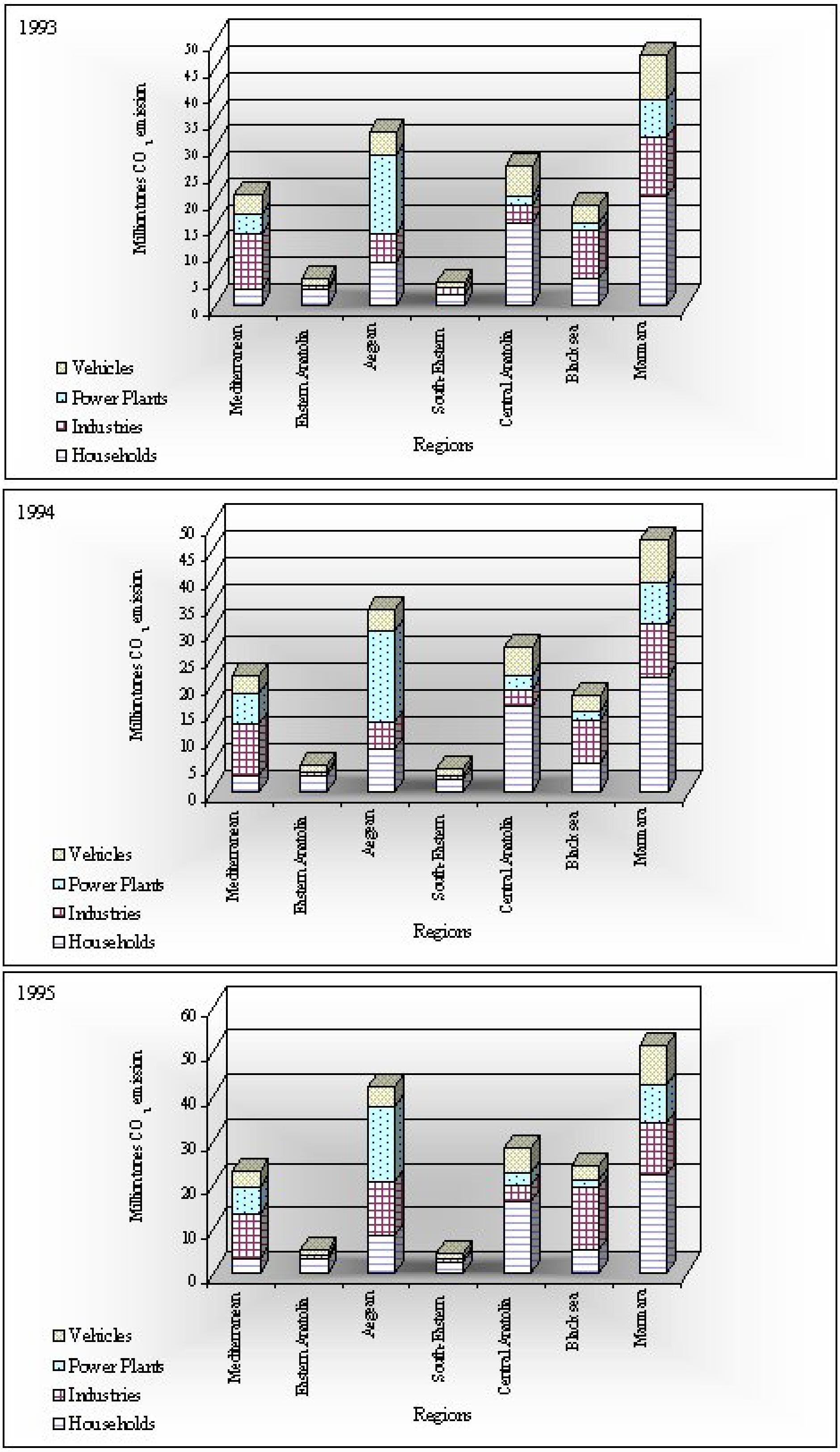


Figure I.1 CO_2 emission from different sources between 1990-2010 (continued)

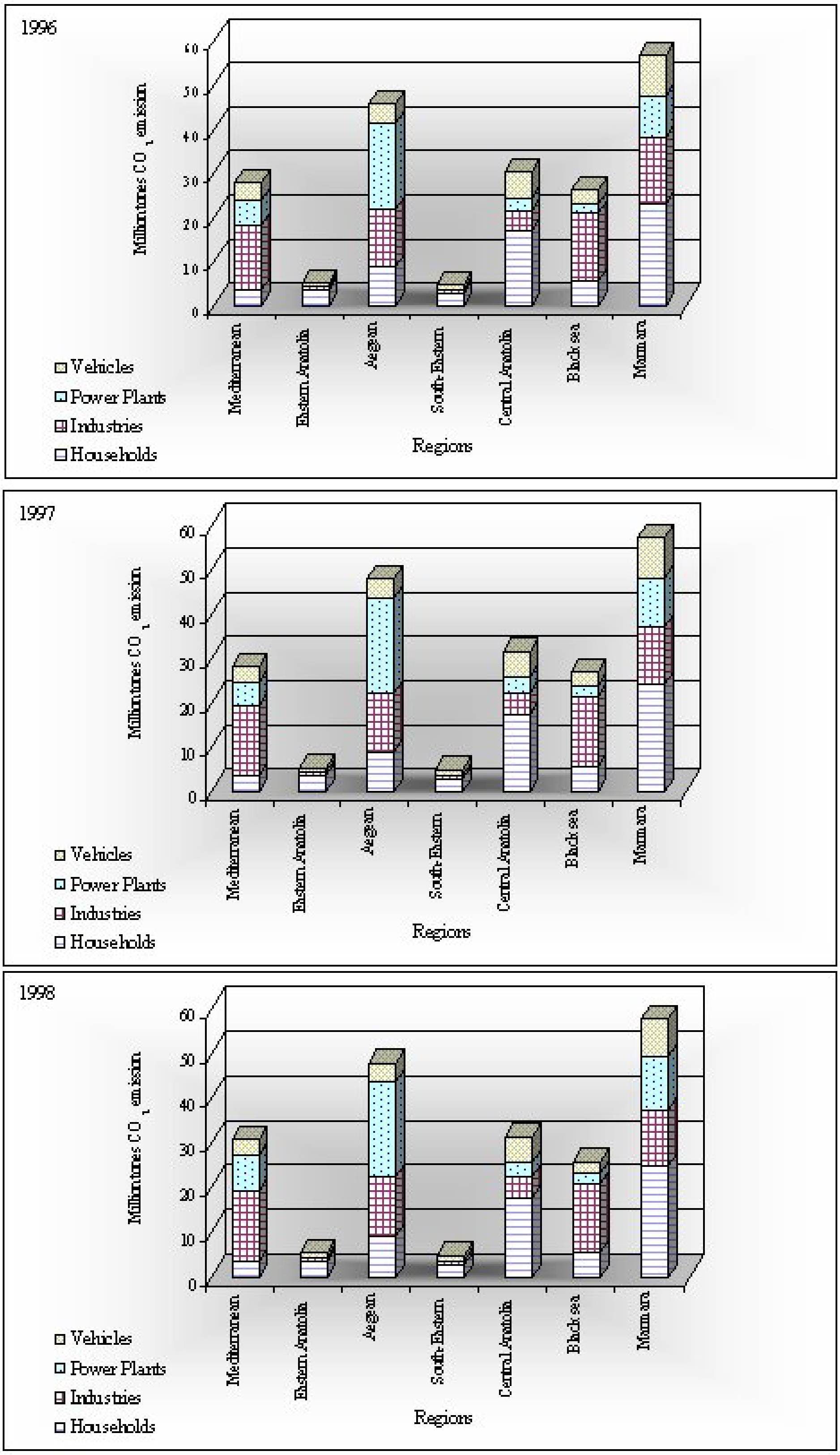


Figure I.1 CO_2 emission from different sources between 1990-2010 (continued)

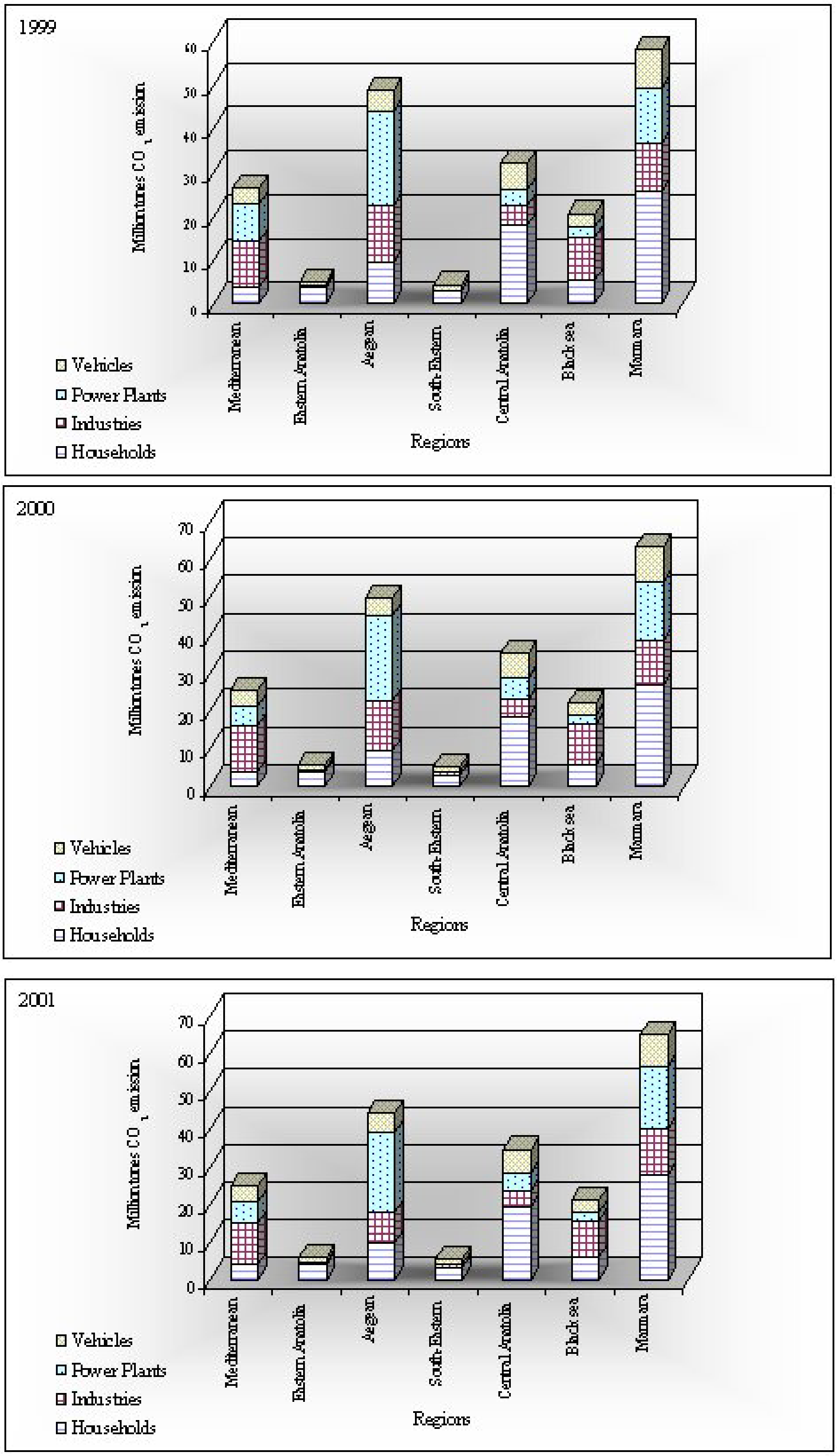
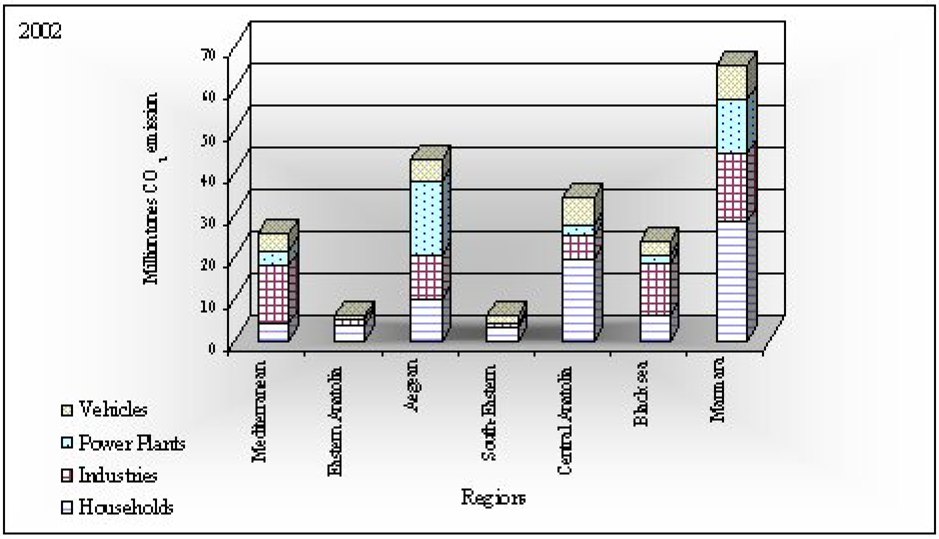
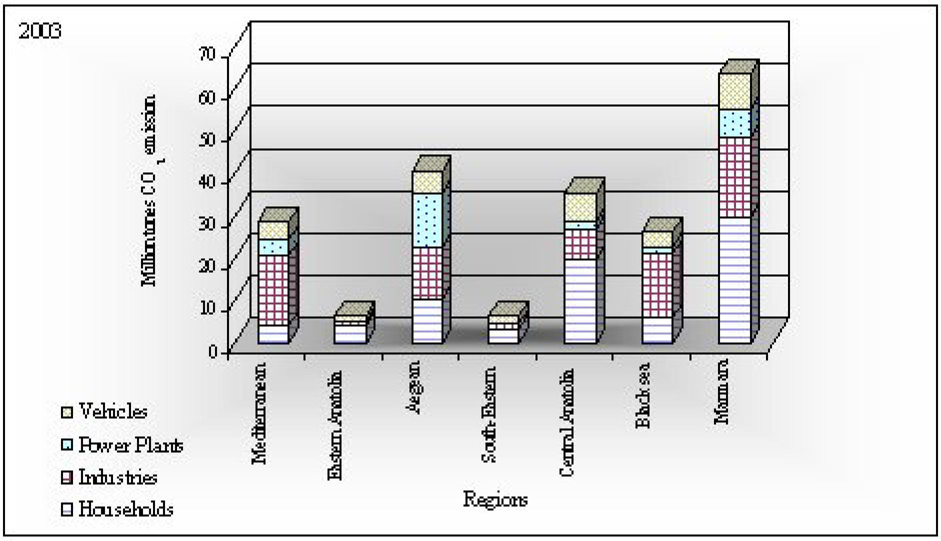


Figure I.1 CO_2 emission from different sources between 1990-2010 (continued)





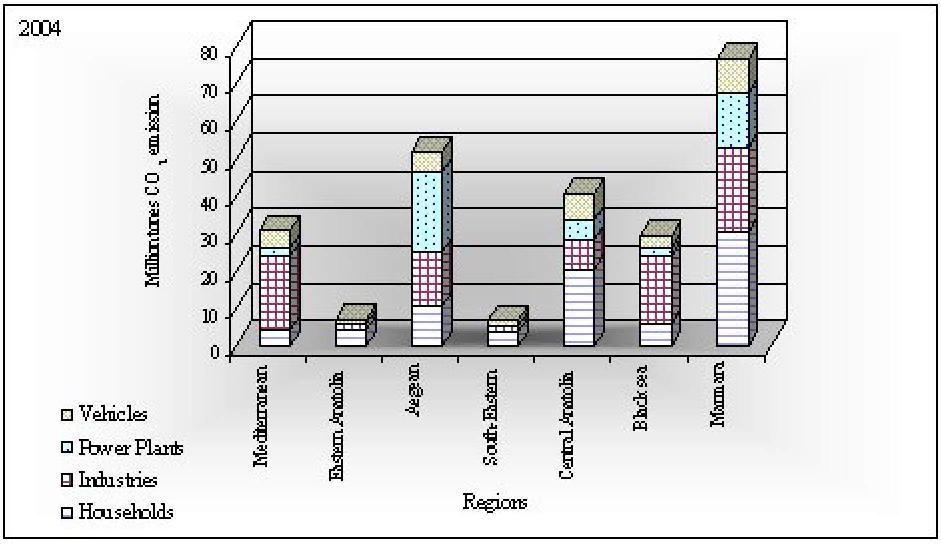
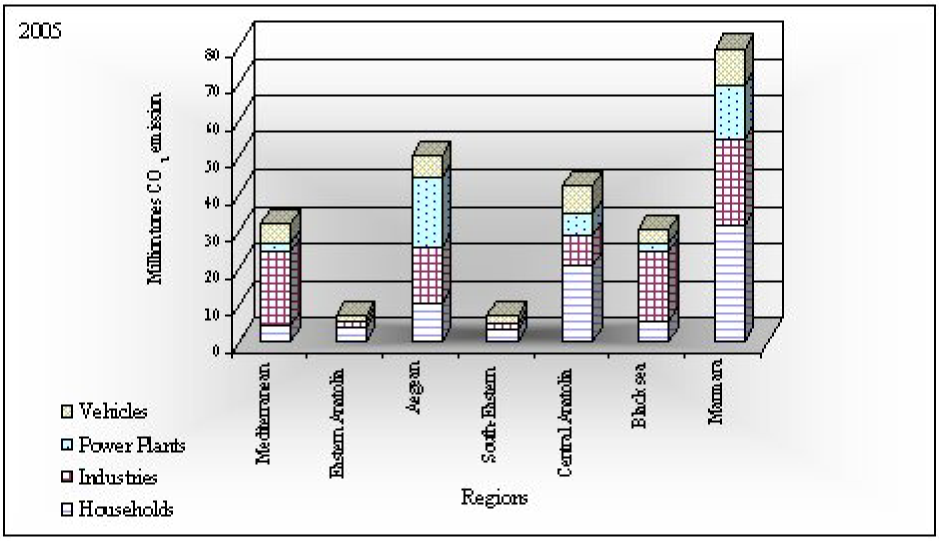
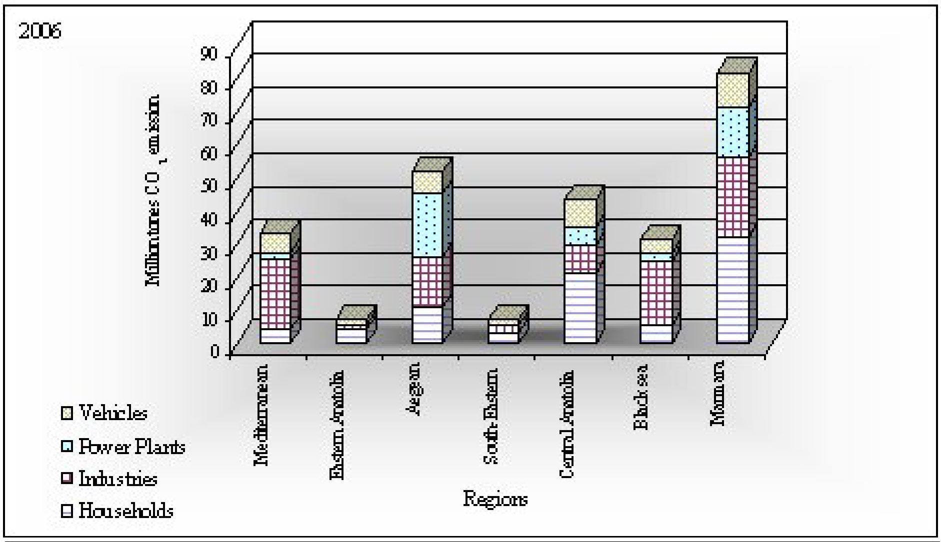


Figure I.1 CO_2 emission from different sources between 1990-2010 (continued)





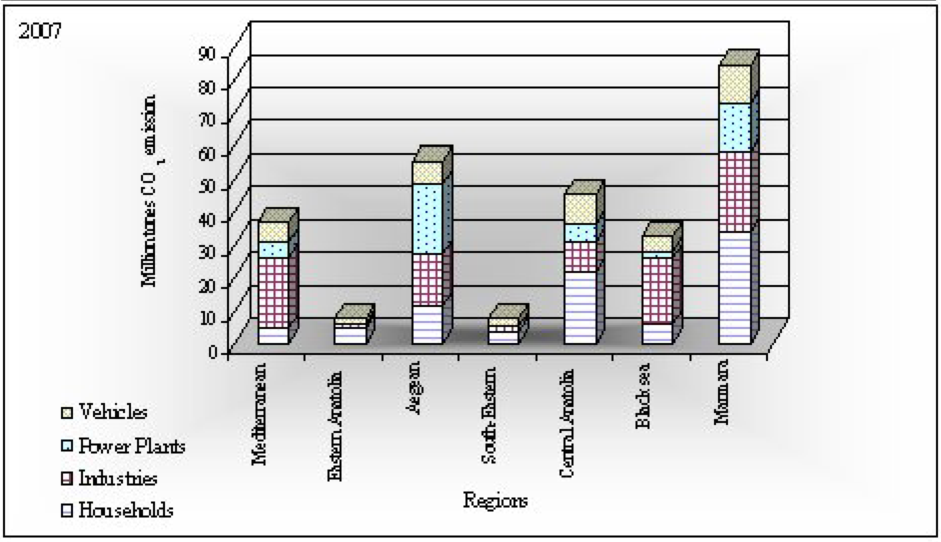


Figure I.1 CO_2 emission from different sources between 1990-2010 (continued)

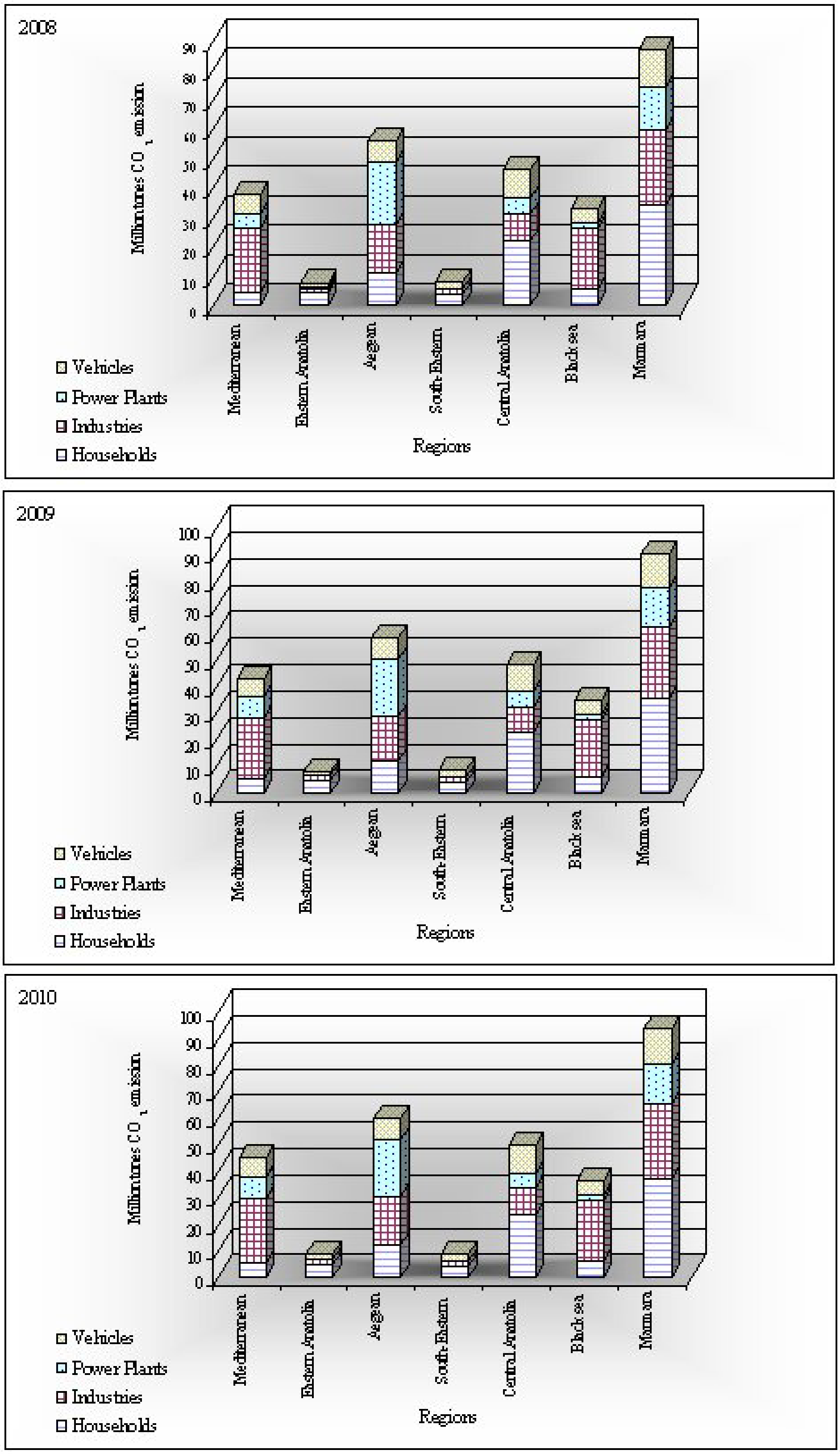


Figure I.1 CO_2 emission from different sources between 1990-2010 (continued)

APPENDIX J

In Appendix J, the following tables are presented for the uncertainty analyses:

- T-Table
- Mean, standard deviation and standard error of the annual CO_2 emissions
- Results of the uncertainty analysis

Table J.1 T-Table [83]

(Probability of a larger absolute value-two tailed test)

d.f	1,000	0.500	0.180	0.100	0.05	d.f
1	0.000	1.000	3.442	6.314	12.706	1
2	0.000	0.816	2.026	2.920	4.303	2
3	0.000	0.765	1.741	2.353	3.182	3
4	0.000	0.741	1.623	2.132	2.776	4
5	0.000	0.727	1.558	2.015	2.571	5
6	0.000	0.718	1.517	1.943	2.447	6
7	0.000	0.711	1.489	1.895	2.365	7
8	0.000	0.706	1.469	1.860	2.306	8
9	0.000	0.703	1.454	1.833	2.262	9
10	0.000	0.700	1.442	1.812	2.228	10
11	0.000	0.697	1.432	1.796	2.201	11
12	0.000	0.695	1.424	1.782	2.179	12
13	0.000	0.694	1.417	1.771	2.160	13
14	0.000	0.692	1.411	1.761	2.145	14
15	0.000	0.691	1.406	1.753	2.131	15
16	0.000	0.690	1.402	1.746	2.120	16
17	0.000	0.689	1.398	1.740	2.110	17
18	0.000	0.688	1.395	1.734	2.101	18
19	0.000	0.688	1.392	1.729	2.093	19
20	0.000	0.687	1.389	1.725	2.086	20
df	0.500	0.250	0.090	0.050	0.025	df

(Probability of a larger absolute value-one tailed test)

(Probability of a larger absolute value-two tailed test)

d.f	1,000	0.500	0.180	0.100	0.05	d.f
21	0.000	0.686	1.387	1.721	2.080	21
22	0.000	0.686	1.385	1.717	2.073	22
23	0.000	0.685	1.383	1.714	2.069	23
24	0.000	0.685	1.381	1.711	2.064	24
25	0.000	0.684	1.379	1.708	2.060	25
26	0.000	0.684	1.378	1.706	2.056	26
27	0.000	0.684	1.376	1.703	2.052	27
28	0.000	0.683	1.375	1.701	2.048	28
29	0.000	0.683	1.374	1.699	2.045	29
30	0.000	0.683	1.373	1.697	2.042	30
32	0.000	0.682	1.371	1.694	2.038	32
34	0.000	0.682	1.369	1.691	2.034	34
36	0.000	0.681	1.367	1.688	2.030	36
38	0.000	0.681	1.366	1.686	2.027	38
40	0.000	0.681	1.365	1.684	2.024	40
45	0.000	0.680	1.362	1.679	2.016	45
50	0.000	0.679	1.360	1.676	2.012	50
75	0.000	0.678	1.353	1.665	1.993	75
100	0.000	0.677	1.350	1.660	1.984	100
*	0.000	0.674	1.341	1.645	1.960	*
df	0.500	0.250	0.090	0.050	0.025	df

(Probability of a larger absolute value-one tailed test)

*Unlimited

Table.J.2 Mean, standard deviation and standard error of the annual CO_2 emissions

Year	District				Province				Region			
	Mean	N	Std. Deviation	Std. Error Mean	Mean	N	Std. Deviation	Std. Error Mean	Mean	N	Std. Deviation	Std. Error Mean
1990	156370.59	911	461994.56	15306.56	1780670.08	80	2825391.53	315888.38	20350515.16	7	13490145.84	5098795.86
1991	144428.08	911	446048.34	14778.24	1841617.37	80	2946034.15	329376.63	21047055.69	7	14026377.49	5301472.38
1992	148822.03	911	455983.45	15107.41	1917341.24	80	3141253.76	351202.85	21912471.31	7	14772113.09	5583333.94
1993	153023.01	911	436253.01	14453.71	1962056.49	80	3270725.80	365678.26	22423502.80	7	15174756.43	5735518.82
1994	151964.54	911	462301.50	15316.73	1984968.23	80	3337130.45	373102.53	22685351.23	7	15426477.12	5830660.30
1995	175650.87	911	545170.84	18062.32	2245403.07	80	3832840.85	428524.63	25661749.33	7	17341676.11	6554537.47
1996	192098.65	911	655710.88	21724.67	2470850.86	80	4196996.98	469238.53	28238295.55	7	19163306.59	7243049.08
1997	194246.22	911	655117.91	21705.02	2527682.91	80	4319796.23	482967.90	28887804.73	7	19608352.49	7411260.62
1998	195832.08	911	683534.94	22646.52	2544055.43	80	4398917.17	491813.89	29074919.21	7	19710634.65	7449919.64
1999	187793.75	911	597058.30	19781.42	2451891.91	80	4311046.51	481989.65	28021621.87	7	20339999.54	7687797.21
2000	199202.07	911	611388.25	20256.20	2599657.34	80	4490340.18	502035.29	29710369.62	7	21674707.03	8192269.22
2001	192660.65	911	595679.04	19735.73	2514332.08	80	4314404.07	482365.04	28735223.80	7	21361430.19	8073861.70
2002	201192.88	911	592504.98	19630.57	2559231.34	80	4221062.21	471929.10	29248358.21	7	21080550.56	7967699.18
2003	210090.42	911	608801.89	20170.51	2598914.75	80	4248187.69	474961.82	29701882.81	7	20010477.26	7563249.49
2004	240680.79	911	741267.98	24559.30	3043494.34	80	5086638.27	568703.45	34782792.41	7	24766930.83	9361019.96
2005	249311.81	911	766375.86	25391.16	3123600.22	80	5227297.62	584429.64	35698288.18	7	25315016.37	9568176.82
2006	257987.67	911	790099.70	26177.17	3222396.54	80	5403273.67	604104.36	36827388.97	7	26074182.96	9855114.82
2007	269426.70	911	824012.81	27300.76	3375193.13	80	5624256.64	628811.01	38573635.78	7	27010769.48	10209111.25
2008	277265.13	911	843860.50	27958.35	3464453.22	80	5791170.77	647472.58	39593751.12	7	27725798.38	10479366.77
2009	292696.33	911	909125.72	30120.68	3640175.96	80	6052167.79	676652.93	41602010.93	7	28704066.02	10849117.19
2010	305127.73	911	949833.37	31469.38	3781738.59	80	6299693.28	704327.12	43219869.60	7	29780168.77	11255845.80

N: Sample Size

Table J.3 Results of the uncertaintyanalysis

Paired	District						t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference					
				Lower	Upper	Interval			
1991 & 1990	-11942.50	210257.67	6966.15	-25614.09	1729.08	27343.16	-1.71	910	0.087
1992 & 1990	-7548.56	207836.39	6885.93	-21062.70	5965.59	27028.29	-1.10	910	0.273
1993 & 1990	-3347.58	225957.29	7486.30	-18039.99	11344.84	29384.84	-0.45	910	0.655
1994 & 1990	-4406.05	210974.63	6989.90	-18124.25	9312.15	27436.40	-0.63	910	0.529
1995 & 1990	19280.28	279554.22	9262.04	1102.83	37457.73	36354.90	2.08	910	0.038
1996 & 1990	35728.06	358362.63	11873.08	12426.25	59029.87	46603.62	3.01	910	0.003
1997 & 1990	37875.63	364449.19	12074.74	14178.06	61573.21	47395.15	3.14	910	0.002
1998 & 1990	39461.49	375302.21	12434.32	15058.22	63864.76	48806.54	3.17	910	0.002
1999 & 1990	31423.16	319065.26	10571.10	10676.59	52169.74	41493.15	2.97	910	0.003
2000 & 1990	42831.48	352266.19	11671.10	19926.08	65736.88	45810.80	3.67	910	0.000
2001 & 1990	36290.06	346878.72	11492.60	13734.97	58845.16	45110.18	3.16	910	0.002
2002 & 1990	44822.29	346665.84	11485.55	22281.04	67363.54	45082.50	3.90	910	0.000
2003 & 1990	53719.83	360871.07	11956.19	30254.91	77184.74	46929.83	4.49	910	0.000
2004 & 1990	84310.21	475143.03	15742.19	53414.99	115205.42	61790.44	5.36	910	0.000
2005 & 1990	92941.22	494957.87	16398.69	60757.58	125124.86	64367.28	5.67	910	0.000
2006 & 1990	101617.08	515065.86	17064.89	68125.96	135108.20	66982.24	5.96	910	0.000
2007 & 1990	113056.12	526049.95	17428.81	78850.78	147261.45	68410.68	6.49	910	0.000
2008 & 1990	120894.54	543951.72	18021.92	85525.18	156263.91	70738.73	6.71	910	0.000
2009 & 1990	136325.74	583504.22	19332.36	98384.55	174266.93	75882.37	7.05	910	0.000
2010 & 1990	148757.14	622595.33	20627.50	108274.14	189240.15	80966.02	7.21	910	0.000
Maximum	148757.14	622595.33	20627.50	108274.14	189240.15	80966.02	7.21		0.655
Minimum	-11942.50	207836.39	6885.93	-25614.09	1729.08	27028.29	-1.71		0.000

Table J.3. Results of the uncertainty analysis (Continued)

Paired	Province						t	df	Sig (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference					
				Lower	Upper	Interval			
1991 & 1990	60947.30	240827.23	26925.30	7353.82	114540.77	107186.95	2.26	79	0.026
1992 & 1990	136671.16	420524.25	47016.04	43088.08	230254.25	187166.18	2.91	79	0.005
1993 & 1990	181386.42	627376.43	70142.82	41770.63	321002.20	279231.57	2.59	79	0.012
1994 & 1990	204298.16	671321.68	75056.05	54902.83	353693.48	298790.64	2.72	79	0.008
1995 & 1990	464732.99	1328914.53	148577.16	168997.55	760468.43	591470.88	3.13	79	0.002
1996 & 1990	690180.78	1608738.87	179862.47	332173.49	1048188.08	716014.59	3.84	79	0.000
1997 & 1990	747012.84	1730116.65	193432.92	361994.24	1132031.44	770037.20	3.86	79	0.000
1998 & 1990	763385.35	1751751.45	195851.77	373552.17	1153218.54	779666.38	3.90	79	0.000
1999 & 1990	671221.84	1719814.93	192281.15	288495.77	1053947.90	765452.13	3.49	79	0.001
2000 & 1990	818987.27	1909545.94	213493.73	394038.63	1243935.90	849897.26	3.84	79	0.000
2001 & 1990	733662.01	1727182.80	193104.91	349296.30	1118027.71	768731.41	3.80	79	0.000
2002 & 1990	778561.27	1678720.87	187686.70	404980.24	1152142.30	747162.06	4.15	79	0.000
2003 & 1990	818244.67	1749775.71	195630.87	428851.16	1207638.18	778787.02	4.18	79	0.000
2004 & 1990	1262824.26	2527247.91	282554.91	700412.79	1825235.73	1124822.95	4.47	79	0.000
2005 & 1990	1342930.14	2667881.43	298278.21	749222.21	1936638.07	1187415.86	4.50	79	0.000
2006 & 1990	1441726.46	2838756.94	317382.67	809992.05	2073460.87	1263468.82	4.54	79	0.000
2007 & 1990	1594523.05	3012411.46	336797.84	924143.72	2264902.39	1340758.66	4.73	79	0.000
2008 & 1990	1683783.15	3175705.66	355054.69	977064.47	2390501.82	1413437.35	4.74	79	0.000
2009 & 1990	1859505.88	3403242.23	380494.05	1102151.42	2616860.34	1514708.92	4.89	79	0.000
2010 & 1990	2001068.51	3654896.21	408629.82	1187711.20	2814425.82	1626714.62	4.90	79	0.000
Maximum	2001068.51	3654896.21	408629.82	1187711.20	2814425.82	1626714.62	4.90		0.026
Minimum	60947.30	240827.23	26925.30	7353.82	114540.77	107186.95	2.26		0.000

Table J.3. Results of the uncertainty analysis (Continued)

Paired	Region								
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			t	df	Sig. (2-tailed)
				Lower	Upper	Interval			
1991 & 1990	696540.53	793418.31	299883.93	-37249.02	1430330.08	1467579.10	2.32	6	0.059
1992 & 1990	1561956.15	1568065.77	592673.15	111737.19	3012175.11	2900437.92	2.64	6	0.039
1993 & 1990	2072987.64	2074097.71	783935.25	154767.18	3991208.09	3836440.91	2.64	6	0.038
1994 & 1990	2334836.07	2329236.42	880368.61	180651.67	4489020.47	4308368.79	2.65	6	0.038
1995 & 1990	5311234.17	5004235.43	1891423.21	683088.31	9939380.03	9256291.72	2.81	6	0.031
1996 & 1990	7887780.39	6422473.50	2427466.81	1947983.08	13827577.70	11879594.61	3.25	6	0.017
1997 & 1990	8537289.57	7005348.83	2647772.98	2058422.49	15016156.65	12957734.16	3.22	6	0.018
1998 & 1990	8724404.05	6951085.49	2627263.36	2295722.20	15153085.91	12857363.72	3.32	6	0.016
1999 & 1990	7671106.71	7656185.73	2893766.20	590315.89	14751897.53	14161581.64	2.65	6	0.038
2000 & 1990	9359854.46	8831994.95	3338180.32	1191621.49	17528087.44	16336465.95	2.80	6	0.031
2001 & 1990	8384708.64	8229893.10	3110607.21	773327.00	15996090.29	15222763.29	2.70	6	0.036
2002 & 1990	8897843.05	7861864.51	2971505.48	1626831.09	16168855.02	14542023.93	2.99	6	0.024
2003 & 1990	9351367.65	6615647.51	2500479.72	3232914.18	15469821.12	12236906.94	3.74	6	0.010
2004 & 1990	14432277.25	11475647.44	4337387.04	3819073.51	25045481.00	21226407.49	3.33	6	0.016
2005 & 1990	15347773.03	11979545.18	4527842.48	4268541.60	26427004.45	22158462.86	3.39	6	0.015
2006 & 1990	16476873.81	12729016.16	4811115.88	4704497.34	28249250.29	23544752.95	3.43	6	0.014
2007 & 1990	18223120.62	13593893.84	5138008.92	5650865.70	30795375.55	25144509.85	3.55	6	0.012
2008 & 1990	19243235.96	14305829.59	5407095.34	6012550.29	32473921.63	26461371.34	3.56	6	0.012
2009 & 1990	21251495.77	15234053.58	5757931.03	7162346.09	35340645.45	28178299.37	3.69	6	0.010
2010 & 1990	22869354.44	16313416.47	6165891.86	7781960.57	37956748.31	30174787.73	3.71	6	0.010
Maximum	22869354.44	16313416.47	6165891.86	7781960.57	37956748.31	30174787.73	3.74		0.059
Minimum	696540.53	793418.31	299883.93	-37249.02	1430330.08	1467579.10	2.32		0.010

APPENDIX K

In Appendix K, the following ground level CO_2 concentration maps are presented:

- Ground level CO_2 concentration of industries without uptake in 1990 and 2004
- Ground level CO_2 concentration of households without uptake in 1990 and 2004
- Ground level CO_2 concentration of thermal power plants without uptake in 1990 and 2004
- Ground level CO_2 concentration of road vehicles without uptake in 1990 and 2004
- Ground level CO_2 concentration of industries with uptake in 1990 and 2004
- Ground level CO_2 concentration of households with uptake in 1990 and 2004
- Ground level CO_2 concentration of thermal power plants with uptake in 1990 and 2004
- Ground level CO_2 concentration of road vehicles with uptake in 1990 and 2004

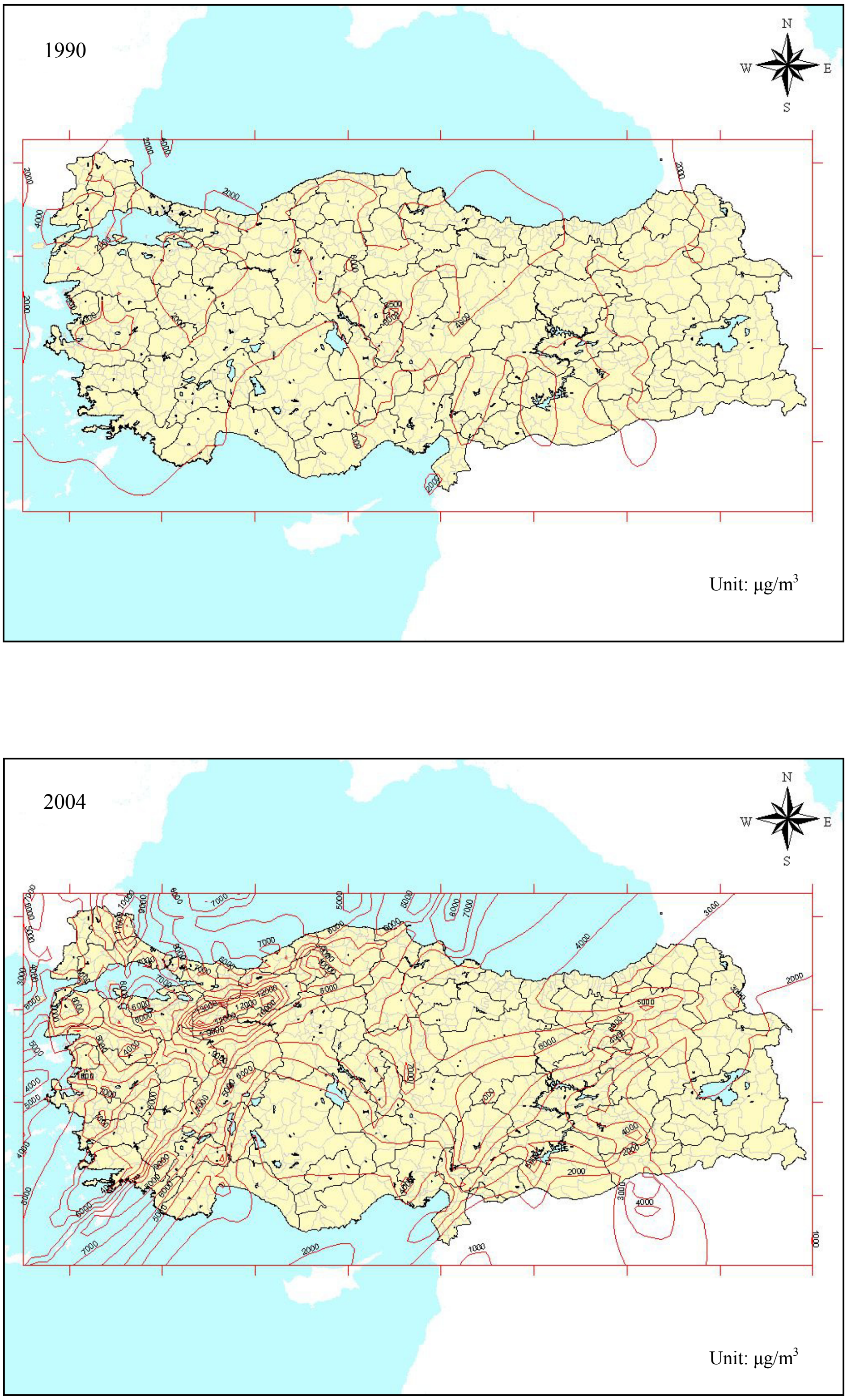
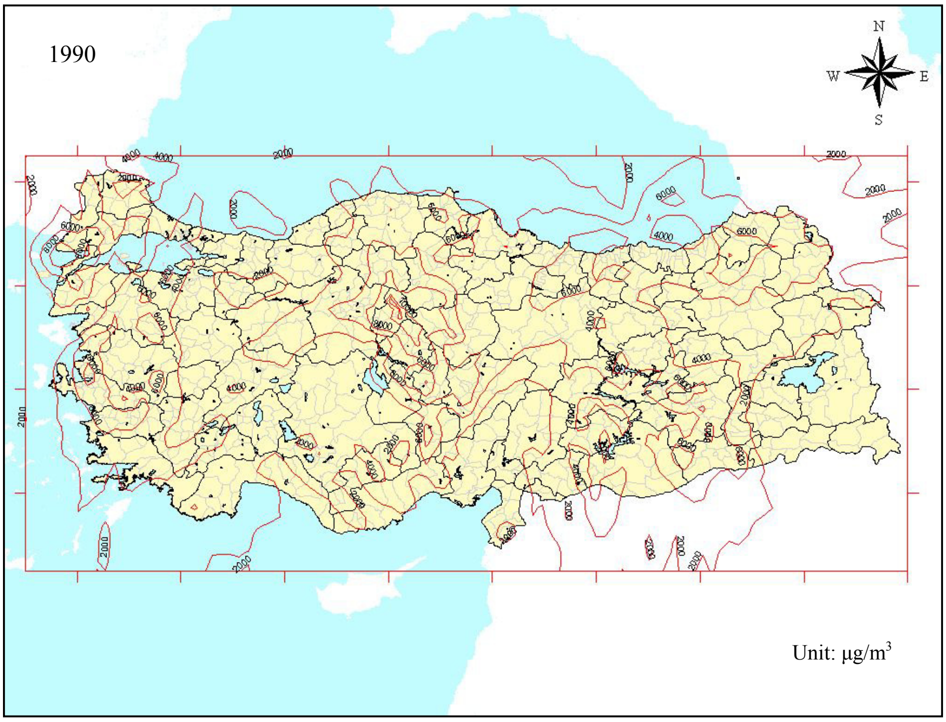


Figure K.1 Ground level CO_2 concentration of industries without uptake in 1990 and 2004



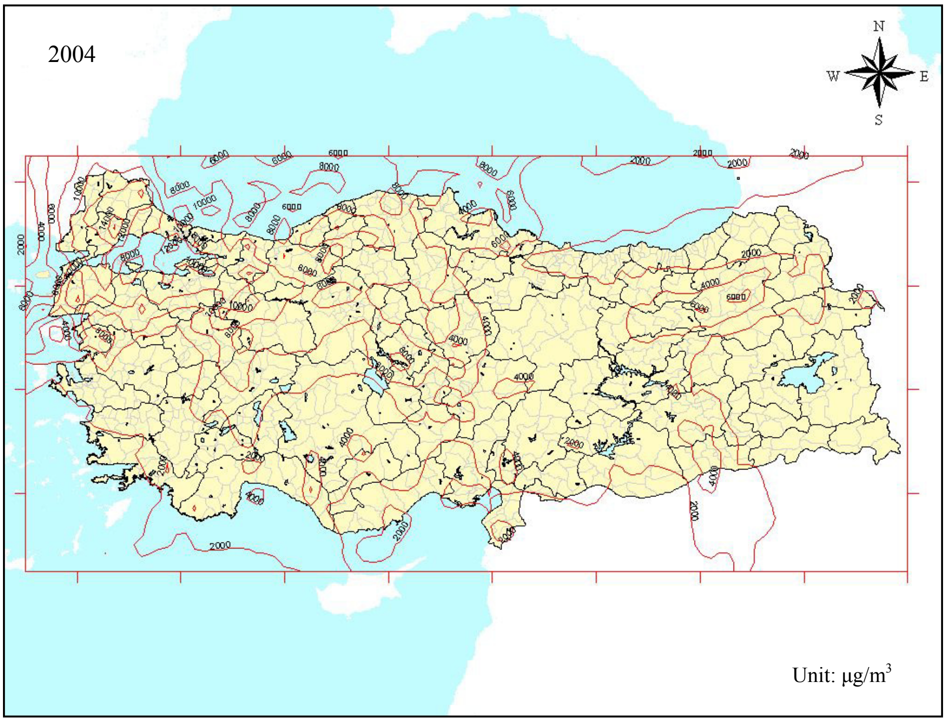
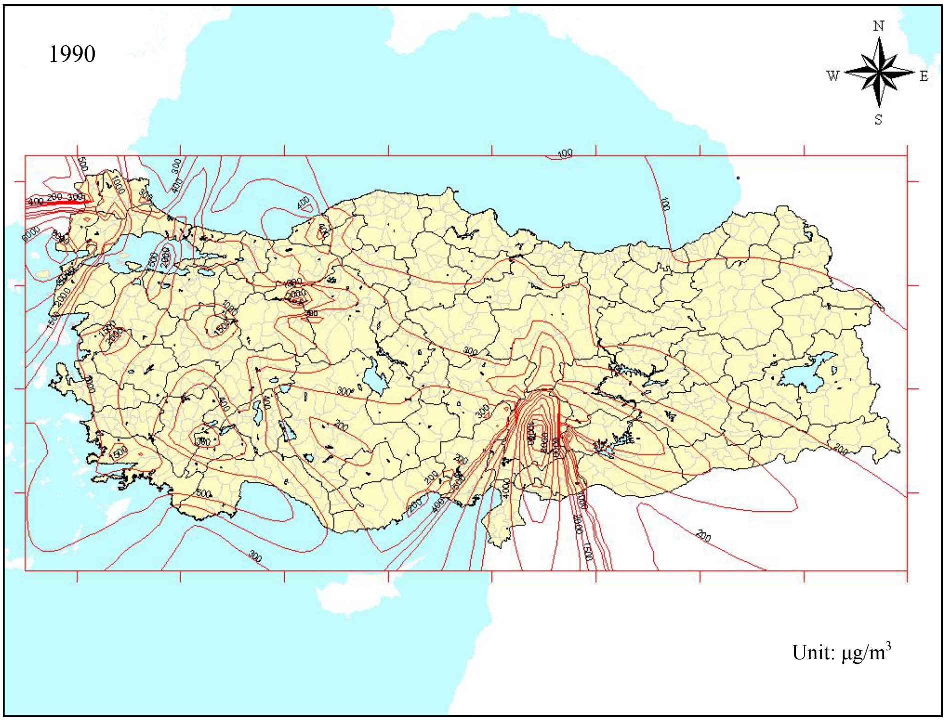


Figure K.2 Ground level CO_2 concentration of households without uptake in 1990 and 2004



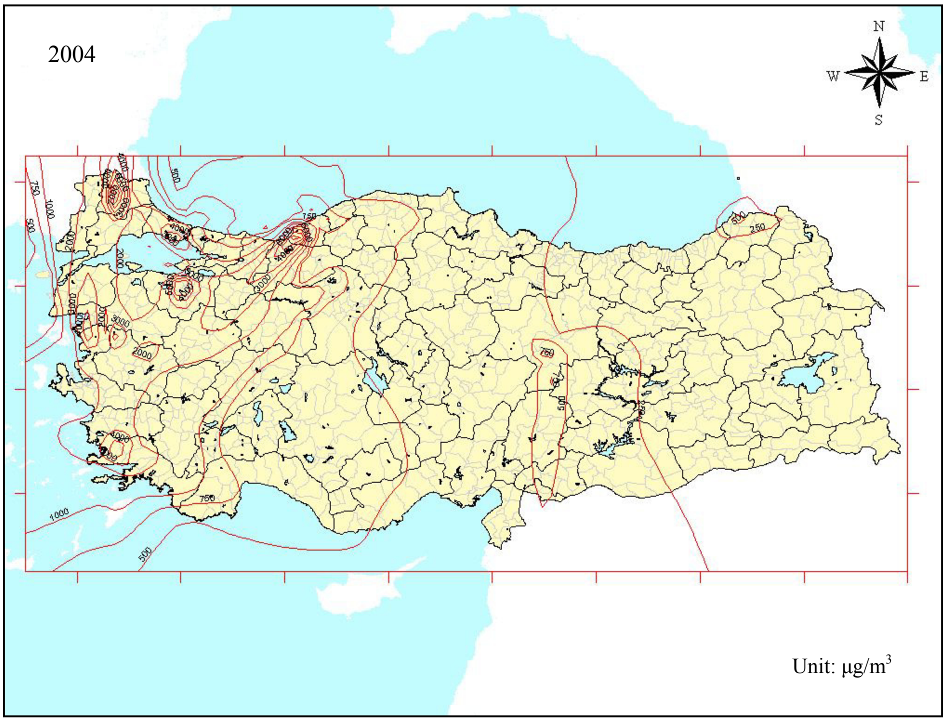
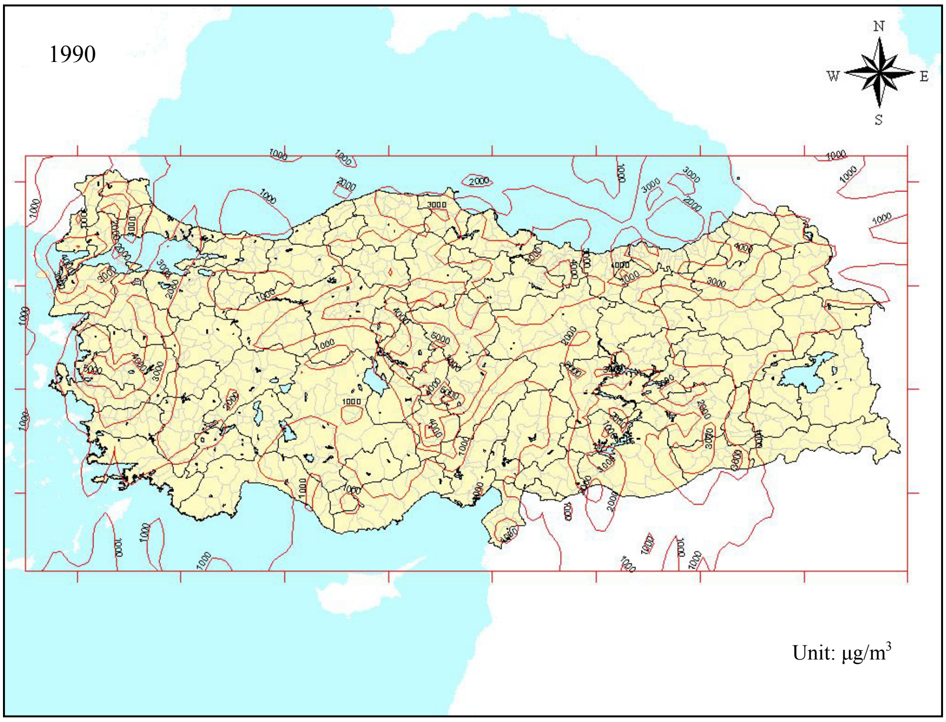


Figure K.3 Ground level CO_2 concentration of thermal power plants without uptake in 1990 and 2004



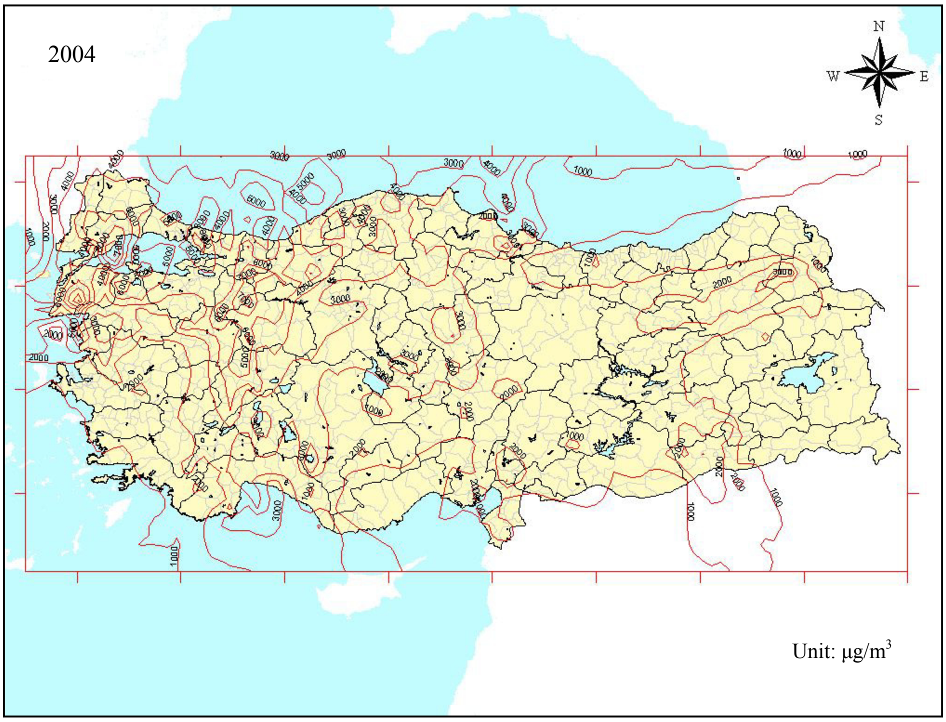
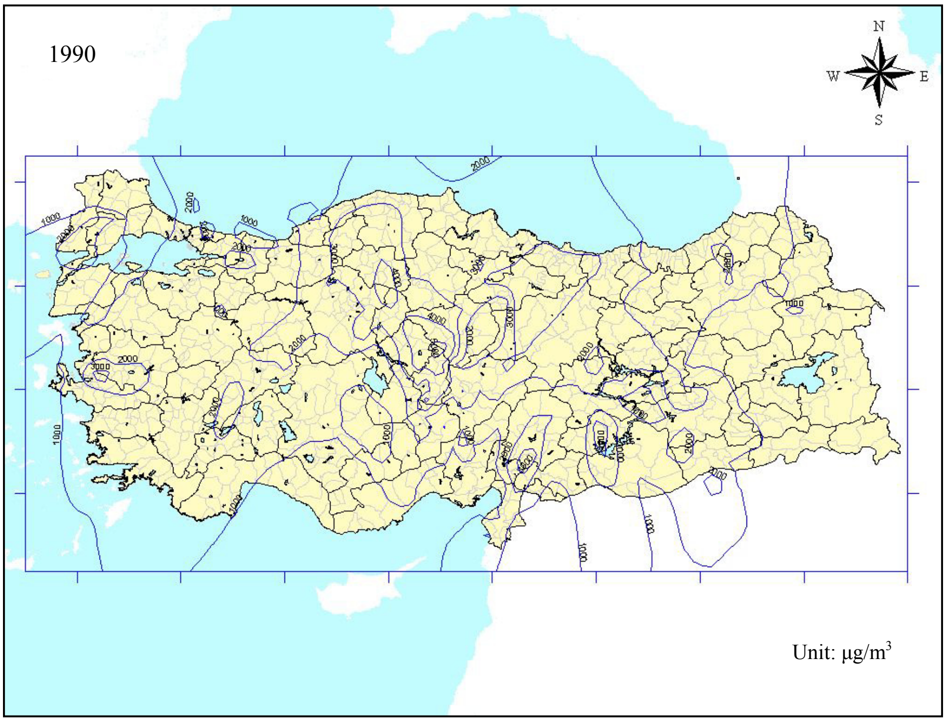


Figure K.4 Ground level CO_2 concentration of road vehicles without uptake in 1990 and 2004



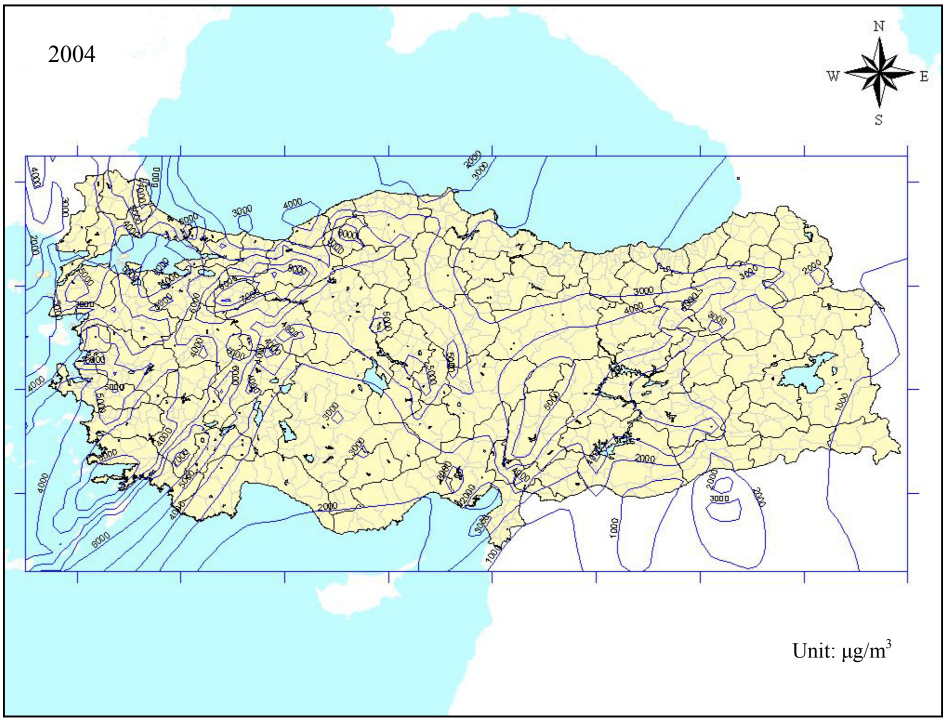
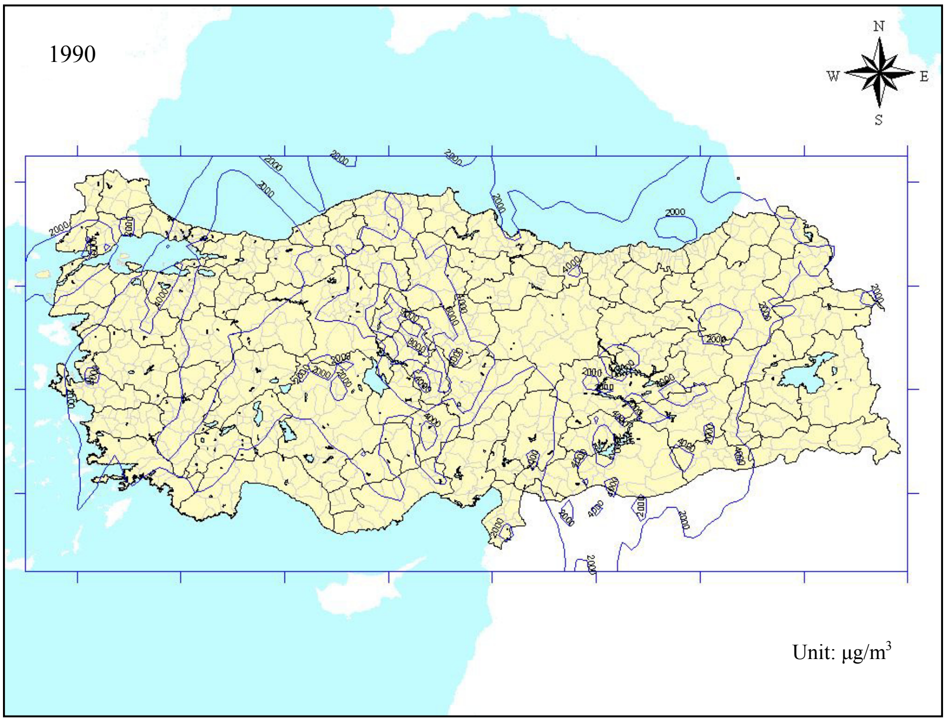


Figure K.5 Ground level CO_2 concentration of industries with uptake in 1990 and 2004



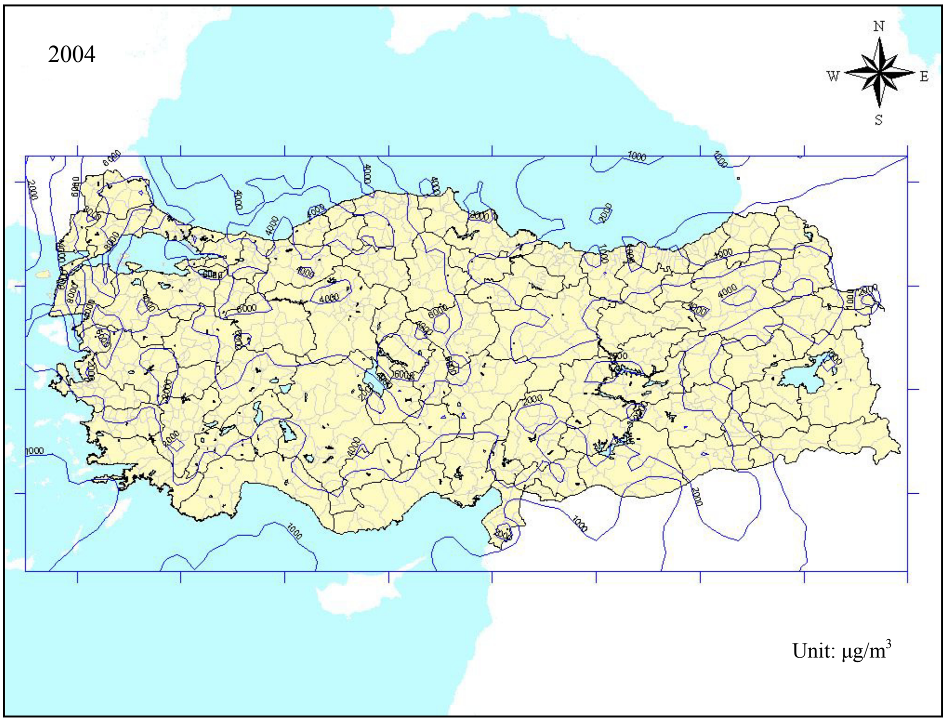
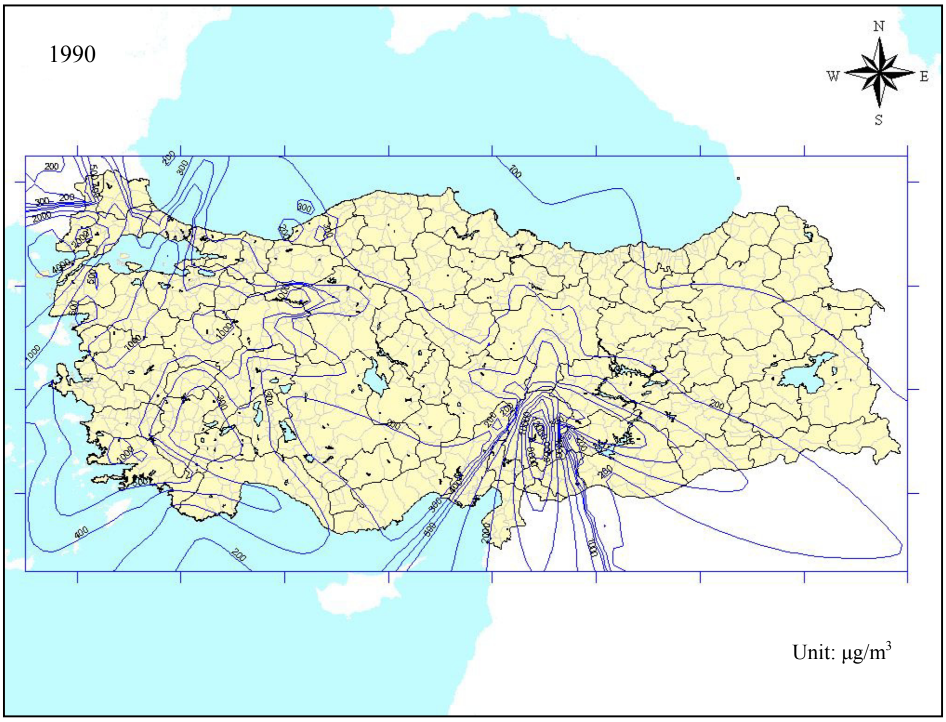


Figure K.6 Ground level CO_2 concentration of households with uptake in 1990 and 2004



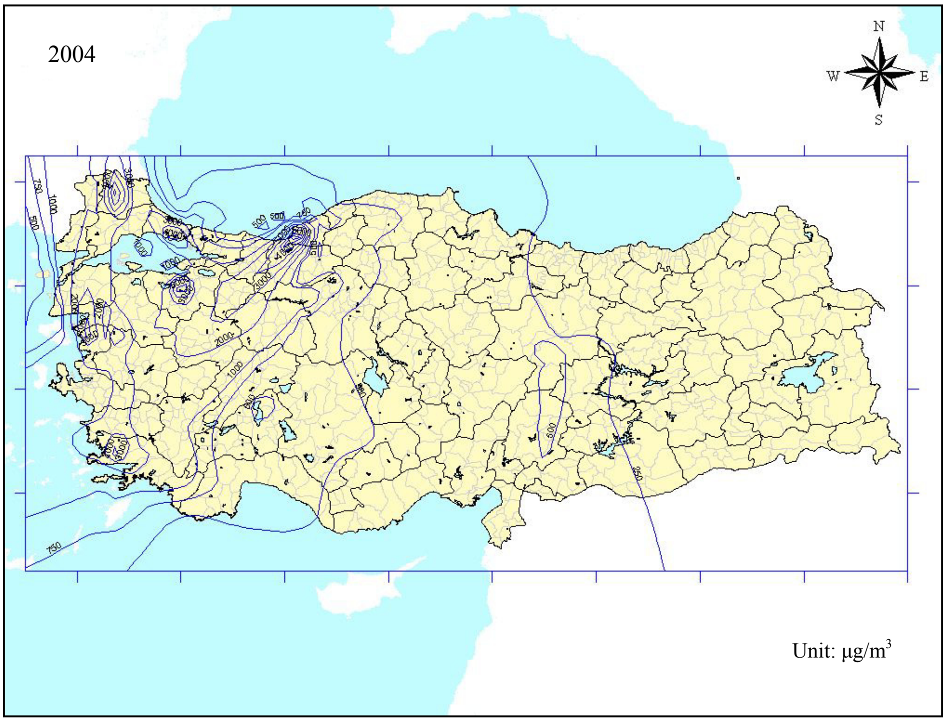
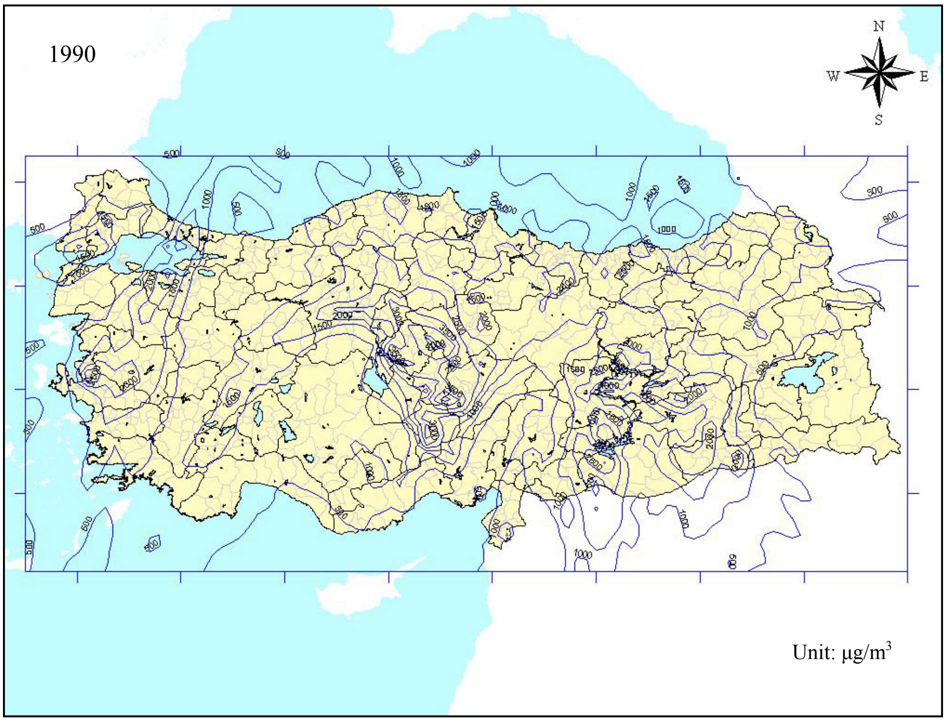


Figure K.7 Ground level CO_2 concentration of thermal power plant with uptake in 1990 and 2004



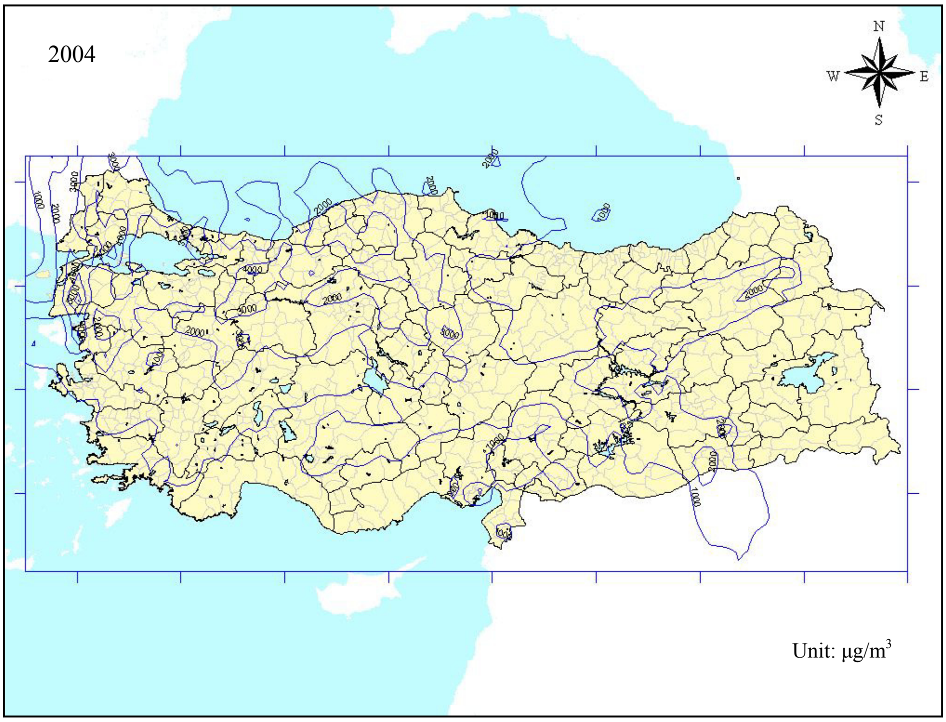


Figure K.8 Ground level CO_2 concentration of road vehicles with uptake in 1990 and 2004

APPENDIX L

In Appendix L, the following results of the normalized sensitivity analyses for ISCLT3 model were presented:

- Sensitivities at two receptors according to the percent changes of the each variables in the ISCLT3 model

Table L.1 Sensitivities at two receptors according to the percent changes of the each variable in the ISCLT3 model

Parameter		Base Case	Percent Change of Values and the Relative Errors at Two Receptor Points																			
			+10%		+5%		+3%		+2%		+1%		-1%		-2%		-3%		-5%		-10%	
			Receptor 1	Receptor 2	Receptor 1	Receptor 2	Receptor 1	Receptor 2	Receptor 1	Receptor 2	Receptor 1	Receptor 2	Receptor 1	Receptor 2	Receptor 1	Receptor 2	Receptor 1	Receptor 2	Receptor 1	Receptor 2	Receptor 1	Receptor 2
Source Pathway																						
Source Elevation (m)		643	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emission Rate (g/s)	Stack(1)	11627.90	0.31	0.31	0.08	0.08	0.03	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.03	0.08	0.08	0.31	0.31
	Stack(2)	11627.90	0.31	0.31	0.08	0.08	0.03	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.03	0.08	0.08	0.31	0.31
	stack(3)	13724.73	0.37	0.37	0.09	0.09	0.03	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.03	0.09	0.09	0.37	0.37
Release Height (m)		120	-0.17	-0.16	-0.04	-0.04	-0.02	-0.02	-0.01	-0.01	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.02	-0.05	-0.04	-0.19	-0.18
Temperature in Satck (°K)		433	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stackgas Exit Velocity (m/s)	Stack(1)	2.074	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Stack(2)	2.074	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	stack(3)	2.448	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stack Diameter (m)		5.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Receptor Pathway																						
Receptor Elevation (m)	Receptor(1)	1220	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Receptor(2)	949	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Meteorological Pathway																						
Air temperature (°K)		285.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mixing height (m)	Z_{am}	609.9	-0.03	-0.02	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	-0.03	-0.02
	Z_{pm}	1704.2	-0.88	-0.89	-0.23	-0.23	-0.08	-0.09	-0.04	-0.04	-0.01	-0.01	-0.01	-0.01	-0.04	-0.04	-0.09	-0.09	-0.25	-0.26	-1.07	-1.09

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2003	State Institute of Statistics – European Union Information Flow and Coordination Division	Chief of Division
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1. Can A., Atımtay A., **Time Series Analysis of Mean Temperature Data in Turkey** (Turkish) – 2nd Statistic Conference, (2-6 May, Antalya)-p.4-8., 2001.

2. Can A., Atımtay A., **Time Series Analysis of Minumum and Maximum Temperature Data in Turkey** (Turkish) – 3rd Statistic Conference, (16-20 April, Antalya), p.323-326., 2003.

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