NILU: OR 33/2000

NILU: OR 33/2000
REFERENCE: E-100087
DATE: AUGUST 2000
ISBN: 82-425-1193-4

Air Pollution Modelling in Zaragoza

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Preface

Gratitude to :

CAI (Caja de Ahorros de la Inmaculada): “Programa Europa”.
NILU (Norsk Institutt for Luftforskning): Specially to Frederick Gram and Svein Knudsen.
Excmo. Ayuntamiento de Zaragoza: Servicio de Medio Ambiente.
Universidad de Zaragoza: Specially to Josè Luis Ovelleiro (Departamento de Quìmica Tècnica y Medio Ambiente).
My family.

For the financial, scientific, data, etc aid I have received.

Contents

Summary

The concentrations of SO_2, particles and NO_x in Zaragoza is modelled, using programs in the KILDER Air Pollution Modelling System.

Gaussion dispersion models for point and area sources are used to give seasonal, ground-level concentrations in a 500x500 m^2-grid, based upon

- emission data from "Estudio de la Emisiones a la Atmòsfera du la Cuidad de Zaragoza, año 1996", using the CORINAIR methodology
- wind data from Zaragoza, combined with stability data from Bilbao.

For SO_2 there is a good agreement between the calculated winter values and annual mean values. Domestic heating is the main source. Since the industry is said to use only gas, their SO_2-emission is 0. For the summer season the heating emission is given as 0. It seems that traffic is not the only SO_2-source during the summer season.

Particles gives a bad agreement between calculated winter values and annual mean values. At the Louis Vives Station there is good agreement, and this means that the background value for particles cannot be higher than 10 $\mu g/m^3$. The monitoring stations are located close to roads with high traffic, and will thus not be representative for the concentrations in the grid.

The industrial particle emissions reported are low, since they all are using natural gas. We would expect large particle emissions from the steelwork Rico y Echeverria and from Amylan Ibèrica, but this is not reported.

For the summer season the measured and calculated concentrations are so far that they have not been considered.

The calculated NO_x-values are low, far below the reported NO_2-concentrations. The emissions are mainly as NO, nitrogen monoxide, while in the atmosphere ozone, O_3, oxidizes NO to NO_2, nitrogen dioxide. The NO_x concentration field is relatively flat, while the measurement values vary from 189 (Luis Vives) to 68 $\mu g\ NO_2/m^3$ (Av. Navarra). It seems that most of the monitoring stations are influenced by the nearest road traffic.

Air Pollution Modelling in Zaragoza

1 Introduction

This report is a study of the situation of air pollution in Zaragoza in 1996. Zaragoza is a Spanish municipality placed in the north east of Spain. Zaragoza is the 5th biggest city in Spain, with more than 600,000 habitants. Figure 1 and Figure 2 show maps of the city and surroundings.

Figure 1: Geographical situation of Zaragoza

Like all big cities, Zaragoza has pollution problems. We can group the polluting sources that affect Zaragoza into 4 main categories. One of the groups is domestic heating, that has its biggest influence during the winter season. There is a tendency in Zaragoza to change the coal, diesel, fuel-oil heating with natural gas heating. The air pollution emitted from the use of natural gas is different and less than the other fossil fuels and emissions are reduced. The other group is industry.

In Zaragoza there is not a big problem with industrial emission, due to the number of industries inside the city is not big enough and they are using, as it is said in the "Estudio de las Emisiones a la Atmòsfera en la Ciudad de Zaragoza" (1996), natural gas for their combustion systems. The third group is traffic. The number of cars and travels inside Zaragoza has been steadily increasing over the years. For example the number of vehicles has been increasing in almost all places with heavy traffic in Zaragoza since 1988 (Plan General de Ordenaciòn Urbana de Zaragoza, Mayo 1999. Datos principales del tràfico de Zaragoza. Tabla III.3). Traffic is one of the most important air pollution problems in Zaragoza. The last contributor is the background emission, that is not measured in Zaragoza and it is therefore difficult to estimate. Background concentrations are representative for the air pollution from sources outside the city and from long range transport.

Other effects such as secondary pollutants through chemical reactions will also affect the air pollution level in Zaragoza.

Because of this problem, the Ayuntamiento de Zaragoza has created a monitoring network to know which are the immission levels inside the city.

This study wants to establish a connection between emissions and concentrations in Zaragoza. For achieving this, we need a model to calculate the contributions from the different sources, and from this we can make an abatement strategy.

For carrying out this objective we have used the "KILDER" air pollution modelling system (Gram, 1996) and the information provided by the Servicio de Medio Ambiente of the Excelentìsimo Ayuntamiento de Zaragoza and the emission data of the "Estudio de las Emisiones a la Atmòsfera en la Ciudad de Zaragoza" (1996).

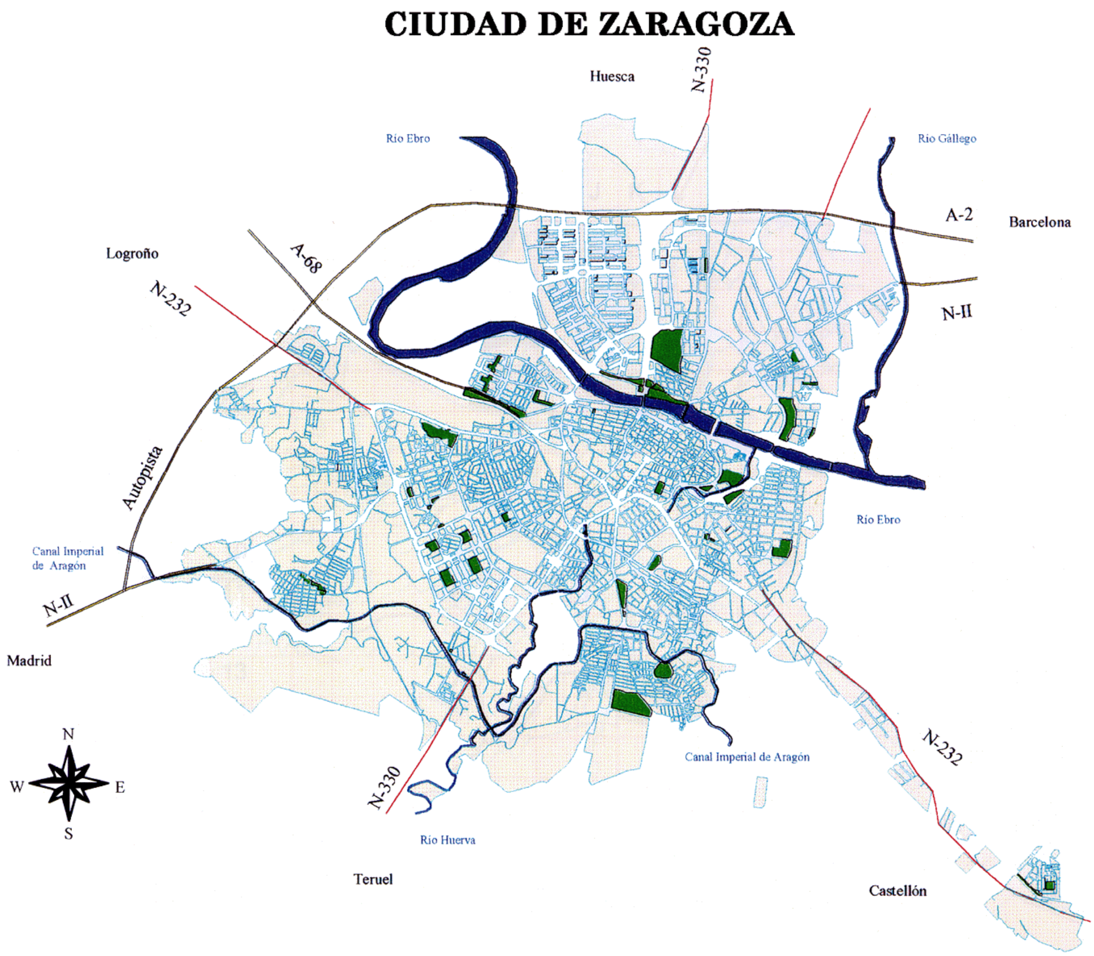

Figure 2: Map of Zaragoza.

2 Statistical programs and description of the dispersion models

The KILDER Air Pollution Modelling System is a system of small PC-programs for calculation of long-term emission, dispersion, concentration and exposure from different source categories. It has been developed from active use at NILU for more than 20 years to an integrated set of about 25 different programs.

The KILDER system may be divided into three parts:

- The dispersion models POI-KILD and ARE-KILD,
- Meteorological programs WINDFREC, STABFREC and METFREC,
- Supporting programs for calculating emissions and exposure.

The programs POI-KILD and ARE-KILD are multiple source Gaussian type dispersion models calculating sector-averaged long-term averaged ground level concentrations in a regular grid of receptor points. The models are using average emission data and a frequency matrix of wind direction, wind speed and stability classes.

POI-KILD is using emissions from several point sources (mainly factory stacks, but other stacks can be considered), taking into account data on dispersion, topography, buildings and penetration through an upper stable layer. ARE-KILD is using a field with area source emissions, like traffic emissions, domestic heating emissions and other sources. Each area source is divided into 100 point sources, and the impact from the area source within its own square is calculated separately.

The meteorological programs WINDFREC, STABFREC and METFREC are analysing wind, stability and a joint frequency distribution of wind direction, wind speed and stability.

The supporting programs may be divided into several groups:

- programs for input/output etc. of fields, presentation and for field handling;
- programs for preparing area code fields and distribution of data;
- programs for calculating emissions from traffic, industry and combustion;
- programs for exposure calculations.

For further information see the KILDER USER GUIDE. Figure 3 shows some elements of the "KILDER" air pollution modelling system.

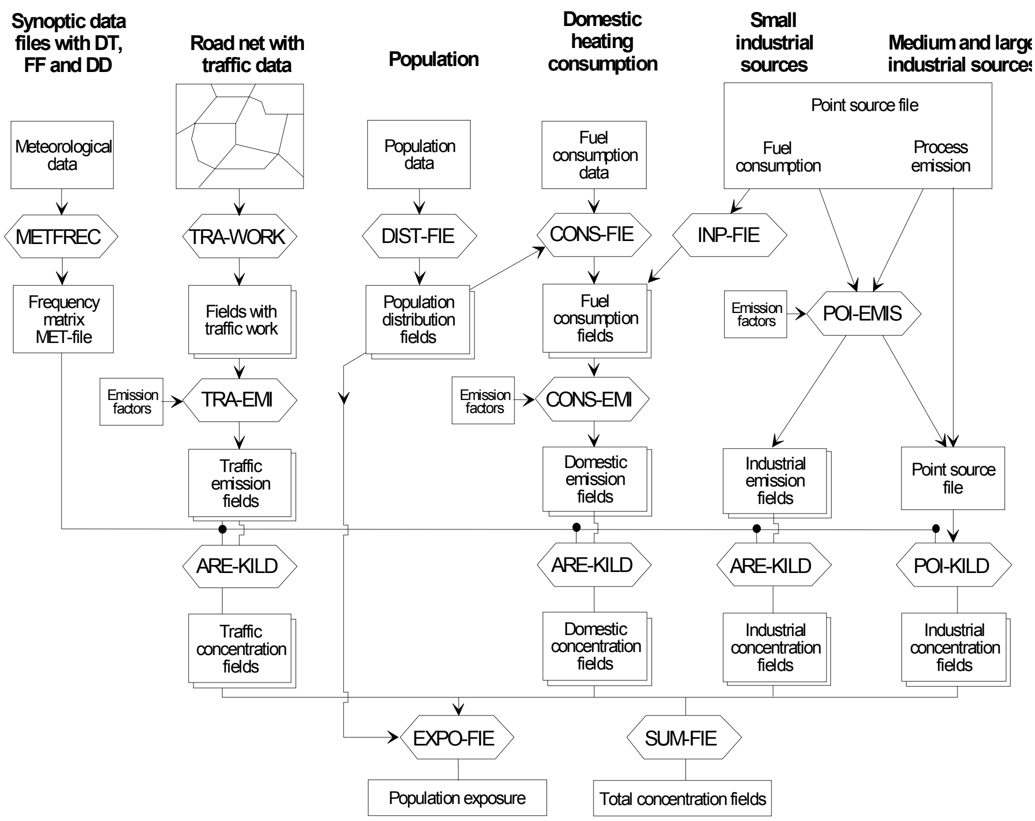

Figure 3: The "KILDER" air pollution modelling system

The model system is described in more detail in Appendix A.

3 Monitoring network (Description and purpose of the network).

The automatic pollutant control network for atmospheric pollution in Zaragoza is constituted by 7 remote stations, 1 mobile unit (see Table 1 and Figure 4), and the central station placed in a building in connection to the City Council of Zaragoza. (See description of each station in Appendix B).

Figure 4: Monitoring network of Zaragoza.

The analysers installed in the remote stations are doing continuous measurements, they are calibrated periodically in an automatic way and allow calibration from the central station. In each station there is a computer that controls the monitoring station and transmits the data to the central station.

Therefore, the automatic pollutant control network for atmospheric pollution allows the measurement of the pollutants in real time, with alarming, for each pollutant, the immission limit values with a variable alarm point according to the pre-set values.

The registered data for each remote station and for each pollutant are checked, controlled and verified, selecting the representative values, before transferring them to the database for their posterior treatment.

The object of the network is the study of the immission values according to the prevailing legislation for a posterior analysis of the atmospheric pollution situation in the city of Zaragoza.

Table 1: Overview of the parameters measured in the Zaragoza monitoring network

	SO_2	TSP	NO_2	CO	H_2S
El Picarral		X	X	X	X
M. Servet	X	X	X	X	
L. Vives	X	X	X	X	
R. de Flor	X	X	X	X	
Av. Navarra	X	X	X	X	
Paraninfo	X	X	X	X	
J. Ferràn	X	X	X	X	X
Mobil unit	X	X	X	X	X

4 Air pollution Laws and Regulations for Spain

This is a summary table for the limit values collected in laws and regulations related to the pollutant of the study.

The legislation put into effect for the immission levels is different for each pollutant. The laws and regulation for air pollution come from Royal Decrees and the emission levels are controlled by the City Council of Zaragoza.

The laws for immission levels are collected in the following decrees and they are issued by the Spanish Government:

- SO_2 and TSP: Royal Decree 1613/1985 de 1 de Octubre.
- NO_2: Royal Decree 717/1987 de 27 de Mayo.
- H_2S and CO: Decree 833/1975 de 6 de Febrero that develops the law 38/72 de Proteccon del. Ambiente Atmosfèrico.
- O_3: Royal Decree 1494/1995 de 8 de Octubre.

In these laws there are different immission levels for human and plant health protection depending on the considered time period.

There is a more detailed information about the laws and immission values in Appendix C.

Table 2: Values for each pollutant for human health protection in Spain. The values of the table are in µg/m³.

	½ h	1 h	8 h	24 h	Winter period	1 year
SO_2				100-150	130-180	40-60 80-120*
TSP				100-150	130	40-60 250-300*
NO_x		200*				50 ** 135 *
CO	45 mg/m³		15 mg/m³	34-60 mg/m³		
O_3		200-360	110			
H_2S	100			40		

* Percentile 98
** Percentile 50

5 Emission survey for Zaragoza

5.1 Introduction

The emission data were obtained from the "Estudio de la Emisiones a la Atmòsfera en la Ciudad de Zaragoza, año 1996". The emission data were grouped in 3 tables: traffic emission, winter heating, and all sources (traffic + winter heating emissions).

The "Estudio de la Emisiones a la Atmòsfera en la Ciudad de Zaragoza, año 1996" gives emissions for the year 1996 for the following contaminants: NOx, VOC, NMVOC, TSP, CH_4, N_2O, NH_3, SO_2, Pb, CO_2 and CO.

This study will use the emissions for NOx, TSP and SO_2 from traffic emission, winter heating emissions and industrial sources. The data for the industrial sources was obtained from the "Estudio de la Emisiones a la Atmòsfera en la Ciudad de Zaragoza, año 1996" and from provided data from the Servicio de Medio Ambiente of the City Council.

5.2 Map and emission grid

The map used for this study is the same that the one used in the "Estudio de la Emisiones a la Atmòsfera en la Ciudad de Zaragoza, año 1996". The axis were changed and deleted two rows of the map (as can be seen in Figure 5), which we considered not necessary for the study. This map is the Callejero of Zaragoza of the Geographical Information Service of the City Council of Zaragoza at scale of 1:10.000 (which in Figure 5 is reduced to about 1:6.140).

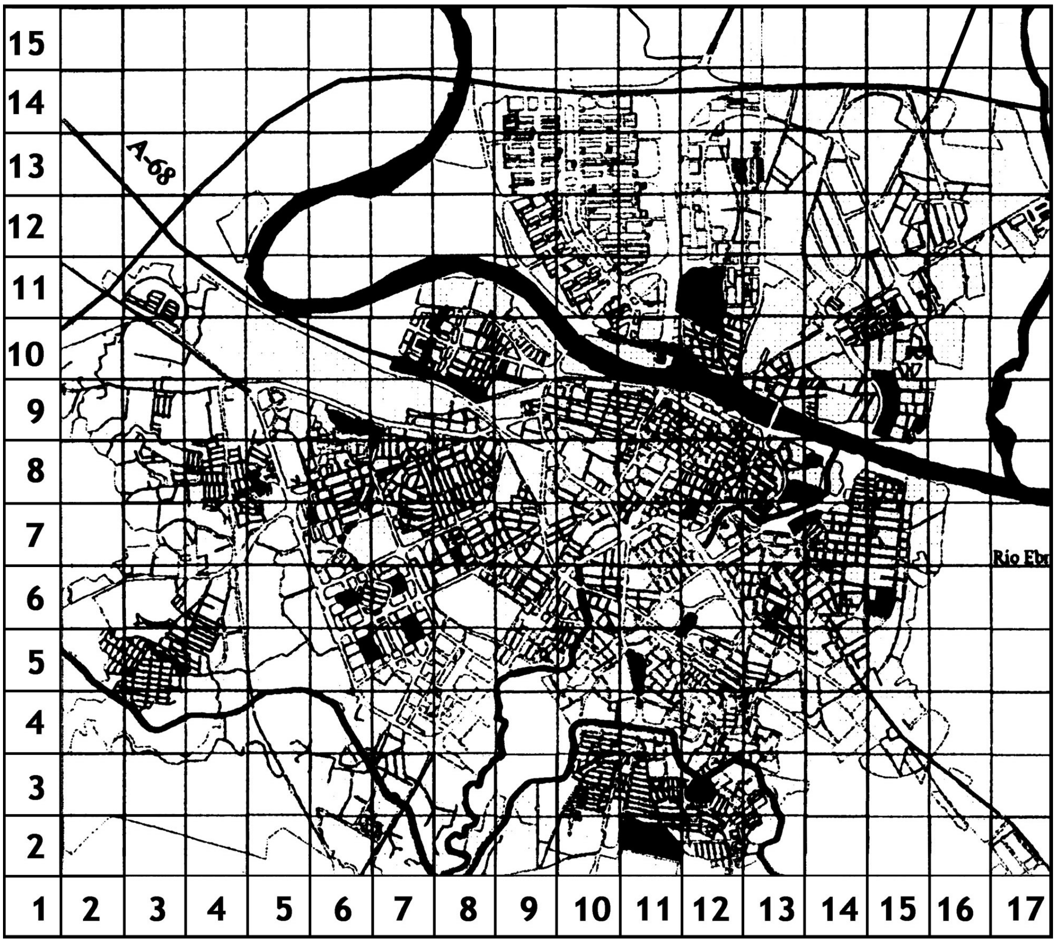

Figure 5: Grid map for Zaragoza.

The grid is still the same, a 500 x 500 squared meters grid, 17x15 squares.

5.3 Population distribution

With the total population of the city and the population in each district we distributed the population in the 500 x 500 m^2 squares. We estimated the population in each grid point taking into account the population for each district and the district population density map.

Table 3: Population distribution.

```
MAP OF : POPULATION        UNIT: INTEGER            SOURCE: POP. DATA
PERIOD : 1996             PLACE: ZARAGOZA        GRID SIZE:  500 METER
CREATED: 2000/03/06 13.52  FILE: POPULATION.FLD

    MAXIMUM VALUE IS  1.1633E+04, IN (11, 6)
                SUM= 5.71209E+05    SCALE FACTOR:      10.
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=14	.	.	.	.	.	.	.	.	416.	520.	208.	208.	.	104.	.	.	.
J=13	.	.	.	.	.	.	.	.	416.	312.	208.	312.	104.	.	.	.	.
J=12	.	.	.	.	.	.	.	.	416.	520.	312.	416.	312.	.	.	.	312.
J=11	.	.	443.	.	.	.	148.	148.	104.	416.	312.	208.	312.	104.	208.	.	.
J=10	.	.	.	.	.	.	443.	739.	739.	104.	208.	520.	312.	520.	416.	104.	.
J= 9	.	.	96.	.	622.	415.	415.	622.	415.	778.	584.	389.	416.	.	312.	.	.
J= 8	.	.	.	385.	385.	1036.	1036.	1036.	829.	195.	698.	778.	973.	195.	606.	.	.
J= 7	.	.	.	96.	289.	622.	829.	1036.	1036.	931.	1163.	931.	1010.	1010.	808.	.	.
J= 6	.	.	96.	.	.	622.	622.	152.	759.	759.	1163.	1163.	1154.	1010.	404.	.	.
J= 5	.	289.	289.	289.	.	608.	608.	152.	608.	608.	923.	1154.	692.	461.	.	.	.
J= 4	.	.	289.	.	.	.	456.	152.	.	578.	923.	1154.	461.	.	.	.	.
J= 3	.	.	.	.	.	152.	456.	.	.	578.	722.	433.	144.	.	.	.	.
J= 2	.	.	.	.	.	304.	152.	.	.	.	289.	578.	144.	.	.	.	.
J= 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

As we can see, the highest population concentration is between the columns number 7 and number 13; this is part of the Delicias and Margen Izquierda districts, most of San Josè and Ensanche districts and the whole Casco Antiguo and Centro districts.

5.4 Exhaust emissions from traffic

Exhaust emission from traffic is the most important pollution source in Zaragoza. For obtaining this data for each pollutant, procedures from CORINAIR were followed (see bibliography), and its results were given in kg/day.

Traffic emission data is in Appendix D.

Figure 6 is a reference map with the most important roads inside the city.

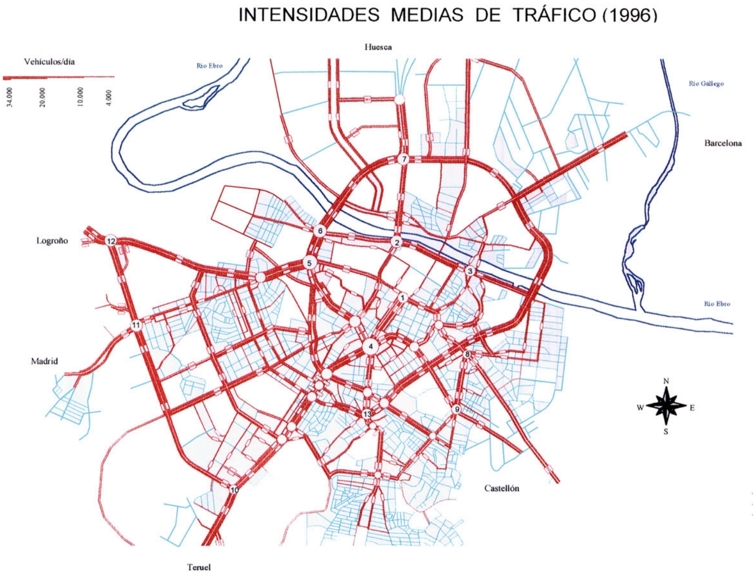

Figure 6: Mean traffic inside the main roads in Zaragoza in 1996.

5.5 Emissions from industry

The industrial stacks constitute the less important pollution source from a quantitative point of view. There is not a high industrial density in the map of Zaragoza but it was not taken into account for this study other important sources outside the map.

The selected industries were:

- Rico y Echeverrìa
- Sociedad Anònima de Industrias de Celulosa Aragonesa
- Amylum Ibèrica
- Ebroacero
- La Zaragozana

Figure 7 shows the location of the industries in Zaragoza.

The data for each industrial source were not very detailed. Total emission in ton/year and the emission factor for natural gas data were inside the “Estudio de la Emisiones a la Atmòsfera en la Ciudad de Zaragoza, año 1996” for all the industries. This data was not enough for running the program for dispersion calculations for point sources called POI-KILD.

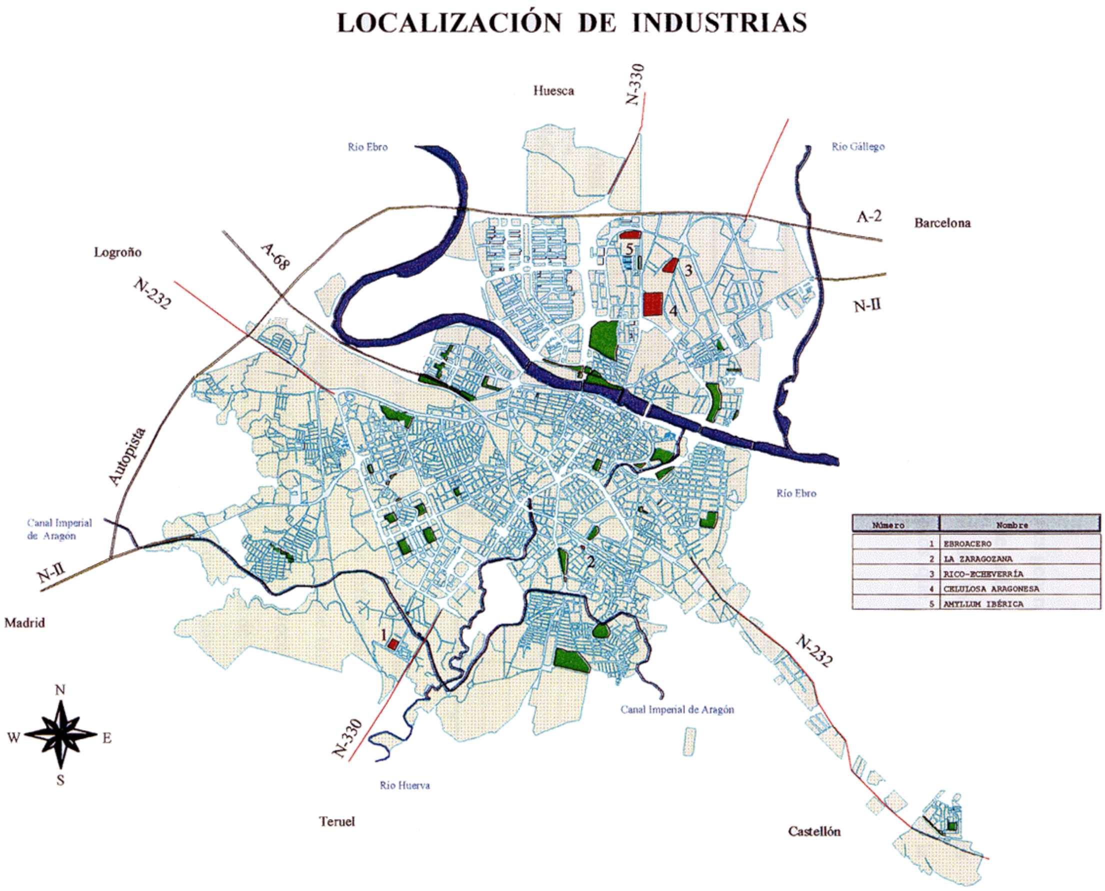

Figure 7: Map of industries in Zaragoza.The pollutants considered for the industrial emissions study in Zaragoza are NO_x, CO, CO_2, NMVOC, CH_4, N_2O. This is due to in the "Estudio de la Emisiones a la Atmòsfera en la Ciudad de Zaragoza, año 1996" report it was only taken into account the emissions for combustion processes and all the industries had natural gas as energy source.

Industrial emission data is in Appendix D.

More information was asked for the Servicio de Medio Ambiente, but there was still some information missing, and some estimations were done to obtain some values like stacks height, diameters, etc. Fortunately among these data there was some fuel consumption for some industries and a distribution for the unknown consumption among the other factories were done until total consumption was reached.

Table 4: Consumption distribution of natural gas for the factories inside the map of Zaragoza.

Factories	Consumption (m^3/year)
RICO-ECHEVERRÌA	6×10^6
CELULOSA ARAGONESA (SAICA)	102×10^6
LA ZARAGOZANA	2×10^6
EBROACERO	13×10^6
AMYLUM IBÈRICA	21×10^6
Total consumption	144×10^6

Table 4 shows our consumption distribution for the factories.

Table 5: Emission factors for natural gas.

POLLUTANT	g/m^3
SO_2	0
NO_x	2,3
CO	10,35
CO_2	2,53
COVNM	0,23
CH_4	0,23
N_2O	0,09
Particles	0

Table 5 shows CORINAIR emission factors for natural gas.

Table 6 and Table 7 show the data about stacks height, gas velocity, kg/h for particles and NOx that we used for running the model. It has been considered also some particles emissions for industrial point sources. This industrial data comes from other study done in Zaragoza about particles (“Medidas de las Emisiones Gaseosas en la Industria”, years 1992, 1994, 1996 and 1998). According to the emission factors there is no SO_2emission from industry in Zaragoza. Industrial emission data are shown in Appendix D.

Table 6: Factory data for particles.

Source data:

	Name	Relative coordinates X	Relative coordinates Y	Stack base m	Stack height m	Stack diameter m	Gas temp. oC	Exit velocity m/s	Building height m	Building width m	Part emission kg/h
1	RICO FUND1	6.60	5.70	0.00	22.0	2.50	95.	19.9	10.	30.	2.56
2	RICO FUND2	6.60	5.70	0.00	22.0	2.50	95.	19.9	10.	30.	2.56
3	RICO LAMIN	6.60	5.70	0.00	40.0	1.20	650.	2.7	10.	30.	0.09
4	RICO LAMIN	6.60	5.70	0.00	40.0	1.20	650.	2.7	10.	30.	0.15
5	AMYLUM IBE	6.05	6.05	0.00	10.3	1.20	50.	3.9	10.	30.	0.36
6	AMYLUM IBE	6.05	6.05	0.00	20.4	1.80	50.	1.0	10.	30.	0.65
7	AMYLUM IBE	6.05	6.05	0.00	19.0	1.00	56.	11.0	10.	30.	2.11
8	AMYLUM IBE	6.05	6.05	0.00	19.0	1.00	56.	11.0	10.	30.	0.32
9	AMYLUM IBE	6.05	6.05	0.00	9.5	0.60	45.	22.8	10.	30.	0.80
10	AMYLUM IBE	6.05	6.05	0.00	9.5	0.60	45.	22.8	10.	30.	0.40
11	AMYLUM IBE	6.05	6.05	0.00	9.5	0.60	45.	22.8	10.	30.	0.33

Table 7: Factory data for NO_x.

Source data:

	Name	Relative coordinates X	Relative coordinates Y	Stack base m	Stack height m	Stack diameter m	Gas temp. oC	Exit velocity m/s	Building height m	Building width m	NOx emission kg/h
1	RICO FUND1	6.60	5.70	0.00	22.0	2.50	95.	19.9	10.	30.	1.70
2	SAICA CALD	6.30	5.25	0.00	35.0	3.42	135.	19.3	10.	30.	26.70
3	ZARAGOZANA	5.45	2.25	0.00	12.0	0.40	70.	15.0	10.	30.	0.50
4	EBROACERO	2.80	1.00	0.00	30.0	1.68	40.	13.5	10.	30.	3.40
5	AMYLUM IBE	6.05	6.05	0.00	10.3	1.20	50.	3.9	10.	30.	5.50
										SUM	37.80

5.6 Emission from domestic activities

All the process to obtain the emission for domestic activities is explained in the "Estudio de la Emisiones a la Atmòsfera en la Ciudad de Zaragoza, año 1996". Domestic emission data is in Appendix D.

6 Historical data

6.1 Data availability.

For carrying out this study data from the Instituto Nacional de Meteorologìa was requested. We have used the meteorological data from the airport of Zaragoza. The location of the airport is at the south west of Zaragoza.

Data from a study done by NILU and LABEIN for the Basque government in Bilbao in 1986-1987 was also used for obtaining the atmospheric dispersion parameters describing the stability matrix.

Information related to immission and emission concentrations were also necessary to create the model. Immission data was found in the books published by the Ayuntamiento de Zaragoza: "Situaciòn de la Contaminaciòn Atmosfèrica en la Ciudad de Zaragoza durante el Año 1997" and "Evoluciòn de la Contaminaciòn Atmosfèrica en la Ciudad de Zaragoza durante los Años 1995, 1996 y 1997".

Emission data are from the "Estudio de las Emisiones a la Atmòsfera en la Ciudad de Zaragoza Año 1996".

6.2 Wind directions.

The wind direction frequency distribution for Zaragoza for the period 1987-1996 is presented in Figure 8.

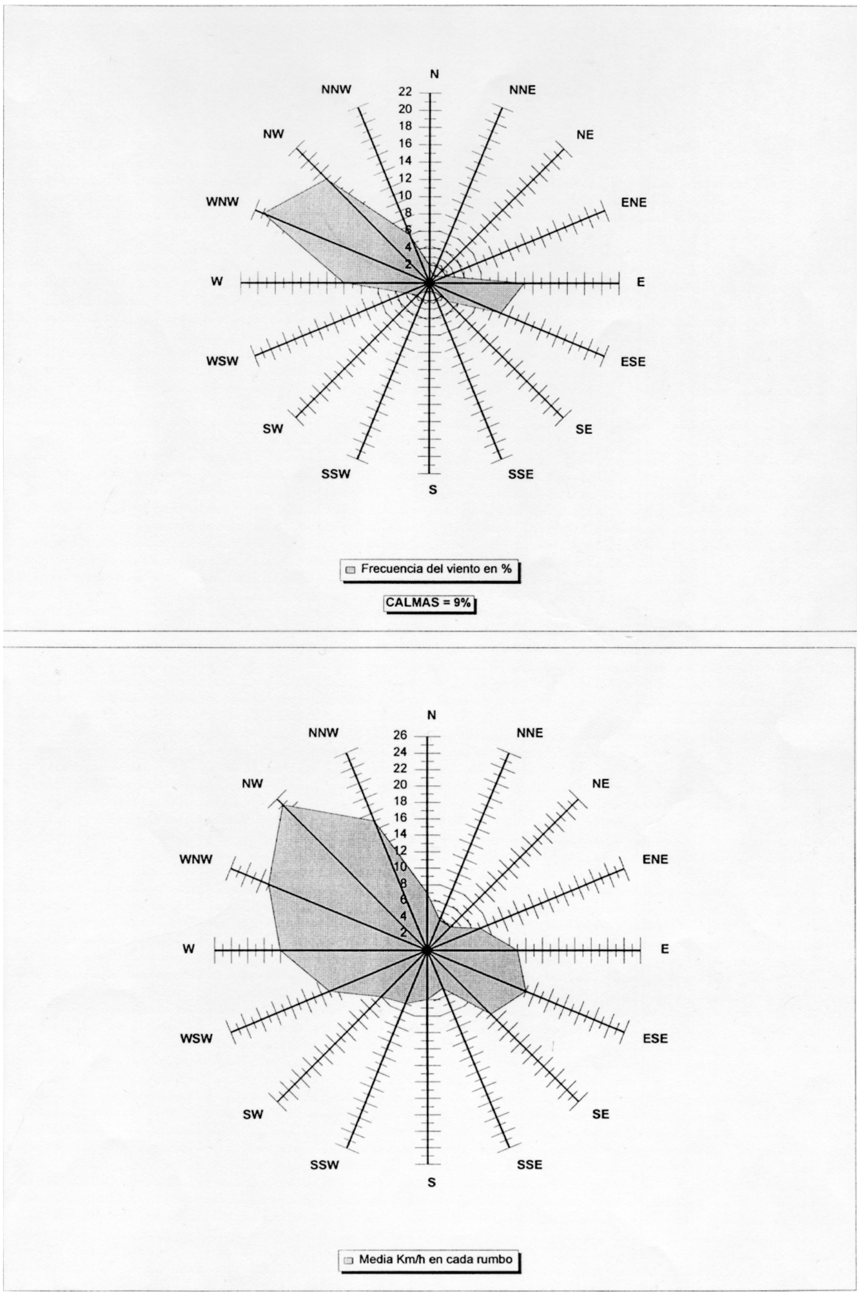

Figure 8: Windrose from Zaragoza.

We worked with a 16 sector wind rose for the period 1994-1999. The wind roses indicate a seasonal variation of the wind in the area with a strong channelling of the winds along the Ebro's valley.

During the summer and winter period, the wind is channelled along the valley axis; winds from NW and E are dominating. In winter the wind flows in NW direction the 21% of the times, in WNW direction the 17% of the times and in E-ESE directions the 17%.

In summer this main directions almost do not change; we have NW-WNW winds the 36% of the times and E-ESE the 23% of the times.

6.3 Temperature.

Data for 1994, 1995, 1996, 1997, 1998 and 1999 were obtained. The data were: Maximum temperature and date, minimum temperature and date, maximum and minimum averaged temperature and month averaged temperature.

Table 8: Mean temperature in Zaragoza.

INSTITUTO NACIONAL DE METEOROLOGIA
ARAGON LA RIOJA Y NAVARRA
BANCO DE DATOS

TEMPERATURAS MEDIAS

PAGINA : 1
FECHA : 02/09/99
PROGRAMA: CLBPBR14

CENTRO METEOROLOGICO: ARAGON-RIOJA-NAVARRA
CUENCA: 9 INDICATIVO: 434 NOMBRE: ZARAGOZA AEROPUERTO PROV: ZARAGOZA LONG: 01-00-29W LAT: 41-39-43 ALT: 247

TEMPERATURA MEDIA DEL MES PERIODO: 1994 - 1999

	ENE.	FEB.	MAR.	ABR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DIC.	A#O
1994	8.0	9.3	13.5	12.8	19.2	22.5	27.4	26.4	19.4	15.4	11.4	7.9	16.1
1995	8.8	10.0	11.0	14.2	18.6	22.3	26.7	24.8	19.5	18.0	11.7	7.0	16.0
1996	8.8	7.0	10.4	13.8	17.6	22.4	24.6	23.4	19.2	15.1	10.6	7.6	15.0
1997	7.0	10.4	13.0	15.0	18.1	20.7	22.7	24.8	21.5	18.2	11.0	7.7	15.8
1998	8.0	8.2	12.6	12.8	17.6	22.8	24.8	25.0	21.2	15.1	9.8	5.6	15.3
1999	6.2	8.3	11.2	14.0	19.8	22.0	25.4	--	--	--	--	--	--
TOTAL													
MEDIA	7.8	8.9	12.0	13.8	18.5	22.1	25.3	24.9	20.2	16.4	10.9	7.2	15.6
MEDIANA	7.5	8.8	11.9	14.0	18.6	22.4	25.1	24.9	19.5	16.7	11.0	7.6	15.8
DESV. (n) ...	0.9	1.2	1.1	0.8	0.8	0.7	1.5	1.0	1.0	1.4	0.7	0.8	0.4
DESV. (n-1)...	1.0	1.3	1.2	0.8	0.9	0.7	1.7	1.1	1.1	1.6	0.7	0.9	0.5
NUM. DE DATOS.	6	6	6	6	6	6	6	5	5	5	5	5	5

It is seen from the temperature data that the year 1996 has a normal temperature distribution for Zaragoza.

6.4 Stability distribution.

There are many ways to calculate the atmospheric dispersion and through this estimate the atmospheric dispersion or mixing. The one used here is vertical temperature.

There was not enough information in the data available to us to estimate the atmospheric stability since that in Zaragoza the temperature data from the Instituto Nacional de Meteorologìa was valid for ground level. We solved this problem “using” a stability matrix done by NILU in Bilbao in 1987. After evaluating the entire stability matrix found in the Bilbao study (see references in bibliography), we considered that Burzeña stability matrix (Burzeña is a station inside Bilbao) was adequate for our purpose due to its characteristics. We did some modifications in the wind rose directions to adjust it to the wind rose of Zaragoza and after that we estimated the stability matrix for Zaragoza using the Burzeña stability information and the information about wind in Zaragoza.

Table 9: Stability matrix for Burzeña during summer season.

Parameter : BULK-RICHARDSON (GOLDER 1972)
Wind : BURZENA
Period : 01.06.86. - 31.08.86.
Unit : Percent

Wind-direction	.0- 2.0 m/s				2.0- 4.0 m/s				4.0- 6.0 m/s				over 6.0 m/s				
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	Rose
30	1.9	.2	.5	.4	1.5	.9	.1	.0	.2	.1	.0	.0	.0	.0	.0	.0	5.7
60	1.4	.0	.1	.1	.7	.4	.1	.0	.1	.0	.0	.0	.0	.0	.0	.0	2.7
90	.8	.1	.3	.2	.2	.2	.0	.0	.0	.1	.0	.0	.0	.0	.0	.0	1.6
120	.8	.3	.4	.2	.6	.4	.1	.0	.0	.1	.0	.0	.0	.0	.0	.0	2.8
150	.8	.3	1.3	1.0	.4	2.9	5.5	.6	.0	1.8	.7	.0	.0	.4	.1	.0	15.5
180	.5	.0	1.2	.8	.1	1.4	3.3	.1	.0	.4	.6	.0	.0	.1	.1	.0	8.4
210	.8	.3	1.2	1.5	.1	.4	.8	.0	.0	.1	.1	.0	.0	.2	.0	.0	5.4
240	.0	.0	.2	.6	.0	.0	.0	.0	.0	.1	.0	.0	.0	.2	.0	.0	.9
270	.2	.0	.4	.7	.1	.1	.0	.0	.0	.1	.0	.0	.0	.0	.0	.0	1 4
300	2.3	.6	1.4	.9	1.8	3.4	.6	.1	1.3	.8	.0	.0	.1	.2	.0	.0	13.4
330	1.7	.3	.4	.6	6.4	3.1	.2	.0	9.1	6.9	.0	.0	1.4	4.6	.0	.0	34.5
360	1.2	.2	.2	.4	2.3	.8	.1	.1	.4	.4	.0	.0	.3	.1	.0	.0	6.2
Calm	.3	.0	.0	1.1													1.4
Total	12.6	2.0	7.4	8.4	13.9	13.9	10.6	.7	11.0	10.7	1.3	.0	1.7	5.6	.1	.0	100.0

	.0- 2.0 m/s	2.0- 4.0 m/s	4.0- 6.0 m/s	over 6.0 m/s	
Occurrence	30.4 %	39.1 %	23.0 %	7.4 %	100.0 %
Wind speed	1.1 m/s	3.1 m/s	4.8 m/s	7.0 m/s	3.2 m/s

Frequency of occurrence of the stability classes

	Class I	Class II	Class III	Class IV	
Occurrence	39.3 %	32.2 %	19.4 %	9.1 %	100.0 %

Number of obs.: 1951
Missing obs. : 257

Table 10: Stability matrix for Burzeña during winter season.

Parameter : BULK-RICHARDSON (GOLDER 1972)
Wind : BURZENA
Period : 01.12.86. - 28.02.87.
Unit : Percent

Wind-direction	.0- 2.0 m/s				2.0- 4.0 m/s				4.0- 6.0 m/s				over 6.0 m/s				
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	Rose
30	.1	.1	.4	.1	.0	.1	.1	.0	.0	.1	.0	.0	.0	.0	.0	.0	1.0
60	.0	.0	.1	.2	.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.3
90	.1	.1	.4	.2	.1	.3	.2	.0	.0	.1	.1	.0	.0	.0	.0	.0	1.4
120	.2	.4	.5	.6	.1	.8	.8	.0	.0	.3	.2	.0	.0	.5	.0	.0	4.4
150	.4	.3	2.0	1.7	.3	4.5	7.0	.7	.0	8.4	2.6	.0	.0	4.4	.4	.0	32.7
180	.1	.2	.9	1.4	.1	1.0	3.3	.7	.0	1.6	.8	.0	.0	2.0	.1	.0	12.1
210	.2	.1	.5	1.1	.0	.5	.6	.1	.0	.8	.0	.0	.0	8.5	.1	.0	12.6
240	.1	.1	.4	.4	.0	.4	.5	.0	.0	.5	.1	.0	.0	1.6	.0	.0	4.0
270	.0	.1	.4	.7	.1	.3	.6	.0	.0	.2	.0	.0	.0	.0	.0	.0	2.3
300	.2	.2	1.0	1.4	.1	2.9	2.9	.1	.1	2.6	.1	.0	.0	1.4	.0	.0	13.1
330	.2	.1	.2	.5	.1	1.9	1.0	.0	.1	3.0	.5	.0	.0	3.6	.0	.0	11.2
360	.1	.1	.5	.1	.1	1.0	.5	.0	.1	1.1	.0	.0	.0	.7	.0	.0	4.3
Calm	.0	.0	.0	.5													.5
Total	1.7	1.9	7.1	8.8	.8	13.7	17.6	1.6	.2	18.8	4.4	.0	.0	22.8	.6	.0	100.0

	.0- 2.0 m/s	2.0- 4.0 m/s	4.0- 6.0 m/s	over 6.0 m/s	
Occurrence	19.5 %	33.7 %	23.4 %	23.4 %	100.0 %
Wind speed	1.3 m/s	3.0 m/s	5.0 m/s	8.3 m/s	4.4 m/s

Frequency of occurrence of the stability classes

	Class I	Class II	Class III	Class IV	
Occurrence	2.7 %	57.3 %	29.6 %	10.4 %	100.0 %

Number of obs.: 1673
Missing obs. : 487

Table 11: Windrose of 16 sectors of Zaragoza.

Instituto Nacional De Meteorologia

Indicativo: 9434 Estacion: ZARAGOZA AEROPUERTO
Provincia: ZARAGOZA Long.: 01 00 29 W Lat.: 41 39 43 Alt.: 0247 m

ROSA DE VIENTOS DE 16 RUMBOS

9434		mes	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NN	CAL
9434	%	1	2	1	1	1	5	11	9	2	2	1	1	5	15	13	19	6	6
9434	V		10	2	5	4	6	11	9	12	6	3	6	12	20	19	27	24	
9434	n		6																
9434	%	2	1	0	1	1	7	8	3	2	2	1	1	3	10	17	27	10	6
9434	V		8	1	2	6	8	10	9	5	5	2	6	15	17	17	28	23	
9434	n		6																
9434	%	3	4	1	0	1	8	9	4	1	2	1	0	1	7	16	27	13	5
9434	V		12	4	2	5	10	13	12	10	4	3	3	1	13	19	25	27	
9434	n		6																
9434	%	4	7	1	2	2	8	7	2	2	1	0	0	2	7	15	24	17	4
9434	V		12	5	5	6	9	12	8	8	4	0	4	8	16	19	28	27	
9434	n		6																
9434	%	5	9	2	2	2	15	18	3	1	1	1	1	3	5	10	16	11	3
9434	V		11	5	7	7	12	16	19	8	8	6	8	17	21	20	24	23	
9434	n		6																
9434	%	6	12	4	2	2	13	7	1	0	0	0	0	1	2	12	26	15	2
9434	V		12	7	5	7	12	18	8	1	2	5	5	4	9	18	25	24	
9434	n		6																
9434	%	7	6	2	2	4	16	7	2	0	0	0	0	0	4	15	24	16	1
9434	V		12	6	8	11	14	16	15	7	3	2	0	5	22	20	25	21	
9434	n		6																
9434	%	8	5	3	2	3	17	11	3	1	1	1	0	1	3	9	25	14	2
9434	V		13	6	5	8	11	14	15	9	11	8	1	2	15	18	24	22	
9434	n		5																
9434	%	9	7	1	1	1	11	8	3	2	1	0	0	1	5	17	21	15	4
9434	V		13	3	2	6	11	13	13	12	5	0	0	8	16	18	22	22	
9434	n		5																
9434	%	10	3	1	1	1	12	12	5	1	2	1	0	2	9	18	18	8	5
9434	V		6	4	4	4	8	12	8	9	6	3	4	7	11	15	23	19	
9434	n		5																
9434	%	11	2	1	0	1	7	9	6	3	2	1	2	3	12	20	17	8	5
9434	V		9	1	1	4	9	12	12	5	6	5	8	12	18	19	25	21	
9434	n		5																
9434	%	12	2	1	0	2	8	9	5	3	2	1	0	3	12	19	18	8	8
9434	V		4	4	1	5	8	12	9	5	3	5	1	14	16	18	26	23	
9434	n		5																
9434	%	13	5	2	1	2	11	10	4	2	1	1	0	2	8	15	22	12	4
9434	V		10	4	4	6	10	13	11	8	5	4	4	9	16	18	25	23	
9434	n		67																

% % de veces que el viento ha soplado de cada rumbo
V Velocidad media en Km/hora
n Numero de meses con observacion
El mes 13 contiene los valores medios anuales

The atmospheric stratification or atmospheric dispersion conditions can be classified as unstable, neutral or stable:

- Unstable atmospheric condition is common on days with strong solar radiation and low wind speed. The sun warms the underlying surface and vertical turbulent eddies are set up causing vertical dispersion in the lower atmospheric layers. High concentrations close to the point sources may occur at the ground because of the vertical mixing in the atmosphere.
- Near neutral atmospheric conditions occur at moderate to high wind speeds, usually connected to cloudy skies. Near neutral atmospheric conditions results in a good horizontal and vertical mixing on the air and the dispersion conditions are good.
- Stable atmospheric conditions occur during clear nights and winter situation with cooling of the ground and lower layer of air. The vertical mixing is poor. Poor vertical mixing results in high concentrations of pollutants released close to the ground and emissions from the tall stacks are being transported far before they reach the ground.

In Burzeña two parameters for describing the stability conditions were evaluated; the vertical temperature difference (ΔT) and the Bulk Richardson number (Ri_B).

Temperatures measured at different heights above the surface and at different altitudes above the sea level were used to evaluate the vertical spread of air pollution in the area. Four stability classes were selected based upon the following criteria:

I :	Unstable	$\Delta T < -0.6$	deg/35m
II:	Neutral	$-0.6 < \Delta T < -0.1$	deg/35m
III:	Light Stable	$-0.1 < \Delta T < 0.6$	deg/35m
IV:	Stable	$0.6 < \Delta T$	deg/35m

The Bulk Richardson number (Ri_B) includes both thermal induced turbulence (temperature stratification) and mechanical induced turbulence (wind profile) to describe the dispersion condition in the area.

$$(Ri_B) = g\,(\Delta\Theta/\Delta z)z^2/(Tu^2)$$

where $\Delta\Theta$ is the potential temperature difference measured between the height difference Δz; z is the height above the surface of the measured wind speed (u) and g/T is the buoyancy parameter.

The criteria for the four classes of turbulence were:

I : Unstable	$Ri_B < -0.009$
II: Neutral	$-0.009 < Ri_B < 0.0075$
III:Light Stable	$0.0075 < Ri_B < 0.05$
IV:Stable	$0.05 < Ri_B$

The information from Burzeña was merged with the information from Zaragoza and one matrix for winter (January, February, March, October, November, December) and one for summer (April, May, June, July, August, September) were obtained.

Table 12: Stability matrix for Zaragoza during summer season.

	0-2.0m/s				2.0-4-0m/s				4.0-6.0m/s				over 6m/s				
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	Rose
N	1,95	0,25	0,44	0,50	2,35	1,06	0,13	0,06	0,37	0,30	0,00	0,00	0,18	0,06	0,00	0,00	7,66
NNE	0,82	0,05	0,14	0,13	0,55	0,32	0,05	0,00	0,08	0,03	0,00	0,00	0,00	0,00	0,00	0,00	2,16
NE	0,90	0,00	0,06	0,06	0,45	0,26	0,06	0,00	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,83
ENE	1,02	0,09	0,28	0,19	0,35	0,27	0,03	0,00	0,03	0,09	0,00	0,00	0,00	0,00	0,00	0,00	2,33
E	4,71	1,02	1,98	1,18	2,03	1,61	0,22	0,00	0,00	0,58	0,00	0,00	0,00	0,00	0,00	0,00	13,33
ESE	1,95	0,73	1,16	0,65	1,42	1,48	1,33	0,12	0,00	0,58	0,15	0,00	0,00	0,08	0,02	0,00	9,66
SE	0,11	0,04	0,19	0,14	0,06	0,44	0,82	0,09	0,00	0,26	0,10	0,00	0,00	0,06	0,01	0,00	2,33
SSE	0,06	0,01	0,12	0,08	0,02	0,17	0,37	0,02	0,00	0,07	0,06	0,00	0,00	0,02	0,01	0,00	1,00
S	0,07	0,02	0,12	0,12	0,01	0,08	0,18	0,00	0,00	0,02	0,03	0,00	0,00	0,02	0,00	0,00	0,66
SSW	0,03	0,01	0,07	0,13	0,00	0,02	0,03	0,00	0,00	0,02	0,00	0,00	0,00	0,03	0,00	0,00	0,33
SW	0,00	0,00	0,03	0,09	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,03	0,00	0,00	0,16
WSW	0,11	0,00	0,30	0,63	0,05	0,05	0,00	0,00	0,00	0,09	0,00	0,00	0,00	0,09	0,00	0,00	1,33
W	0,63	0,09	0,78	1,14	0,42	0,65	0,09	0,02	0,20	0,26	0,00	0,00	0,02	0,03	0,00	0,00	4,33
WNW	1,69	0,43	0,95	0,66	1,96	2,57	0,41	0,06	1,97	1,37	0,00	0,00	0,24	0,71	0,00	0,00	13,00
NW	1,11	0,19	0,26	0,39	4,18	2,02	0,13	0,00	5,95	4,51	0,00	0,00	0,92	3,01	0,00	0,00	22,66
NNW	2,06	0,35	0,36	0,70	4,38	1,64	0,18	0,15	1,86	1,56	0,00	0,00	0,65	0,78	0,00	0,00	14,66
CALM	0,57	0,00	0,00	2,09													2,66
TOTAL	17,79	3,27	7,23	8,87	18,22	12,63	4,02	0,52	10,49	9,76	0,34	0,00	2,00	4,90	0,04	0,00	100,09

Occurrence
Class I 48.51%
Class II 30.56%
Class III 11.63%
Class IV 9.39%
100.09%

Unstable conditions and well developed vertical dispersion of air pollutants most often ocurred during summer time while neutral and light stable conditions are more important during winter.

Table 13: Stability matrix for Zaragoza during winter season.

	0-2.0m/s				2.0-4-0m/s				4.0-6.0m/s				over 6m/s				
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	Rose
N	0.04	0.03	0.14	0.21	0.00	0.14	0.17	0.01	0.00	0.19	0.02	0.00	0.00	1.35	0.01	0.00	2.33
NNE	0.02	0.02	0.08	0.08	0.00	0.08	0.10	0.00	0.00	0.10	0.02	0.00	0.00	0.32	0.00	0.00	0.83
NE	0.00	0.02	0.07	0.11	0.01	0.06	0.10	0.00	0.00	0.05	0.00	0.00	0.00	0.06	0.00	0.00	0.50
ENE	0.01	0.03	0.14	0.24	0.03	0.20	0.28	0.00	0.00	0.16	0.00	0.00	0.00	0.06	0.00	0.00	1.17
E	0.13	0.10	0.45	0.68	0.06	1.61	1.40	0.04	0.06	1.74	0.16	0.00	0.00	1.40	0.00	0.00	7.83
ESE	0.17	0.09	0.17	0.43	0.09	1.64	0.86	0.00	0.09	2.59	0.43	0.00	0.00	3.11	0.00	0.00	9.67
SE	0.11	0.10	0.44	0.16	0.10	1.13	0.57	0.00	0.10	1.38	0.08	0.00	0.00	1.15	0.00	0.00	5.33
SSE	0.12	0.12	0.52	0.12	0.02	0.33	0.22	0.00	0.02	0.36	0.00	0.00	0.00	0.16	0.00	0.00	2.00
S	0.09	0.09	0.50	0.47	0.09	0.41	0.18	0.00	0.00	0.09	0.09	0.00	0.00	0.00	0.00	0.00	2.00
SSW	0.00	0.00	0.25	0.50	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
SW	0.03	0.03	0.17	0.18	0.03	0.14	0.05	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.67
WSW	0.15	0.21	0.53	0.37	0.12	0.52	0.43	0.00	0.00	0.18	0.15	0.00	0.00	0.15	0.00	0.00	2.83
W	0.37	0.69	1.04	1.17	0.20	1.81	2.09	0.08	0.00	1.42	0.62	0.00	0.00	1.31	0.04	0.00	10.83
WNW	0.21	0.16	1.05	0.89	0.16	2.36	3.68	0.37	0.00	4.41	1.37	0.00	0.00	2.31	0.21	0.00	17.17
NW	0.20	0.29	1.46	1.97	0.18	2.11	5.29	0.95	0.00	3.63	1.47	0.00	0.00	3.24	0.20	0.00	21.00
NNW	0.11	0.11	0.50	0.90	0.04	0.54	1.41	0.29	0.00	0.86	0.29	0.00	0.00	3.71	0.07	0.00	8.83
CALM	0.00	0.00	1.75	4.08													5.83
TOTAL	1.77	2.09	9.27	12.57	1.12	13.33	16.82	1.75	0.28	17.21	4.73	0.00	0.00	18.34	0.54	0.00	99.81

Ocurrence	
Class I	3.1726%
Class II	50.973%
Class III	31.356%
Class IV	14.313%
	99.814%

6.5 Results from the monitoring network

The immission data was provided by the Servicio de Medio Ambiente del Ayuntamiento de Zaragoza.

The data registered in each station for each pollutant are checked, controlled, verified and classified according to a criteria established by the Ministerio de Medio Ambiente, according to their origin and verified the reliability of those values.

Table 14: Data availability of the Automatic Monitoring Network of Zaragoza. (Values in %).

Months	1995	1996	1997
January		95,2	92,8
February		98,8	93,3
March		98,1	94,5
April		96,0	88,4
May		95,1	94,5
June		74,0	95,7
July		91,0	97,5
August		89,2	94,4
September		91,0	91,2
October	97,1	97,4	98,0
November	97,1	96,2	92,8
December	93,9	94,2	92,4

As we can see in the previous table, the data availability of the monitoring network is very high. The values are above the 90%. The most significant loss of data is in June 1996 with a value of 74%.

The next tables are the obtained immission values for each compound in all the stations:

TSP (PM_{10})

Table 15: Annual 50 and 98 percentile for TSP. All the values are in $\mu g/m^3$.

	Annual Percentile 50			Annual Percentile 98		
	95-96	96-97	97-98	95-96	96-97	97-98
El Picarral	30	30	42	91	101	106
M. Servet	35	39	51	72	105	104
Luis Vives	10	17	11	38	40	27
R. de Flor	26	25	33	77	80	76
Av. Navarra	41	32	42	92	96	89
Paraninfo	44	37	35	82	84	70
J. Ferràn	48	50	58	131	140	145

Table 16: Annual mean and 24 hours average for TSP. All the values are in $\mu g/m^3$.

	Annual mean			Maximum annual average 24 hours		
	95-96	96-97	97-98	95-96	96-97	97-98
El Picarral	38	38	45	-	-	122
M. Servet	37	43	52	-	-	147
Luis Vives	13	18	13	-	-	40
R. de Flor	28	28	37	-	-	110
Av. Navarra	44	37	45	-	-	121
Paraninfo	45	41	37	-	-	89
J. Ferràn	55	56	41	-	-	191

In most of the stations the immission values for TSP have been increasing. The station with more stable values is Luis Vives.

SO_2

Table 17: Annual 50 and 98 percentile for SO_2. All the values are in $\mu g/m^3$.

	Annual Percentile 50			Annual Percentile 98		
	95-96	96-97	97-98	95-96	96-97	97-98
El Picarral	-	-	-	-	-	-
M. Servet	38	47	25	78	79	78
Luis Vives	26	22	24	81	42	49
R. de Flor	21	22	16	46	35	36
Av. Navarra	35	25	18	68	42	32
Paraninfo	36	28	20	96	87	43
J. Ferràn	11	17	17	18	27	26

Table 18: Annual mean and 24 hours average for SO_2. All the values are in $\mu g/m^3$.

	Annual mean			Maximum annual average 24 hours		
	95-96	96-97	97-98	95-96	96-97	97-98
El Picarral	-	-	-	-	-	-
M. Servet	39	48	34	-	-	34
Luis Vives	30	23	26	-	-	26
R. de Flor	21	21	17	-	-	17
Av. Navarra	38	26	19	-	-	19
Paraninfo	43	34	23	-	-	23
J. Ferràn	11	17	18	-	-	18

There is a progressive drop of the SO_2 values in the immission measurements. J. Ferràn station has stabilised its values around 17 $\mu g/m^3$.

NO_2

Table 19: Annual 50 and 98 percentile for NO_2. All the values are in $\mu g/m^3$.

	Annual Percentile 50			Annual Percentile 98		
	95-96	96-97	97-98	95-96	96-97	97-98
El Picarral	35	34	59	91	85	135
M. Servet	55	66	39	147	185	125
Luis Vives	17	10	27	99	31	90
R. de Flor	25	54	66	90	129	131
Av. Navarra	67	86	52	136	151	155
Paraninfo	30	11	38	75	35	107
J. Ferràn	17	32	30	83	90	77

There is a "unstable" situation in some station with big variations in their immission levels. It is necessary to remark the situation of M. Servet and Av. Navarra stations in the year 1996. It is not a clear as TSP but there is a general tendency to increase the immission levels in the monitoring network.

O_3

Table 20: Annual 50 and 98 percentile for O_3. All the values are in $\mu g/m^3$.

	Annual Percentile 50			Annual Percentile 98		
	95-96	96-97	97-98	95-96	96-97	97-98
El Picarral	60	19	23	190	68	94
M. Servet	13	11	21	56	32	89
Luis Vives	44	30	23	157	84	75
R. de Flor	62	41	14	197	98	52
Av. Navarra	34	41	23	94	65	55
Paraninfo	35	15	11	80	72	58
J. Ferràn	32	22	17	167	109	90

Table 21: Ozone maximum mean values 1997 in each station. All the values are in $\mu g/m^3$.

	Maximum Mean 0-8 H	Maximum Mean 8-16 H	Maximum Mean 16-24 H	Maximum Mean 12-20 H
El Picarral	125	109	114	114
M. Servet	162	149	161	146
Luis Vives	70	70	94	87
R. de Flor	54	59	60	70
Av. Navarra	56	74	72	74
Paraninfo	75	48	65	72
J. Ferràn	82	90	111	109

Ozone is decreasing its values in the entire network.

For H_2S there is no concentration over the values established by laws and for CO there is a decreasing tendency for almost all the stations.

7 Calculated values for SO_2, particles and NO_x.

7.1 SO_2 concentration.

The emission data for SO_2 in Zaragoza available from the ”Estudio de las Emisiones a la Atmòsfera en la Ciudad de Zaragoza” are traffic in summer and traffic and heating in winter.
The results for this pollutant are:

7.1.1 Winter

Traffic:
The maximum value of SO_2 for traffic is 0,5 $\mu g/m^3$ and it is located in grid (11,6); this is the grid which contains Paseo de Sagasta, Residencial Paraìso, Paseo de las Damas and Camino de las Torres. The isolines for concentration go towards to the south east, and it is possible to see that the area covered with the highest concentration belongs to the main streets of the city.

The results from traffic sources are far away from the values permitted by law: limit value for SO_2 in winter 130-180 $\mu g/m^3$.

Table 22: SO_2 -traffic, winter.

```
MAP OF : SO2                 UNIT: UG/M3                SOURCE: TRAFFIC
PERIOD : WINTER             PLACE: ZARAGOZA          GRID SIZE:   500 METER
CREATED: 2000/03/23 14.49  FILE: SO2-TRAF-WINTER.FLD
    MAXIMUM VALUE IS  4.5006E-01, IN (11, 6)
                SUM= 5.17629E+01    SCALE FACTOR:  1.0E-04
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	447.	494.	555.	657.	853.	1411.	1718.	1468.	1208.	1229.	1214.	1237.	1046.	855.	722.	578.	513.
J=14	504.	554.	609.	671.	743.	1040.	1742.	2440.	2460.	2462.	2675.	2767.	2579.	2027.	1591.	1114.	779.
J=13	579.	649.	674.	708.	780.	854.	1112.	1685.	2216.	2405.	2673.	2607.	2608.	2217.	1788.	1389.	1000.
J=12	710.	911.	809.	915.	916.	979.	1097.	1367.	1855.	2341.	2782.	2764.	2594.	2352.	1991.	1793.	1599.
J=11	1067.	2018.	2153.	1920.	1654.	1352.	1427.	1569.	1963.	2567.	3254.	3489.	3322.	2963.	2177.	1680.	1498.
J=10	730.	1228.	2185.	2671.	2735.	2093.	2043.	2220.	2612.	3306.	3678.	3610.	3455.	3267.	2735.	1877.	1499.
J= 9	716.	944.	1574.	2682.	3657.	3445.	3136.	3218.	3113.	3275.	3876.	3988.	3751.	3436.	3054.	2387.	1720.
J= 8	655.	814.	1161.	1789.	2899.	3500.	3417.	3470.	3583.	3341.	3675.	4059.	3953.	3778.	3156.	2647.	2030.
J= 7	626.	793.	1025.	1524.	2470.	3182.	3586.	3776.	4064.	4178.	4080.	4020.	4257.	4066.	3484.	2737.	2238.
J= 6	648.	980.	1312.	1509.	1891.	2763.	3254.	3753.	4064.	4342.	4501.	4239.	3801.	3821.	3313.	2683.	2161.
J= 5	452.	611.	935.	1219.	1433.	1934.	2637.	3120.	3579.	3898.	4118.	4193.	3880.	3624.	3163.	2624.	2123.
J= 4	340.	403.	583.	880.	1058.	1471.	2138.	2670.	2989.	3266.	3504.	3579.	3311.	2996.	2934.	2451.	1979.
J= 3	279.	334.	439.	652.	838.	1051.	1647.	2064.	2224.	2420.	2725.	2841.	2612.	2367.	2261.	2285.	1877.
J= 2	192.	225.	293.	428.	647.	969.	1437.	1742.	1728.	1801.	1891.	2064.	2050.	1875.	1692.	1665.	1679.
J= 1	139.	160.	191.	251.	380.	671.	925.	1256.	1357.	1293.	1353.	1435.	1485.	1446.	1391.	1363.	1397.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

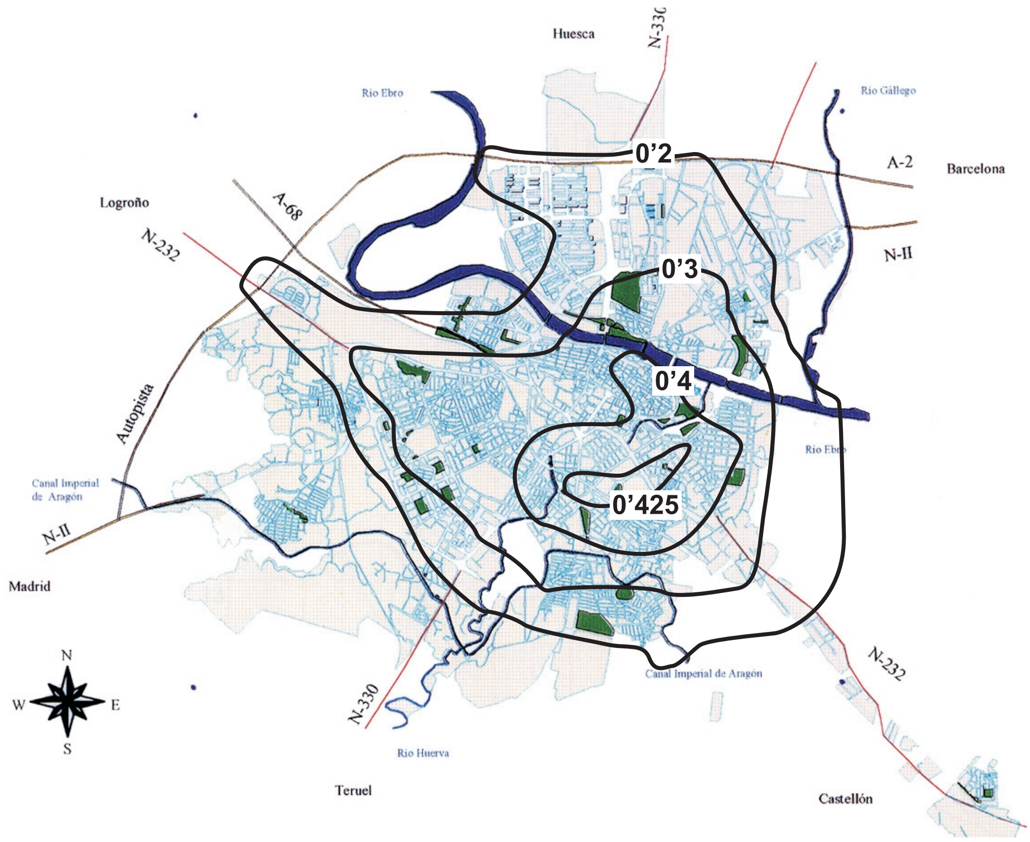

Figure 9: SO_2-traffic, winter.

Heating:
The maximum value of SO_2 is 29 $\mu g/m^3$ in grid number (12,7); this is the grid which contains Plaza de los Sitios, Paseo de la Constituciòn, Avenida Cesàreo Alierta and Paseo de la Mina. The biggest concentration belongs to an area that is described in the ”Estudio de las Emisiones a la Atmòsfera en la Ciudad de Zaragoza” as a place with high building density with heterogeneous heating: coal, diesel, natural gas and fuel oil.

A big number of buildings in the area using coal, diesel and especially fuel-oil can give high concentration in places. The immission values are lower than the values permitted by law.

Table 23: SO_2 -heating, winter

```
MAP OF : SO2                 UNIT: UG/M3                SOURCE: HEATING
 PERIOD : WINTER             PLACE: ZARAGOZA          GRID SIZE:  500 METER
 CREATED: 2000/03/23 14.14  FILE: SO2-HEAT-WINTER.FLD
     MAXIMUM VALUE IS  2.8621E+01, IN (12, 7)
                SUM= 1.48559E+03    SCALE FACTOR: 0.01
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	89.	93.	94.	97.	110.	111.	122.	116.	128.	151.	156.	152.	129.	104.	98.	74.	64.
J=14	106.	104.	109.	116.	119.	113.	141.	137.	150.	175.	187.	188.	189.	178.	138.	90.	79.
J=13	123.	127.	135.	123.	122.	165.	169.	178.	188.	209.	234.	220.	234.	215.	167.	134.	99.
J=12	135.	139.	145.	174.	182.	197.	216.	250.	266.	277.	298.	275.	278.	249.	231.	232.	214.
J=11	153.	224.	256.	261.	277.	268.	329.	360.	410.	412.	425.	399.	364.	331.	325.	319.	263.
J=10	174.	203.	258.	340.	474.	477.	515.	559.	642.	633.	667.	588.	501.	514.	466.	376.	307.
J= 9	194.	237.	305.	374.	481.	599.	722.	861.	1091.	1201.	1393.	1037.	919.	758.	651.	543.	445.
J= 8	224.	275.	392.	495.	583.	706.	936.	1109.	1312.	1903.	2802.	2840.	1761.	1264.	915.	715.	574.
J= 7	239.	283.	357.	473.	594.	719.	947.	974.	1182.	1385.	2075.	2862.	2204.	1659.	1127.	833.	643.
J= 6	231.	281.	370.	470.	569.	897.	1440.	1663.	1372.	1501.	1706.	2184.	2333.	1810.	1267.	885.	645.
J= 5	198.	255.	326.	401.	454.	564.	943.	1471.	1370.	1465.	1601.	1889.	1927.	1651.	1248.	874.	603.
J= 4	134.	172.	231.	292.	352.	534.	691.	964.	1218.	1183.	1221.	1408.	1420.	1352.	1122.	839.	658.
J= 3	113.	138.	172.	215.	239.	361.	462.	653.	827.	926.	990.	1048.	1047.	974.	889.	790.	515.
J= 2	91.	112.	142.	182.	290.	611.	621.	526.	549.	653.	730.	779.	813.	727.	673.	533.	562.
J= 1	51.	64.	75.	86.	98.	215.	413.	383.	396.	408.	471.	553.	535.	524.	533.	532.	562.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

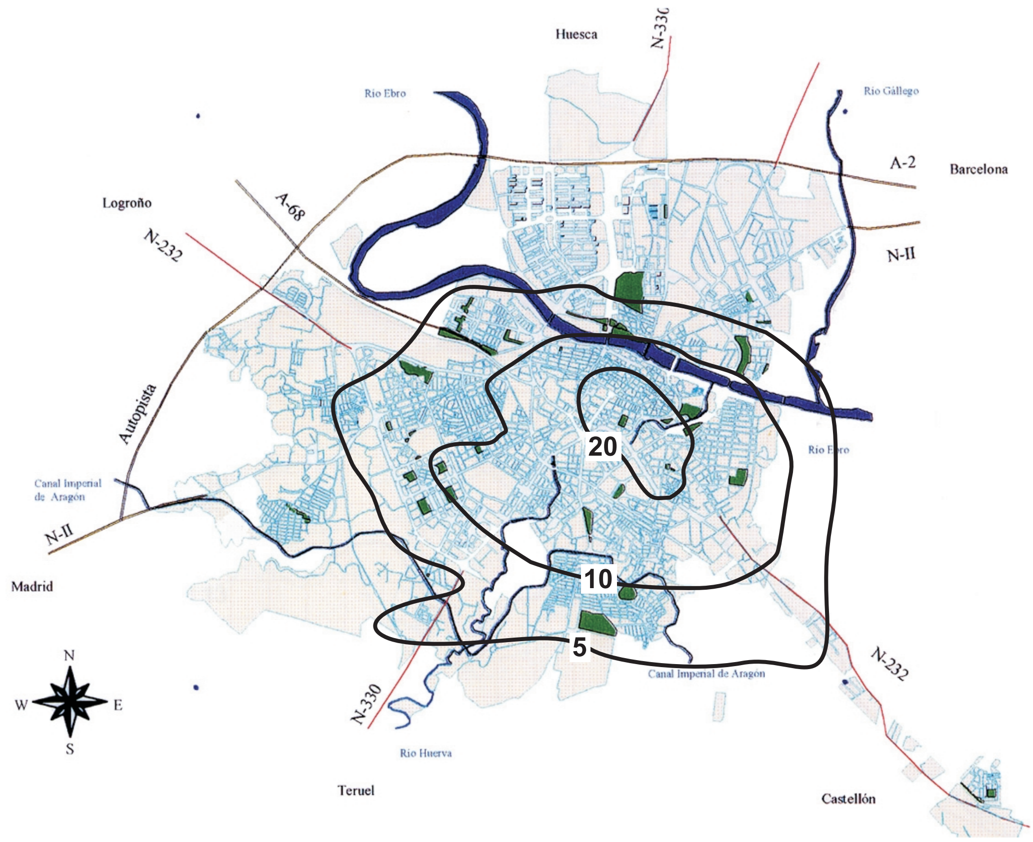

Figure 10: SO_2-heating, winter.

Total:
The maximum value of SO_2 for all sources is 39 µg/m^3 in grid number (12,7); this is the grid which contains Plaza de los Sitios, Paseo de la Constituciòn, Avenida Cesàreo Alierta and Paseo de la Mina.

SO_2 emission from heating is the main source for SO_2 concentrations in Zaragoza. The isolines for concentration go towards the south east, and they are covering the Casco Antiguo, Centro, Las Fuentes, San Josè and Torrero-La Paz districts.

Considering the 50 percentile for the stations between 1995 and 1998, and the annual mean for SO_2, it can be said that there is a background level of 10 µg/m^3. This background contains emissions that are not included in the emission inventory.

In winter there is a contribution from traffic and heating sources around the 50% of the total immission and the other 50% is from other source or sources that it is unable to take into account due to a lack of information. There is a very good coincidence between the calculated values and the immission values as seen in next table:

Table 24: Immission values for SO_2 in winter. All these values are in µg/m^3.

	Annual Percentile 50 average (95-98)	Annual mean average (95-98)	Kilder model*
El Picarral	-	-	13
M. Servet	37	40	32
Luis Vives	24	26	24
R. de Flor	20	20	17
Av. Navarra	26	27	19
Paraninfo	28	33	27
J. Ferràn	15	15	13

* The background level of 10 µg/m^3 has been added.

There is no station with values above the annual limit for 50 Percentile: 80 µg/m^3. Therefore SO_2 is not a problem for population health inside the city, since the area with the highest values has a SO_2 concentration close to 40 µg/m^3. A background level of 10 µg/m^3 has been used in the table and in the next figure.

Table 25: SO_2, total, winter.

```
MAP OF : SO2                UNIT: UG/M3               SOURCE: ALL SOURCES
 PERIOD : WINTER            PLACE: ZARAGOZA         GRID SIZE:  500 METER
 CREATED: 2000/03/23 14.49  FILE: SO2-SUM-WINTER.PRN
     MAXIMUM VALUE IS  3.9023E+01, IN (12, 7)
                 SUM= 4.08735E+03    SCALE FACTOR: 0.01
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	1094.	1098.	1099.	1104.	1119.	1125.	1139.	1130.	1140.	1163.	1168.	1164.	1139.	1112.	1105.	1079.	1069.
J=14	1111.	1110.	1116.	1123.	1127.	1123.	1158.	1161.	1175.	1199.	1213.	1216.	1214.	1198.	1154.	1101.	1087.
J=13	1129.	1134.	1142.	1130.	1130.	1173.	1180.	1195.	1210.	1233.	1261.	1246.	1260.	1237.	1185.	1148.	1109.
J=12	1142.	1148.	1153.	1184.	1191.	1207.	1227.	1264.	1285.	1301.	1326.	1302.	1304.	1273.	1251.	1250.	1230.
J=11	1164.	1244.	1278.	1280.	1294.	1281.	1343.	1376.	1429.	1437.	1458.	1434.	1397.	1360.	1347.	1336.	1278.
J=10	1182.	1216.	1280.	1366.	1501.	1497.	1535.	1582.	1669.	1666.	1703.	1624.	1535.	1547.	1493.	1395.	1322.
J= 9	1201.	1246.	1321.	1401.	1518.	1633.	1753.	1893.	2122.	2233.	2432.	2076.	1956.	1793.	1682.	1567.	1463.
J= 8	1231.	1283.	1403.	1513.	1612.	1741.	1970.	2144.	2348.	2937.	3839.	3880.	2801.	2302.	1947.	1741.	1594.
J= 7	1245.	1291.	1368.	1488.	1619.	1751.	1983.	2012.	2223.	2427.	3116.	3902.	3246.	2700.	2162.	1860.	1666.
J= 6	1237.	1291.	1383.	1485.	1588.	1924.	2473.	2700.	2412.	2544.	2751.	3226.	3371.	2848.	2300.	1912.	1666.
J= 5	1202.	1261.	1336.	1413.	1469.	1583.	1969.	2502.	2405.	2504.	2642.	2931.	2966.	2687.	2280.	1900.	1625.
J= 4	1137.	1176.	1237.	1301.	1363.	1549.	1712.	1991.	2248.	2216.	2256.	2444.	2454.	2382.	2151.	1863.	1678.
J= 3	1115.	1141.	1176.	1221.	1247.	1372.	1478.	1674.	1849.	1951.	2017.	2077.	2073.	1998.	1912.	1813.	1534.
J= 2	1093.	1114.	1145.	1186.	1296.	1620.	1635.	1543.	1566.	1671.	1749.	1800.	1833.	1746.	1690.	1549.	1579.
J= 1	1053.	1066.	1076.	1089.	1102.	1222.	1422.	1396.	1409.	1421.	1485.	1567.	1550.	1538.	1547.	1546.	1576.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

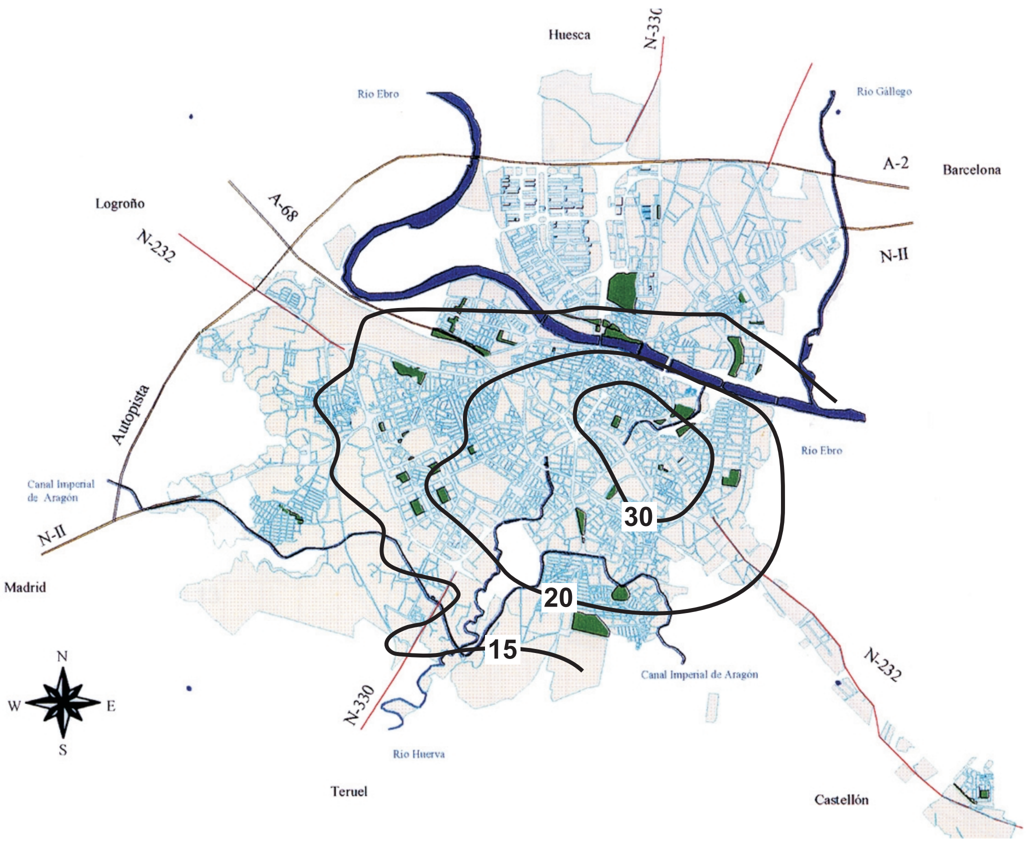

Figure 11: SO_2-total, winter.

7.1.2 Summer

Traffic:
Traffic is the only source included in the SO_2 emission inventory in summer. The values are lower than the winter ones due to the higher rate of unstability of the atmosphere in summer.

The maximum value is 0,3 $\mu g/m^3$ in grid number (10,6); this is the grid which contains Avenida de Goya from Gran Vìa to Paseo de Sagasta.
The isolines are similar to the isolines during the winter period but they have been shifted towards northwest direction.

Table 26: Immission values for SO_2 in summer. All these values are in $\mu g/m^3$.

	Annual Percentile 50 average (95-98)	Annual mean average (95-98)	Kilder model
El Picarral	-	-	0,15
M. Servet	37	40	0,27
Luis Vives	24	26	0,27
R. de Flor	20	20	0,26
Av. Navarra	26	27	0,25
Paraninfo	28	33	0,3
J. Ferràn	15	15	0,12

Comparison of the summer values with the mean and percentiles it is seen that there is a big difference between the measured concentration and the estimated concentrations. Even if we consider the 10 $\mu g/m^3$ background level the values are two times lower than the measured ones in the best cases. This can be because of:

- The stability matrix for summer has been wrongly calculated. But this is not be likely due to that the measured values for summer and winter are comparable and the winter estimated immission data seems to be correct.
- There is a background level higher than 10 $\mu g/m^3$ in winter. This is not a good option since J. Ferràn immission values in some years are close to 10 $\mu g/m^3$.
- There is higher background level in summer from some unknown source.
- The emission data we obtained does not include all sources that affect Zaragoza.

The background concentration contributes 50% to the estimated concentrations for summer and winter. This means that the emission inventory probably underestimates the real emissions in Zaragoza.

Table 27: SO_2 -total, summer.

```
MAP OF : SO2                UNIT: UG/M3              SOURCE: TRAFFIC
 PERIOD : SUMMER            PLACE: ZARAGOZA        GRID SIZE:  500 METER
 CREATED: 2000/03/23 14.50  FILE: SO2-TRAF-SUMMER.FLD
     MAXIMUM VALUE IS  3.2666E-01, IN (10, 6)
                 SUM= 3.70080E+01    SCALE FACTOR:  1.0E-04
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	499.	526.	583.	695.	1014.	1422.	1320.	920.	775.	756.	685.	600.	452.	355.	298.	253.	235.
J=14	560.	586.	618.	667.	766.	1193.	1767.	2107.	2046.	2024.	2136.	2102.	1665.	1228.	866.	525.	356.
J=13	653.	642.	645.	666.	718.	823.	1047.	1437.	1611.	1771.	1738.	1667.	1492.	1195.	950.	643.	461.
J=12	857.	795.	714.	734.	763.	847.	939.	1167.	1431.	1670.	1782.	1588.	1397.	1173.	1115.	1105.	911.
J=11	1665.	2174.	1859.	1502.	1197.	1084.	1194.	1349.	1636.	2060.	2352.	2255.	2029.	1551.	990.	815.	762.
J=10	1089.	1761.	2145.	2363.	2001.	1660.	1690.	1923.	2338.	2612.	2503.	2164.	2046.	1800.	1269.	872.	718.
J= 9	1084.	1415.	1986.	2792.	3097.	2696.	2631.	2511.	2388.	2611.	2727.	2503.	2143.	1904.	1567.	1091.	808.
J= 8	969.	1173.	1510.	2023.	2635.	2663.	2675.	2750.	2536.	2466.	2729.	2631.	2422.	2111.	1628.	1158.	904.
J= 7	915.	1076.	1351.	1926.	2502.	2582.	2828.	3035.	3186.	3035.	2930.	2767.	2728.	2394.	1739.	1250.	953.
J= 6	1010.	1313.	1541.	1709.	2122.	2469.	2662.	2924.	3162.	3267.	3184.	2712.	2366.	2029.	1588.	1161.	915.
J= 5	676.	890.	1101.	1310.	1555.	1907.	2127.	2456.	2711.	2709.	2834.	2662.	2426.	2015.	1473.	1113.	876.
J= 4	492.	587.	767.	936.	1121.	1537.	1894.	2032.	2125.	2214.	2249.	2049.	1810.	1688.	1449.	1056.	805.
J= 3	393.	467.	588.	749.	830.	1079.	1427.	1476.	1443.	1576.	1686.	1522.	1302.	1156.	1152.	1045.	793.
J= 2	261.	304.	397.	557.	729.	1002.	1329.	1203.	1082.	1041.	1124.	1081.	970.	856.	765.	748.	661.
J= 1	185.	214.	258.	330.	481.	678.	860.	921.	831.	774.	777.	767.	706.	640.	619.	585.	555.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Figure 12: SO_2-total, summer.

7.2 Particle concentration.

Emissions of particles from traffic and heating are included for the winter season. The emission are from the “Estudio de las Emisiones a la Atmòsfera en la Ciudad de Zaragoza del año 1996”. Some particles emissions for industrial point sources are included. The industrial data comes from another study done in Zaragoza about particles (“Medidas de las Emisiones Gaseosas en la Industria”, years 1992,1994, 1996, 1998).

The results for particles are:

7.2.1 Winter

Traffic:
The maximum concentration of PM10 from traffic is 0,6 μg/m3. It is located in Residencial Paraiso, Paseo de Sagasta, Camino de las Torres and Paseo de las Damas grid, this is grid (11,6).

The isolines stretch out to the southeast. High concentrations are located close to the biggest roads in the city.

The results from traffic sources are much lower than the values permitted by law: 130 μg/m3.

Table 28: Particles, traffic, winter.

```
MAP OF : PST                  UNIT: UG/M3                SOURCE: TRAFFIC
PERIOD : WINTER              PLACE: ZARAGOZA         GRID SIZE:  500 METER
CREATED: 2000/03/24 10.44  FILE: PART-TRAF-WINTER.FLD
    MAXIMUM VALUE IS  6.0735E-01, IN (11, 6)
                SUM= 6.94434E+01    SCALE FACTOR:  1.0E-04

         1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17

J=15   595. 657. 739. 876.1140.1891.2301.1951.1617.1644.1619.1636.1380.1126. 952. 766. 680.

J=14   669. 733. 809. 893. 988.1383.2305.3177.3230.3291.3588.3710.3439.2659.2059.1450.1025.

J=13   767. 858. 895. 946.1040.1138.1486.2227.2903.3206.3584.3503.3500.2955.2347.1818.1318.

J=12   935.1186.1077.1218.1219.1308.1469.1827.2465.3121.3731.3719.3489.3159.2658.2383.2129.

J=11  1379.2552.2772.2543.2195.1803.1906.2103.2626.3439.4370.4694.4474.3991.2921.2243.1997.

J=10   977.1609.2846.3539.3618.2767.2714.2964.3507.4449.4947.4860.4653.4401.3682.2520.2007.

J= 9   962.1266.2090.3573.4901.4614.4206.4316.4185.4409.5223.5372.5054.4631.4115.3214.2311.

J= 8   883.1096.1552.2392.3889.4702.4593.4668.4821.4499.4955.5473.5330.5094.4253.3565.2733.

J= 7   844.1068.1377.2049.3320.4280.4826.5084.5479.5633.5502.5425.5743.5485.4698.3688.3014.

J= 6   874.1323.1769.2033.2547.3718.4383.5057.5479.5855.6074.5720.5129.5154.4468.3616.2910.

J= 5   610. 824.1261.1641.1932.2605.3552.4205.4825.5257.5555.5658.5237.4889.4265.3535.2860.

J= 4   458. 543. 787.1186.1426.1984.2880.3599.4030.4403.4725.4828.4466.4041.3954.3299.2665.

J= 3   376. 451. 593. 878.1129.1416.2221.2780.2997.3261.3673.3829.3520.3188.3040.3052.2506.

J= 2   258. 303. 395. 576. 871.1307.1939.2349.2328.2427.2546.2781.2763.2526.2279.2236.2243.

J= 1   187. 216. 257. 337. 510. 905.1247.1696.1829.1742.1822.1932.2000.1948.1874.1835.1876.

         1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17
```

Figure 13: Particles, traffic, winter.

Heating:
The maximum value for heating is 7,1 µg/m^3 in grid (12,8); this is Coso, S. Vicente Paul and Plaza de S. Miguel grid. The highest concentration, like SO_2, belongs to an area that is described in the “Estudio de la Emisiones a la Atmòsfera en la Ciudad de Zaragoza” as a place with high building density and heterogeneous heating. The emission factor depending on the fuel are giving in the next table.

The immission values are lower than the values allowed by law.

Table 29: Particles, heating, winter.

```
MAP OF : Partículas        UNIT: UG/M3               SOURCE: HEATING
 PERIOD : WINTER           PLACE: ZARAGOZA         GRID SIZE:  500 METER
 CREATED: 2000/03/24 10.46  FILE: PART-HEAT-WINTER.FLD
     MAXIMUM VALUE IS  7.1446E+00, IN (12, 8)
                 SUM= 2.86207E+02    SCALE FACTOR:  1.0E-03
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	174.	180.	179.	179.	215.	205.	236.	207.	244.	307.	321.	309.	244.	188.	199.	136.	121.
J=14	206.	198.	214.	226.	225.	192.	271.	250.	290.	358.	388.	379.	352.	320.	257.	153.	143.
J=13	241.	249.	262.	229.	208.	322.	323.	342.	370.	431.	490.	446.	450.	403.	295.	241.	166.
J=12	255.	258.	256.	349.	352.	370.	413.	501.	536.	569.	630.	564.	558.	452.	407.	399.	387.
J=11	290.	407.	458.	453.	489.	506.	643.	727.	845.	841.	910.	833.	712.	591.	585.	589.	472.
J=10	337.	389.	480.	614.	846.	880.	1035.	1166.	1324.	1286.	1411.	1208.	969.	1014.	919.	709.	563.
J= 9	385.	464.	589.	716.	913.	1143.	1420.	1777.	2176.	2352.	2903.	1817.	1776.	1543.	1304.	1088.	908.
J= 8	435.	530.	737.	929.	1104.	1344.	1801.	2277.	2788.	4315.	7079.	7145.	3822.	2702.	1938.	1490.	1190.
J= 7	459.	543.	682.	881.	1088.	1318.	1734.	1842.	2268.	2533.	4479.	6962.	4889.	3498.	2323.	1698.	1303.
J= 6	418.	495.	633.	795.	962.	1509.	2443.	2871.	2474.	2741.	3216.	4652.	5342.	3899.	2566.	1747.	1269.
J= 5	332.	426.	539.	655.	745.	931.	1558.	2441.	2337.	2557.	2863.	3728.	4043.	3504.	2552.	1695.	1110.
J= 4	219.	274.	364.	475.	563.	842.	1129.	1616.	2065.	2070.	2220.	2735.	2756.	2758.	2261.	1657.	1298.
J= 3	181.	217.	255.	301.	317.	452.	737.	1053.	1368.	1629.	1796.	1972.	2002.	1850.	1766.	1622.	904.
J= 2	138.	158.	186.	216.	243.	323.	507.	698.	813.	1063.	1261.	1425.	1519.	1306.	1326.	950.	1110.
J= 1	78.	95.	109.	125.	150.	180.	293.	422.	538.	636.	781.	974.	1004.	939.	992.	1030.	1150.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Figure 14: Particles, heating, winter

Industry:
The industrial sources for particles are considered like point sources.
The data related to the industry is:

Table 30: Industrial emission data about particles.

Source data:

	Name	Relative coordinates X	Relative coordinates Y	Stack base m	Stack height m	Stack diameter m	Gas temp. oC	Exit velocity m/s	Building height m	Building width m	Part emission kg/h
1	RICO FUND1	6.60	5.70	0.00	22.0	2.50	95.	19.9	10.	30.	2.56
2	RICO FUND2	6.60	5.70	0.00	22.0	2.50	95.	19.9	10.	30.	2.56
3	RICO LAMIN	6.60	5.70	0.00	40.0	1.20	650.	2.7	10.	30.	0.09
4	RICO LAMIN	6.60	5.70	0.00	40.0	1.20	650.	2.7	10.	30.	0.15
5	AMYLUM IBE	6.05	6.05	0.00	10.3	1.20	50.	3.9	10.	30.	0.36
6	AMYLUM IBE	6.05	6.05	0.00	20.4	1.80	50.	1.0	10.	30.	0.65
7	AMYLUM IBE	6.05	6.05	0.00	19.0	1.00	56.	11.0	10.	30.	2.11
8	AMYLUM IBE	6.05	6.05	0.00	19.0	1.00	56.	11.0	10.	30.	0.32
9	AMYLUM IBE	6.05	6.05	0.00	9.5	0.60	45.	22.8	10.	30.	0.80
10	AMYLUM IBE	6.05	6.05	0.00	9.5	0.60	45.	22.8	10.	30.	0.40
11	AMYLUM IBE	6.05	6.05	0.00	9.5	0.60	45.	22.8	10.	30.	0.33

The information about the point sources was not complete. We therefore made the following assumptions: in stack height, in stack diameters, in exit velocity, in building size and in the emissions for some industry. It was also said in the "Estudio de las Emisiones a la Atmòsfera en la Ciudad de Zaragoza del año 1996" that all the industries were using natural gas for energy and combustion of gas have low emissions of particles.

The maximum value for particles is 3 $\mu g/m^3$ in grid (13,12); this is S. Juan de la Peña, Camino de los Molinos grid.

The immission values are lower than the values allowed by law.

Table 31: Particles, industry, winter.

```
MAP OF : Part               UNIT: UG/M3               SOURCE: POINT SOURCES
 PERIOD : WINTER            PLACE: ZARAGOZA         GRID SIZE:  500 METER
 CREATED: 2000/03/24 11.34  FILE: PART-POINT-WINTER.FLD
     MAXIMUM VALUE IS  2.9647E+00, IN (12,13)
                 SUM= 4.68587E+01    SCALE FACTOR:  1.0E-03
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	83.	92.	104.	118.	136.	159.	190.	232.	292.	250.	212.	207.	250.	131.	60.	49.	128.
J=14	102.	113.	126.	144.	166.	168.	204.	256.	336.	470.	446.	369.	245.	108.	251.	184.	155.
J=13	103.	114.	127.	144.	166.	195.	235.	295.	411.	594.	986.	2965.	348.	504.	944.	634.	464.
J=12	103.	114.	127.	144.	166.	195.	235.	294.	388.	167.	232.	201.	2636.	2205.	1231.	675.	516.
J=11	102.	113.	126.	142.	72.	81.	92.	107.	126.	95.	59.	94.	969.	2013.	1076.	813.	652.
J=10	47.	52.	57.	63.	34.	39.	45.	53.	32.	38.	47.	55.	129.	497.	1177.	963.	597.
J= 9	23.	24.	27.	29.	32.	36.	41.	25.	29.	28.	35.	87.	88.	358.	365.	829.	720.
J= 8	22.	24.	26.	28.	31.	19.	21.	18.	21.	25.	28.	65.	79.	271.	296.	630.	641.
J= 7	21.	23.	25.	27.	16.	18.	15.	17.	20.	21.	26.	51.	63.	214.	247.	228.	571.
J= 6	21.	22.	13.	14.	12.	13.	14.	15.	17.	21.	22.	42.	52.	176.	210.	198.	185.
J= 5	20.	12.	13.	11.	11.	12.	13.	14.	15.	18.	19.	36.	44.	43.	144.	174.	165.
J= 4	11.	9.	9.	10.	11.	11.	12.	13.	15.	16.	30.	31.	38.	38.	126.	155.	148.
J= 3	8.	8.	9.	9.	10.	10.	11.	13.	14.	14.	27.	33.	34.	33.	112.	139.	134.
J= 2	8.	8.	9.	9.	9.	10.	10.	12.	12.	13.	24.	30.	30.	30.	100.	126.	122.
J= 1	7.	8.	8.	8.	9.	9.	11.	11.	11.	12.	22.	27.	27.	27.	91.	115.	112.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

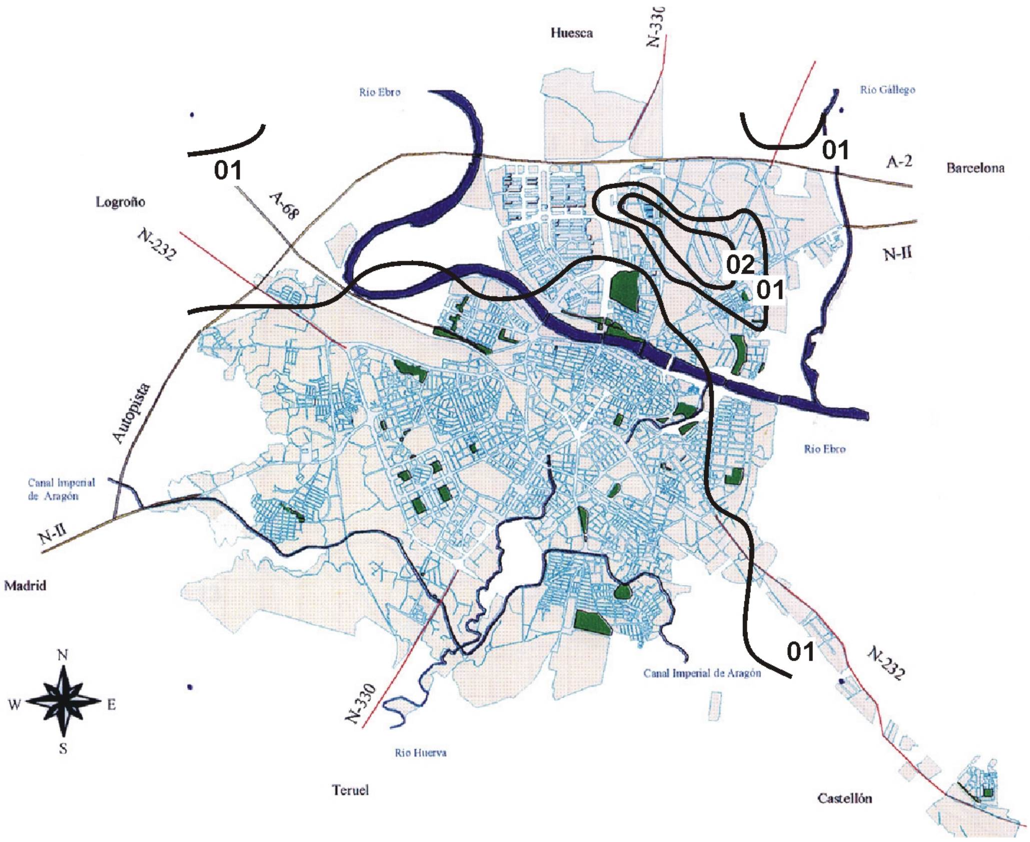

Figure 15: Particles, industry, winter.

Total:
The maximum value is 18 µg/m^3 in grid number (12,8); the same grid as heating. It was considered a background value of 10 µg/m^3 for particles.
Heating is the most important source for particles; the heating values are more important than the traffic values (approximately two times bigger) and more important than the industrial values (approximately 5 times bigger).
Comparing the immission values from the monitoring network with the values obtained running the model :

Table 32: Immission values for particles in winter.

	Annual Percentile 50 average (95-98)	Annual mean average (95-98)	Kilder model
El Picarral	34	40	11
M. Servet	42	44	16
Luis Vives	13	15	13
R. de Flor	28	31	12
Av. Navarra	38	42	12
Paraninfo	39	41	14
J. Ferràn	52	51	11

There is a big difference between the values measured in the stations and the Kilder model values.

- There are strange values for the Luis Vives station in the 50 Percentile and in the annual mean. There are problems to explain these low values above all if it is considered that the station is placed in an area with high traffic density.
- The high immission values measured in the J. Ferràn and El Picarral stations can be influenced by a high number of diesel vehicles in the surrounding roads, a different paving of the roads, the production processes of the factories close to the stations or the emissions from the A-2 highway (it has not been taken into account in the "Estudio de las Emisiones a la Atmòsfera en la Ciudad de Zaragoza del año 1996" the emissions from this road).
- In the Kilder model the average over the grids is flat for all the stations.
- Differences between the measurements and the model:
  The model gives an average for all the sources in each grid. One station only represents a point inside each grid, and each grid covers an area of 500 x 500 m^2. The location of the monitoring station close to the roads can give higher immission values for particles than the average of the grid because they are placed close to the sources and because of the re-suspension.
- The model result for particles represents only the local emission and other unknown sources or external (outside the city) sources can increase the immission levels inside the city.

Table 33: Particles, total, winter.

```
MAP OF : PST              UNIT: UG/M3              SOURCE: ALL SOURCES
 PERIOD : WINTER          PLACE: ZARAGOZA        GRID SIZE:  500 METER
 CREATED: 2000/03/24 11.34  FILE: PART-SUM-WINTER.PRN
     MAXIMUM VALUE IS  1.7756E+01, IN (12, 8)
                 SUM= 2.95251E+03    SCALE FACTOR: 0.01
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	1032.	1034.	1036.	1038.	1047.	1055.	1066.	1063.	1070.	1072.	1069.	1068.	1063.	1043.	1035.	1026.	1032.
J=14	1038.	1038.	1042.	1046.	1049.	1050.	1071.	1082.	1095.	1116.	1119.	1112.	1094.	1069.	1071.	1048.	1040.
J=13	1042.	1045.	1048.	1047.	1048.	1063.	1071.	1086.	1107.	1135.	1184.	1376.	1115.	1120.	1147.	1106.	1076.
J=12	1045.	1049.	1049.	1061.	1064.	1070.	1079.	1098.	1117.	1105.	1124.	1114.	1354.	1297.	1190.	1131.	1112.
J=11	1053.	1078.	1086.	1085.	1078.	1077.	1093.	1104.	1123.	1128.	1141.	1140.	1213.	1300.	1195.	1163.	1132.
J=10	1048.	1060.	1082.	1103.	1124.	1120.	1135.	1151.	1171.	1177.	1195.	1175.	1156.	1195.	1246.	1192.	1136.
J= 9	1050.	1061.	1082.	1110.	1144.	1164.	1188.	1223.	1262.	1282.	1346.	1244.	1237.	1236.	1208.	1224.	1186.
J= 8	1055.	1066.	1092.	1120.	1152.	1183.	1228.	1276.	1329.	1479.	1760.	1776.	1443.	1348.	1266.	1248.	1210.
J= 7	1056.	1067.	1084.	1111.	1144.	1176.	1223.	1237.	1284.	1312.	1505.	1756.	1553.	1426.	1304.	1230.	1217.
J= 6	1053.	1065.	1082.	1101.	1123.	1189.	1289.	1339.	1304.	1335.	1385.	1527.	1591.	1459.	1322.	1231.	1174.
J= 5	1041.	1052.	1068.	1083.	1095.	1120.	1193.	1288.	1283.	1310.	1344.	1433.	1461.	1404.	1312.	1222.	1156.
J= 4	1028.	1034.	1045.	1060.	1072.	1105.	1143.	1199.	1248.	1253.	1272.	1325.	1324.	1320.	1278.	1214.	1171.
J= 3	1023.	1027.	1032.	1040.	1044.	1060.	1097.	1134.	1168.	1197.	1219.	1239.	1239.	1220.	1218.	1207.	1129.
J= 2	1017.	1020.	1023.	1028.	1034.	1046.	1071.	1095.	1106.	1132.	1154.	1173.	1182.	1159.	1165.	1130.	1146.
J= 1	1010.	1012.	1014.	1017.	1021.	1028.	1043.	1060.	1073.	1082.	1099.	1119.	1123.	1116.	1127.	1133.	1145.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

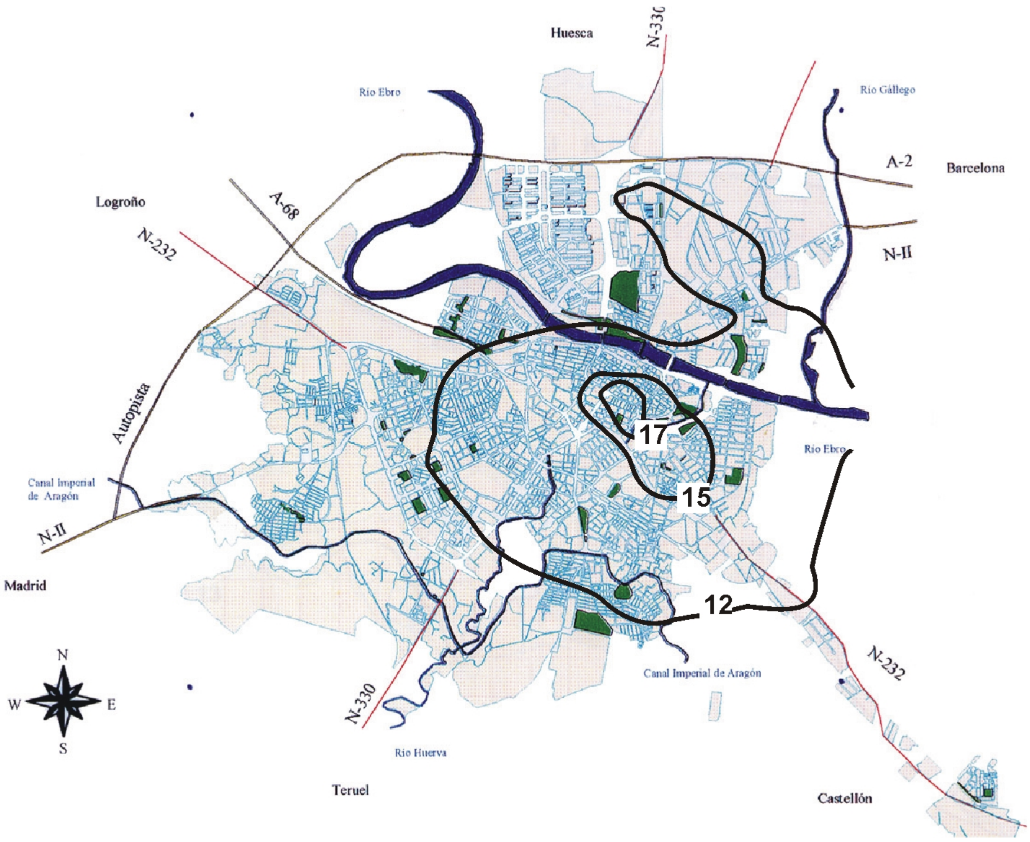

Figure 16: Particles, total, winter.

7.2.2 Summer

The measuring concentrations and the estimated concentrations are so far that they have not been considered.

7.3 NO_2 concentration.

Emissions from traffic, winter heating and industry are included here and the information is taken from the "Estudio de las Emisiones a la Atmòsfera en la Ciudad de Zaragoza del año 1996". NO_x concentrations are modelled.

The compound measured in the monitoring network is NO_2. Approximately a 10% of the emissions of NO_x is NO_2 and the rest (90%) is NO.

NO and NO_2 are involved in chemical reactions with O_3 and sunlight, therefore their concentrations are interconnected in the immission levels. This means that NO_2 is formed from the NO using O_3 so that NO_2 concentrations, as a first approximation, can be set to the NO_x concentration.

The result for NO_x are:

7.3.1 Winter

Traffic:
The maximum concentration of NO_x from traffic is 11,4 µg/m^3 and it is located in grid (11,6); this is the grid which contains Paseo de Sagasta, Residencial Paraìso, Paseo de las Damas and Camino de las Torres grid.

The immission values are far away from the 50 Percentile permitted by law for NO_2 :50 µg/m^3.

There is a small peak in the concentration level in grid (9,5); this is Avenida de Navarra, Vìa Hispanidad and Autovìa de Logroño grid. The isolines are covering the main streets of Zaragoza.

Table 34: NO_x, traffic, winter

```
MAP OF : NOX              UNIT: UG/M3              SOURCE: TRAFFIC
PERIOD : WINTER          PLACE: ZARAGOZA         GRID SIZE:  500 METER
CREATED: 2000/03/20 14.00  FILE: TRAF-NOX-WINTER.FLD

    MAXIMUM VALUE IS  1.1405E+01, IN (11, 6)
                SUM= 1.31284E+03    SCALE FACTOR: 0.01
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	114.	126.	141.	167.	216.	358.	436.	373.	307.	312.	308.	314.	266.	217.	184.	147.	130.
J=14	128.	141.	155.	170.	189.	264.	443.	621.	626.	625.	679.	702.	655.	516.	406.	284.	198.
J=13	147.	165.	171.	180.	198.	217.	282.	428.	564.	610.	678.	661.	661.	563.	455.	353.	254.
J=12	181.	232.	205.	232.	233.	248.	278.	347.	471.	594.	706.	701.	657.	596.	505.	455.	406.
J=11	272.	516.	549.	488.	420.	343.	362.	398.	498.	651.	825.	884.	842.	751.	552.	426.	380.
J=10	185.	312.	556.	678.	695.	532.	519.	563.	662.	838.	932.	915.	876.	828.	693.	476.	380.
J= 9	181.	239.	400.	681.	928.	874.	795.	816.	789.	830.	982.	1011.	951.	871.	774.	605.	436.
J= 8	166.	206.	295.	454.	735.	888.	866.	880.	908.	847.	931.	1029.	1002.	958.	800.	671.	515.
J= 7	159.	201.	260.	386.	626.	807.	909.	957.	1030.	1059.	1034.	1019.	1079.	1031.	883.	694.	567.
J= 6	164.	248.	333.	383.	479.	700.	825.	951.	1030.	1100.	1141.	1074.	963.	968.	840.	680.	548.
J= 5	115.	155.	237.	309.	363.	490.	669.	791.	907.	988.	1044.	1062.	983.	918.	802.	665.	538.
J= 4	86.	102.	148.	223.	268.	373.	542.	677.	758.	828.	888.	907.	839.	759.	744.	621.	502.
J= 3	71.	85.	111.	165.	213.	266.	417.	523.	564.	613.	691.	720.	662.	600.	573.	580.	476.
J= 2	49.	57.	74.	109.	164.	246.	364.	442.	438.	457.	479.	523.	520.	475.	429.	422.	426.
J= 1	35.	41.	48.	64.	96.	170.	235.	318.	344.	328.	343.	364.	376.	367.	353.	345.	354.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Figure 17: NO_x, traffic, winter.

Heating:
The maximum value for heating is 5,8 μg/m^3 in grid (12,7); this is Plaza de los Sitios, Paseo de la Constituciòn, Avenida Cesàreo Alierta and Paseo de la Mina grid.

The isolines are covering a bigger area for heating than the area covered by other pollutant isolines.

The immission values are below the value allowed by law.

Table 35:NO$_x$, heating, winter.

```
MAP OF : NOx                UNIT: UG/M3               SOURCE: HEATING
 PERIOD : WINTER            PLACE: ZARAGOZA         GRID SIZE:  500 METER
 CREATED: 2000/03/20 16.16  FILE: HEAT-NOX-WINTER.FLD
     MAXIMUM VALUE IS  5.8031E+00, IN (12, 7)
                SUM= 4.92031E+02    SCALE FACTOR:  1.0E-03
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	345.	366.	378.	416.	478.	551.	659.	750.	896.	950.	951.	896.	684.	568.	491.	413.	365.
J=14	405.	429.	459.	506.	565.	679.	854.	1075.	1491.	1868.	2168.	2180.	1627.	1111.	841.	636.	530.
J=13	457.	488.	541.	576.	643.	789.	939.	1172.	1652.	2240.	2785.	3125.	2559.	1649.	1187.	884.	700.
J=12	485.	510.	572.	656.	757.	881.	1051.	1270.	1736.	2378.	2965.	3438.	3196.	2158.	1544.	1193.	991.
J=11	510.	655.	753.	843.	954.	1078.	1540.	1742.	1739.	2056.	2650.	2985.	2961.	2432.	1767.	1376.	1077.
J=10	545.	629.	801.	1059.	1333.	1432.	1839.	2231.	2418.	2353.	2622.	2846.	2671.	2545.	2000.	1517.	1178.
J= 9	576.	712.	954.	1198.	1427.	1683.	2242.	2858.	3398.	3683.	3917.	3669.	3332.	2701.	2319.	1844.	1462.
J= 8	617.	746.	1037.	1345.	1641.	1930.	2572.	3119.	3546.	4384.	5483.	5632.	4542.	3579.	2856.	2289.	1851.
J= 7	623.	726.	912.	1257.	1758.	2080.	2726.	3123.	3584.	4031.	5031.	5803.	5256.	4576.	3597.	2850.	2173.
J= 6	594.	715.	930.	1155.	1421.	2153.	3182.	4073.	3883.	4206.	4610.	5218.	5232.	4744.	4117.	3221.	2345.
J= 5	526.	675.	858.	1029.	1150.	1400.	2148.	3300.	3640.	4147.	4518.	4965.	5016.	4580.	3910.	3161.	2436.
J= 4	389.	494.	708.	844.	951.	1321.	1672.	2222.	2954.	3508.	3961.	4357.	4564.	4408.	3889.	3087.	2476.
J= 3	319.	377.	480.	647.	759.	1114.	1701.	1885.	2179.	2868.	3518.	3866.	3781.	3503.	3206.	2798.	2140.
J= 2	246.	283.	338.	415.	494.	758.	1411.	1674.	1619.	2225.	2853.	3211.	3348.	2947.	2545.	2183.	1994.
J= 1	154.	183.	206.	239.	278.	343.	635.	1070.	1108.	1185.	1629.	2017.	2230.	2224.	2016.	1859.	1774.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Figure 18: NO$_x$, heating, winter.

Industries:
The industrial sources for NO_x are considered like point sources. The data related to the industry are shown in Table 36.

The NO_x emission data for each industry comes from an estimation from the total emission data of the "Estudio de las Emisiones a la Atmòsfera en la Ciudad de Zaragoza del año 1996" for all the industries inside Zaragoza. There are also some estimations in "physical measurements" like stack heights and so on. The higher value is 5 $\mu g/m^3$ in grid (13,12); this is S. Juan de la Peña grid. There is an isolated peak far from the rest of isolines of the same level in the (10,5) and (11,5) grids; these are S. Juan de la Cruz, J. Pablo Bonet grid and Pignatelly park grid. The values are lower than the immission values allowed by law.

Table 36: Industrial data for NO_x

Source data:

	Name	Relative coordinates X	Relative coordinates Y	Stack base m	Stack height m	Stack diameter m	Gas temp. oC	Exit velocity m/s	Building height m	Building width m	NOx emission kg/h
1	RICO FUND1	6.60	5.70	0.00	22.0	2.50	95.	19.9	10.	30.	1.70
2	SAICA CALD	6.30	5.25	0.00	35.0	3.42	135.	19.3	10.	30.	26.70
3	ZARAGOZANA	5.45	2.25	0.00	12.0	0.40	70.	15.0	10.	30.	0.50
4	EBROACERO	2.80	1.00	0.00	30.0	1.68	40.	13.5	10.	30.	3.40
5	AMYLUM IBE	6.05	6.05	0.00	10.3	1.20	50.	3.9	10.	30.	5.50
										SUM	37.80

Table 37: NO_x, industry, winter.

```
MAP OF : NOx              UNIT: UG/M3              SOURCE: POINT SOURCES
 PERIOD : WINTER          PLACE: ZARAGOZA        GRID SIZE:  500 METER
 CREATED: 2000/03/13 10.44  FILE: STACKS-NOX.FLD
     MAXIMUM VALUE IS  4.9664E+00, IN (13,12)
                 SUM= 9.83193E+01    SCALE FACTOR:  1.0E-03
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	192.	211.	233.	259.	289.	325.	371.	352.	419.	387.	292.	336.	460.	267.	110.	89.	194.
J=14	221.	244.	271.	305.	345.	341.	394.	465.	476.	655.	682.	607.	567.	211.	415.	289.	219.
J=13	215.	236.	260.	311.	352.	404.	469.	564.	711.	998.	1382.	4357.	782.	954.	1549.	969.	696.
J=12	218.	239.	262.	291.	324.	367.	421.	493.	698.	366.	467.	375.	4966.	3663.	1872.	982.	705.
J=11	221.	242.	263.	291.	197.	209.	222.	221.	238.	248.	163.	178.	1719.	3398.	1547.	1121.	876.
J=10	164.	165.	178.	187.	187.	198.	208.	204.	71.	81.	99.	108.	214.	807.	1775.	1458.	891.
J= 9	160.	158.	170.	88.	94.	98.	107.	67.	68.	73.	82.	162.	172.	641.	624.	1287.	1121.
J= 8	84.	92.	83.	90.	98.	82.	81.	68.	69.	66.	81.	131.	165.	540.	536.	1116.	1047.
J= 7	90.	98.	108.	92.	82.	86.	72.	74.	75.	89.	91.	125.	162.	482.	484.	557.	961.
J= 6	94.	106.	107.	83.	89.	85.	65.	79.	102.	126.	135.	173.	199.	353.	434.	405.	557.
J= 5	116.	126.	116.	134.	81.	85.	72.	89.	124.	266.	1019.	1035.	383.	250.	438.	409.	375.
J= 4	111.	135.	162.	143.	184.	88.	43.	45.	100.	92.	120.	367.	370.	313.	468.	433.	387.
J= 3	115.	120.	147.	237.	407.	113.	98.	95.	226.	203.	199.	307.	419.	332.	428.	400.	369.
J= 2	99.	119.	146.	39.	46.	80.	597.	373.	222.	198.	198.	252.	224.	283.	424.	368.	343.
J= 1	28.	31.	34.	25.	26.	75.	183.	341.	282.	245.	230.	220.	230.	179.	300.	363.	338.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

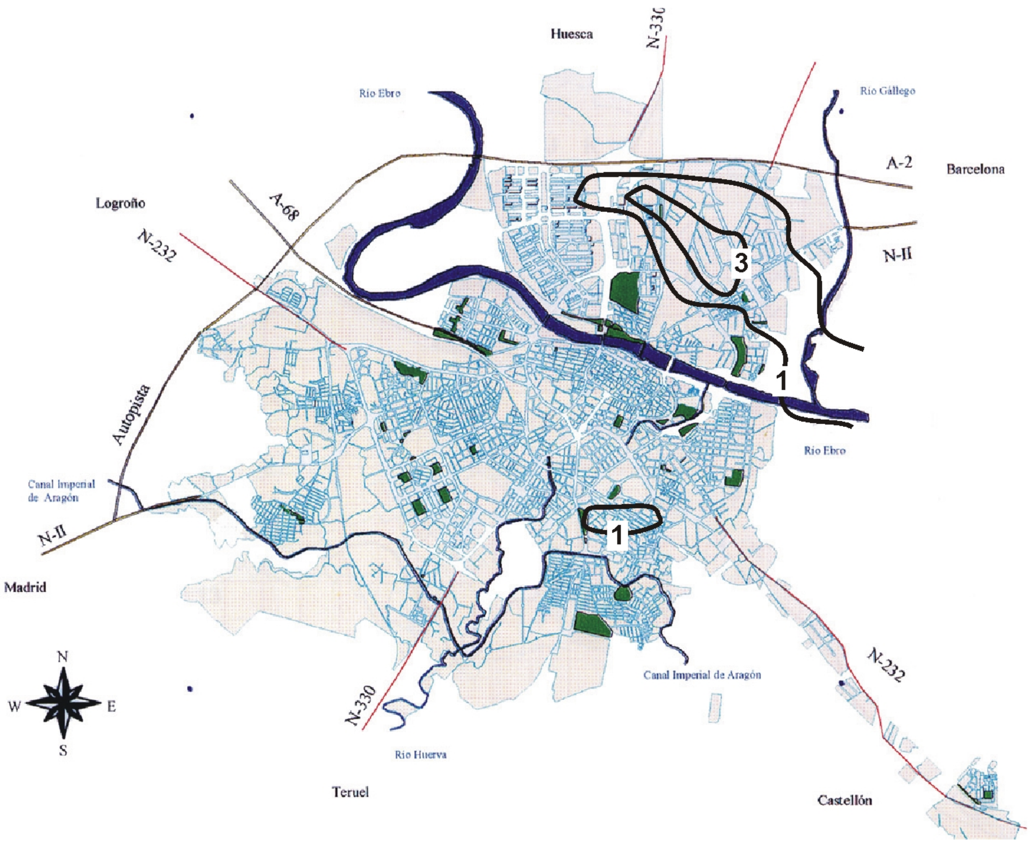

Figure 19: NO_x, industry, winter

Total:

The higher concentration for NO_x is 23 µg/m^3 in grid (12,8); this is Coso, S. Vicente Paul and Plaza de S. Miguel grid. It was considered a background value of 10 µg/m^3. The values are lower than the immission values allowed by law. The most important source is traffic, heating is two times lower than traffic and stacks ten times lower than traffic. There are some differences between the measured values in the monitoring network and the values from the Kilder model.

Table 38: Immission values for NO_x (as NO_2) during winter season. All these values are in µg/m^3.

	Annual Percentile 50 average (95-98)	Kilder Model*
El Picarral	43	18
M. Servet	53	23
Luis Vives	18	18
R. de Flor	48	18
Av. Navarra	68	19
Paraninfo	26	20
J. Ferràn	26	17

* background level of 10 µg/m^3 .

- There is a low 50 Percentile value in Paraninfo monitoring station. This is a strange value for a station placed close to streets with high number of vehicles. The value is very low in 1996 with 11 µg/m^3 .
- There is also a low 50 Percentile value in Luis Vives monitoring station. This station is also near one of the main streets of Zaragoza and its values are very low, especially in 1996 with 10 µg/m^3.
- The immission from the Kilder model is flat for all the stations and the values are lower than the measured values. The Kilder model gives an average for all the sources in each 500 x 500 m^2 grid and one station is only a single point inside each grid.
- The stations are close to the sources of NO_x , mainly the roads, and the closer to the roads the higher values are obtained
- Zaragoza shows the same tendency like other big cities in Europe, for example Oslo. During 1995, 1996 and 1997 NO_2 has been increasing its values whereas O_3 has been decreasing its values due to this increase in NO_2 levels.
- NO_2 immission levels can be influenced by the highways close to the roads, a background level and other unknown sources inside or outside the city.

Table 39: NO_x, total, winter.

```
MAP OF : NOx                 UNIT: UG/M3              SOURCE: ALL SOURCES
 PERIOD : WINTER             PLACE: ZARAGOZA        GRID SIZE:  500 METER
 CREATED: 2000/03/20 15.06  FILE: SUM-NOX-WINTER.PRN
     MAXIMUM VALUE IS  2.3232E+01, IN (12, 8)
                 SUM= 4.09104E+03    SCALE FACTOR: 0.01
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	1144.	1159.	1176.	1206.	1259.	1396.	1472.	1405.	1346.	1354.	1366.	1372.	1327.	1258.	1209.	1171.	1162.
J=14	1164.	1181.	1198.	1216.	1239.	1309.	1484.	1643.	1602.	1583.	1727.	1816.	1747.	1562.	1476.	1336.	1239.
J=13	1185.	1207.	1219.	1235.	1259.	1284.	1357.	1512.	1643.	1647.	1797.	2221.	1845.	1713.	1650.	1485.	1351.
J=12	1224.	1278.	1260.	1295.	1300.	1324.	1366.	1447.	1601.	1650.	1759.	1843.	2295.	2051.	1758.	1608.	1515.
J=11	1319.	1570.	1611.	1558.	1488.	1417.	1470.	1512.	1585.	1687.	1820.	1956.	2121.	2190.	1798.	1612.	1524.
J=10	1231.	1365.	1617.	1750.	1784.	1621.	1631.	1698.	1791.	1942.	1999.	2003.	1999.	2025.	1963.	1702.	1535.
J= 9	1226.	1291.	1467.	1739.	1960.	1920.	1883.	1934.	1978.	2045.	2190.	2205.	2135.	2071.	1952.	1840.	1631.
J= 8	1197.	1243.	1345.	1511.	1777.	1912.	1920.	1932.	1985.	2039.	2205.	2323.	2263.	2205.	2018.	1904.	1712.
J= 7	1185.	1227.	1286.	1416.	1664.	1823.	1938.	1922.	1889.	1991.	2136.	2239.	2306.	2308.	2119.	1899.	1767.
J= 6	1183.	1268.	1351.	1388.	1461.	1642.	1802.	1986.	1921.	1922.	2057.	2146.	2071.	2150.	2078.	1886.	1712.
J= 5	1137.	1184.	1269.	1338.	1357.	1425.	1561.	1749.	1829.	1892.	2097.	2235.	2151.	2080.	2017.	1859.	1695.
J= 4	1107.	1132.	1195.	1271.	1313.	1378.	1438.	1517.	1654.	1782.	1890.	2015.	2049.	1986.	1973.	1825.	1675.
J= 3	1097.	1116.	1153.	1228.	1296.	1341.	1475.	1492.	1524.	1636.	1763.	1877.	1868.	1816.	1782.	1765.	1628.
J= 2	1074.	1088.	1111.	1139.	1201.	1304.	1506.	1542.	1452.	1491.	1596.	1691.	1721.	1674.	1616.	1579.	1562.
J= 1	1047.	1054.	1065.	1082.	1116.	1196.	1287.	1404.	1392.	1352.	1401.	1473.	1525.	1507.	1497.	1478.	1472.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

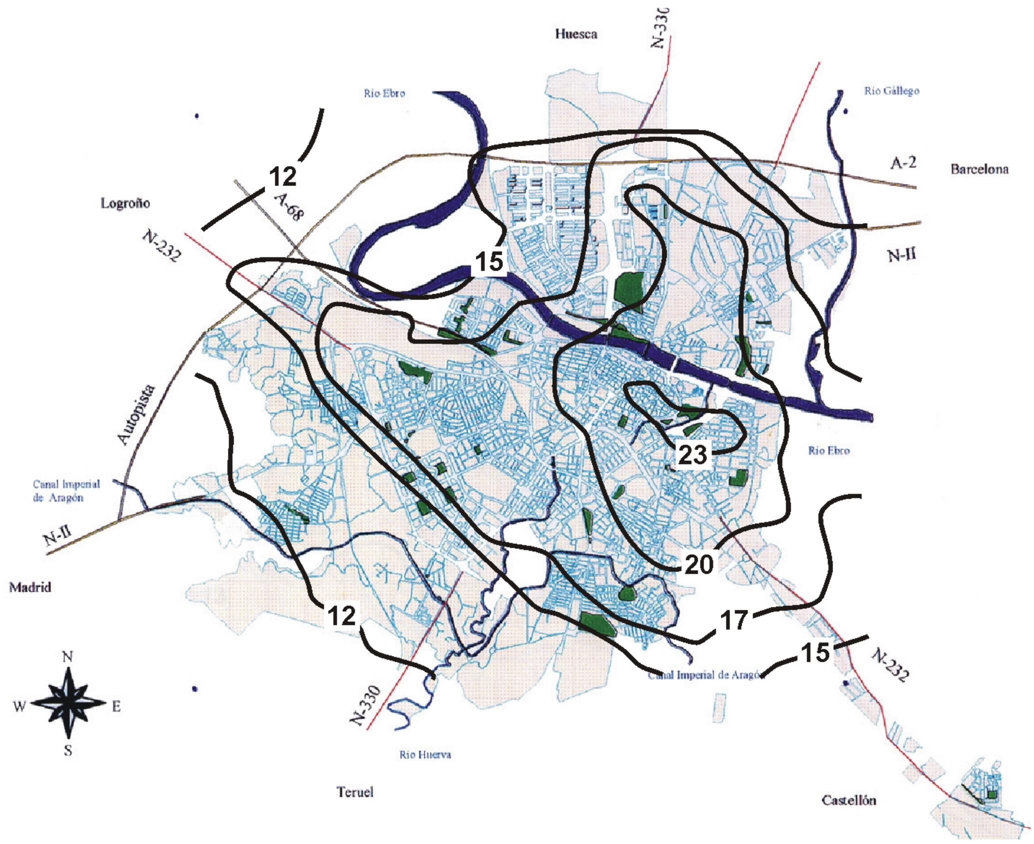

Figure 20: NO_x, total, winter.

7.3.2 Summer

Traffic:
The maximum value for traffic is 8,3 μg/m^3 and it is located in grid (10,6); this is the grid which contains Avenida de Goya from Gran Vìa to Paseo de Sagasta.

The immission values are far away from the 50 Percentile permitted by law for NO_2: 50 μg/m^3.

There is a small peak in the concentration level in grids (9,4) and (9,5); these are Avenida de Navarra, Vìa Hispanidad and Autovìa de Logroño grids.

The isolines have more or less the same shape as the isolines map during winter season, but now the area covered by the same concentration is smaller than in winter season due to the different meteorology.

Table 40: NO_x, traffic,summer.

```
MAP OF : NOX               UNIT: UG/M3               SOURCE: TRAFFIC
 PERIOD : SUMMER           PLACE: ZARAGOZA         GRID SIZE:  500 METER
 CREATED: 2000/03/20 14.00  FILE: NOX-TRAF-SUMMER.FLD
     MAXIMUM VALUE IS  8.2779E+00, IN (10, 6)
                 SUM= 9.38564E+02    SCALE FACTOR:  1.0E-03
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	1267.	1335.	1480.	1764.	2573.	3608.	3349.	2335.	1967.	1921.	1742.	1528.	1152.	903.	758.	642.	597.
J=14	1421.	1487.	1570.	1694.	1946.	3033.	4498.	5367.	5200.	5135.	5417.	5335.	4232.	3130.	2211.	1338.	906.
J=13	1657.	1629.	1637.	1690.	1823.	2089.	2658.	3657.	4094.	4493.	4407.	4227.	3785.	3039.	2420.	1636.	1173.
J=12	2178.	2018.	1811.	1863.	1937.	2149.	2380.	2964.	3632.	4234.	4518.	4025.	3542.	2977.	2831.	2802.	2311.
J=11	4247.	5550.	4731.	3813.	3038.	2750.	3029.	3421.	4150.	5222.	5962.	5716.	5141.	3932.	2512.	2068.	1934.
J=10	2762.	4478.	5447.	6001.	5086.	4217.	4291.	4878.	5926.	6621.	6343.	5484.	5186.	4563.	3219.	2212.	1820.
J= 9	2749.	3589.	5037.	7078.	7852.	6837.	6670.	6366.	6055.	6618.	6911.	6343.	5431.	4826.	3972.	2766.	2050.
J= 8	2457.	2974.	3830.	5127.	6678.	6751.	6780.	6969.	6428.	6251.	6917.	6668.	6139.	5351.	4127.	2936.	2291.
J= 7	2318.	2728.	3426.	4882.	6341.	6544.	7167.	7691.	8073.	7691.	7426.	7012.	6914.	6067.	4408.	3167.	2415.
J= 6	2560.	3328.	3906.	4333.	5377.	6257.	6745.	7410.	8013.	8278.	8067.	6873.	5996.	5141.	4023.	2943.	2320.
J= 5	1715.	2255.	2791.	3320.	3941.	4834.	5392.	6225.	6871.	6864.	7181.	6747.	6148.	5106.	3733.	2822.	2221.
J= 4	1249.	1489.	1944.	2373.	2841.	3896.	4801.	5149.	5386.	5611.	5700.	5193.	4587.	4278.	3672.	2678.	2040.
J= 3	998.	1185.	1491.	1898.	2104.	2734.	3617.	3742.	3658.	3994.	4272.	3858.	3300.	2931.	2924.	2656.	2014.
J= 2	662.	772.	1007.	1413.	1847.	2539.	3370.	3050.	2743.	2638.	2850.	2740.	2458.	2169.	1939.	1899.	1678.
J= 1	469.	544.	654.	838.	1220.	1719.	2181.	2335.	2108.	1961.	1970.	1945.	1789.	1623.	1570.	1484.	1408.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

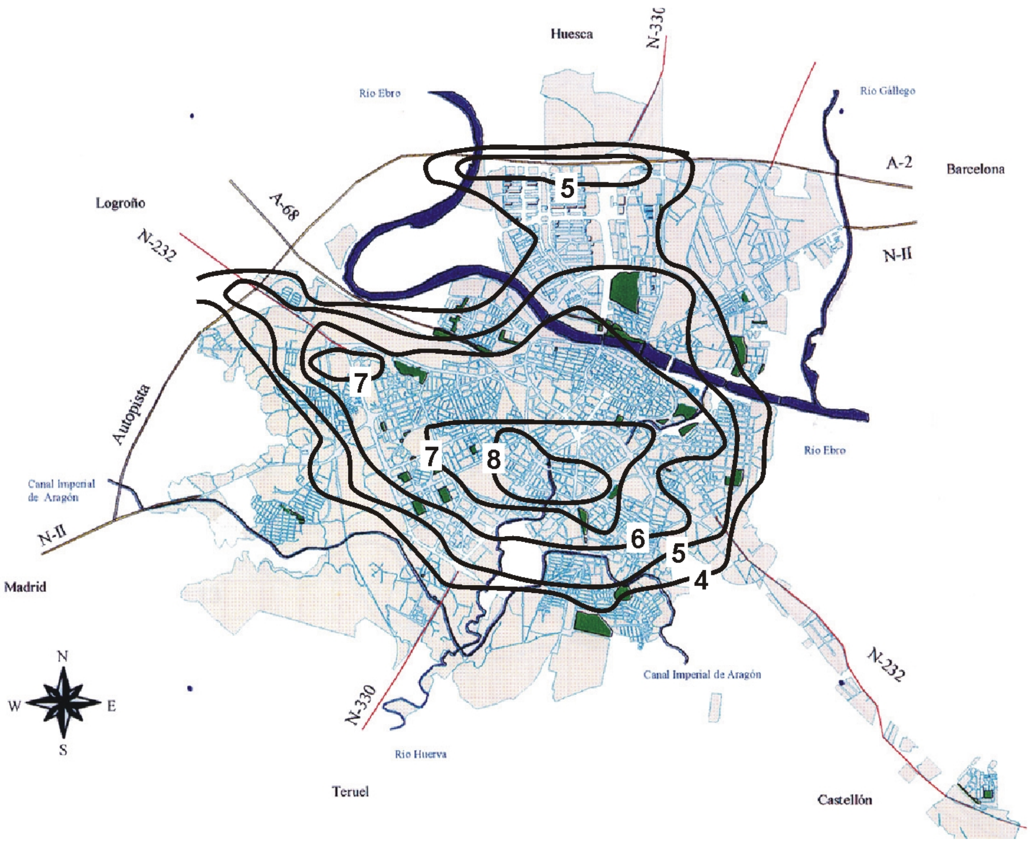

Figure 21: NO_x, traffic, summer.

Industries:
The industrial data are the same as those used for winter (see table 35). The highest value is 6,7 $\mu g/m^3$ in grid (12,13); this is Av. Salvador Allende grid.

There are two isolated peaks far from the rest of isolines of the same level in the (7,2) and (11,5) grids; these are Vìa Ibèrica, las Nieves grid and Pignatelly park grid.

The values are lower than the immission values allowed by law. In summer season there is a higher concentration for NO_x than in winter season.

Table 41: NO_x, industry, summer.

```
MAP OF : NOx                 UNIT: UG/M3                SOURCE: POINT SOURCES
 PERIOD : SUMMER             PLACE: ZARAGOZA          GRID SIZE:  500 METER
 CREATED: 2000/03/20 16.26  FILE: STACKS-NOX-SUMMER.FLD
MAXIMUM VALUE IS  6.6966E+00, IN (12,13)
                 SUM= 1.04311E+02    SCALE FACTOR:  1.0E-03
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	248.	270.	295.	323.	356.	399.	453.	422.	523.	207.	129.	151.	122.	66.	30.	22.	118.
J=14	303.	332.	365.	398.	446.	414.	476.	564.	601.	866.	385.	286.	144.	54.	258.	178.	134.
J=13	341.	373.	410.	411.	460.	525.	610.	739.	948.	1432.	1989.	6697.	186.	574.	705.	444.	321.
J=12	343.	375.	412.	456.	507.	573.	660.	784.	943.	331.	506.	835.	6530.	2020.	965.	451.	325.
J=11	350.	383.	410.	453.	262.	277.	290.	295.	306.	302.	232.	319.	1605.	1150.	926.	582.	447.
J=10	224.	230.	245.	250.	242.	254.	264.	268.	87.	95.	148.	169.	558.	1208.	833.	692.	600.
J= 9	211.	215.	229.	99.	106.	100.	110.	83.	83.	86.	118.	346.	452.	813.	1133.	1032.	533.
J= 8	87.	95.	91.	100.	110.	96.	82.	81.	86.	100.	104.	263.	398.	702.	685.	885.	799.
J= 7	93.	97.	108.	101.	94.	98.	102.	114.	99.	109.	106.	218.	347.	602.	599.	779.	708.
J= 6	95.	105.	105.	94.	104.	104.	98.	119.	165.	122.	120.	203.	339.	371.	520.	485.	630.
J= 5	202.	227.	109.	121.	98.	104.	112.	145.	209.	415.	2357.	674.	384.	322.	466.	443.	411.
J= 4	202.	244.	295.	118.	136.	103.	66.	67.	96.	98.	207.	521.	381.	336.	445.	422.	385.
J= 3	272.	320.	432.	406.	650.	74.	94.	84.	154.	139.	193.	356.	324.	288.	395.	378.	354.
J= 2	249.	319.	430.	148.	256.	297.	1006.	551.	147.	132.	199.	284.	268.	253.	347.	339.	321.
J= 1	62.	74.	93.	108.	160.	546.	711.	534.	322.	252.	270.	307.	294.	224.	239.	302.	288.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

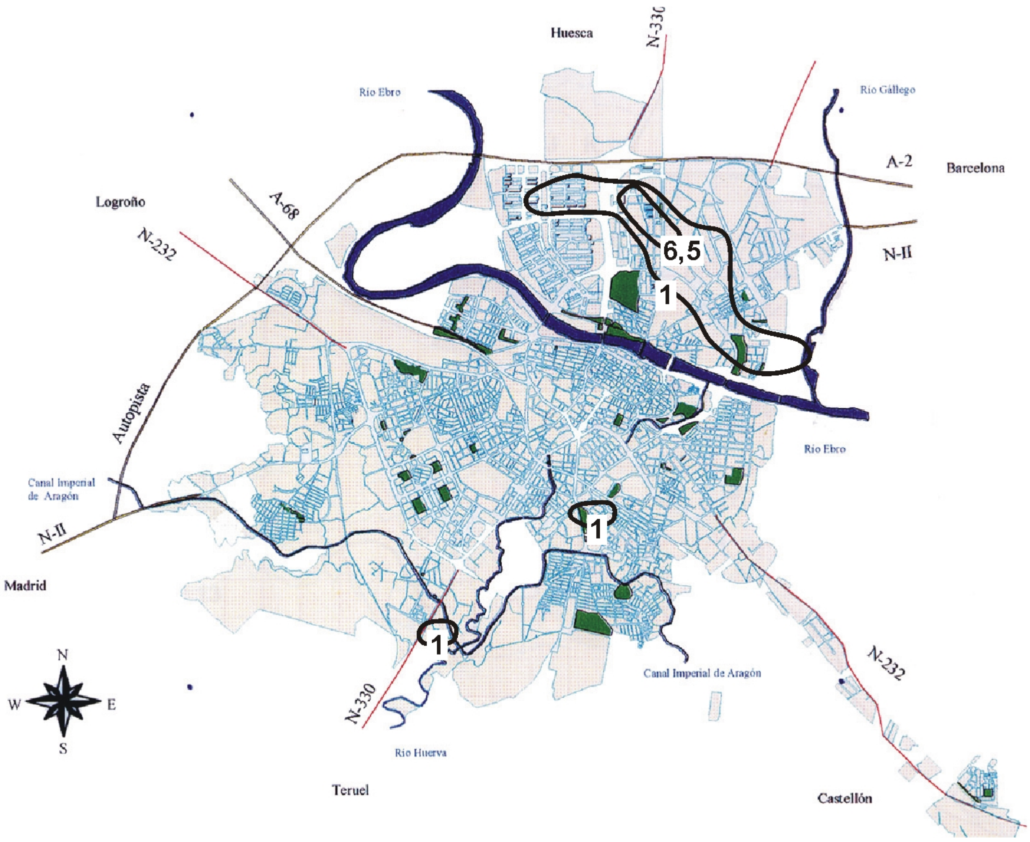

Figure 22: NO_x, industry, summer.

Total:

The highest concentration for NO_x is 16 µg/m^3 in grid (12,13); this is Av. Salvador Allende grid. It was considered a background value of 5 µg/m^3. The values are lower than the immission values allowed by law. Traffic and stacks sources have the same concentration values during summer season; there is not a dominant source for NO_x.

There are some differences between the measured values in the monitoring network and the values from the Kilder model.

Table 42: Immission values for NO_x during summer season. All these values are in µg/m^3.

	Annual Percentile 50 average(95-98)	Kilder Model *
El Picarral	43	9
M. Servet	53	12
Luis Vives	18	12
R. de Flor	48	12
Av. Navarra	68	11
Paranifo	26	13
J. Ferràn	26	9

* background level of 5 µg/m^3 has been included.

- There is a low 50 Percentile value in Paraninfo monitoring station. This is a strange value for a station placed close to streets with high number of vehicles. The value is very low in 1996 with 11 µg/m^3 .

- There is also a low 50 Percentile value in Luis Vives monitoring station. This station is also near one of the main streets of Zaragoza and its values are very low, especially in 1996 with 10 µg/m^3.

- The immission from the Kilder model is flat for all the stations and the values are lower than the measured values. The Kilder model gives an average for all the sources in each 500 x 500 m^2 grid and one station is only a single point inside each grid.

- The stations are close to the sources of NOx , mainly the roads, and the closer to the roads the higher values are obtained.

- Zaragoza shows the same tendency like other big cities in Europe, for example Oslo. During 1995, 1996 and1997 NO2 has been increasing its values whereas O3 has been decreasing its values due to this increase in NO2 levels.

- NO2 immission levels can be influenced by the highways close to the roads, a background level and other unknown sources inside or outside the city.

- The isolines with the same concentration levels in NO_x are now covering a smaller area than the area covered during winter. The higher concentrations have been moved towards west.

- There are 3 separated areas with high concentration:

1. Grids (9,4) and (9,5). These are Avenida de Navarra, Vìa Hispanidad and Autovìa de Logroño grids. There is a concentration of almost 13 $\mu g/m^3$.

2. Grids (9,7), (9,6), (10,6) and (11,6). These are Avenida de Goya and Avenida Tenor Fleta grids. There is a concentration higher than 13 $\mu g/m^3$.

3. Grids (12,13) and (13,12). These are Avenida Salvador Allende and S. Juan de la Peña grids. The concentration values are higher than 15 $\mu g/m^3$.

Table 43: NO_X, total, summer.

```
MAP OF : NOx                UNIT: UG/M3              SOURCE: ALL SOURCES
 PERIOD : SUMMER            PLACE: ZARAGOZA        GRID SIZE:  500 METER
 CREATED: 2000/03/20 16.17  FILE: SUM-NOX-SUMMER.PRN
     MAXIMUM VALUE IS  1.5923E+01, IN (12,13)
                SUM= 2.31788E+03    SCALE FACTOR: 0.01
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	652.	660.	678.	709.	793.	901.	880.	776.	749.	713.	687.	668.	627.	597.	579.	566.	572.
J=14	672.	682.	693.	709.	739.	845.	997.	1093.	1080.	1100.	1080.	1062.	938.	818.	747.	652.	604.
J=13	700.	700.	705.	710.	728.	761.	827.	940.	1004.	1093.	1140.	1592.	897.	861.	812.	708.	649.
J=12	752.	739.	722.	732.	744.	772.	804.	875.	958.	956.	1002.	986.	1507.	1000.	880.	825.	764.
J=11	960.	1093.	1014.	927.	830.	803.	832.	872.	946.	1052.	1119.	1104.	1175.	1008.	844.	765.	738.
J=10	799.	971.	1069.	1125.	1033.	947.	956.	1015.	1101.	1172.	1149.	1065.	1074.	1077.	905.	790.	742.
J= 9	796.	880.	1027.	1218.	1296.	1194.	1178.	1145.	1114.	1170.	1203.	1169.	1088.	1064.	1010.	880.	758.
J= 8	754.	807.	892.	1023.	1179.	1185.	1186.	1205.	1151.	1135.	1202.	1193.	1154.	1105.	981.	882.	809.
J= 7	741.	783.	853.	998.	1143.	1164.	1227.	1280.	1317.	1280.	1253.	1223.	1226.	1167.	1001.	895.	812.
J= 6	765.	843.	901.	943.	1048.	1136.	1184.	1253.	1318.	1340.	1319.	1208.	1134.	1051.	954.	843.	795.
J= 5	692.	748.	790.	844.	904.	994.	1050.	1137.	1208.	1228.	1454.	1242.	1153.	1043.	920.	826.	763.
J= 4	645.	673.	724.	749.	798.	900.	987.	1022.	1048.	1071.	1091.	1071.	997.	961.	912.	810.	743.
J= 3	627.	650.	692.	730.	775.	781.	871.	883.	881.	913.	947.	921.	862.	822.	832.	803.	737.
J= 2	591.	609.	644.	656.	710.	784.	938.	860.	789.	777.	805.	802.	773.	742.	729.	724.	700.
J= 1	553.	562.	575.	595.	638.	726.	789.	787.	743.	721.	724.	725.	708.	685.	681.	679.	670.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

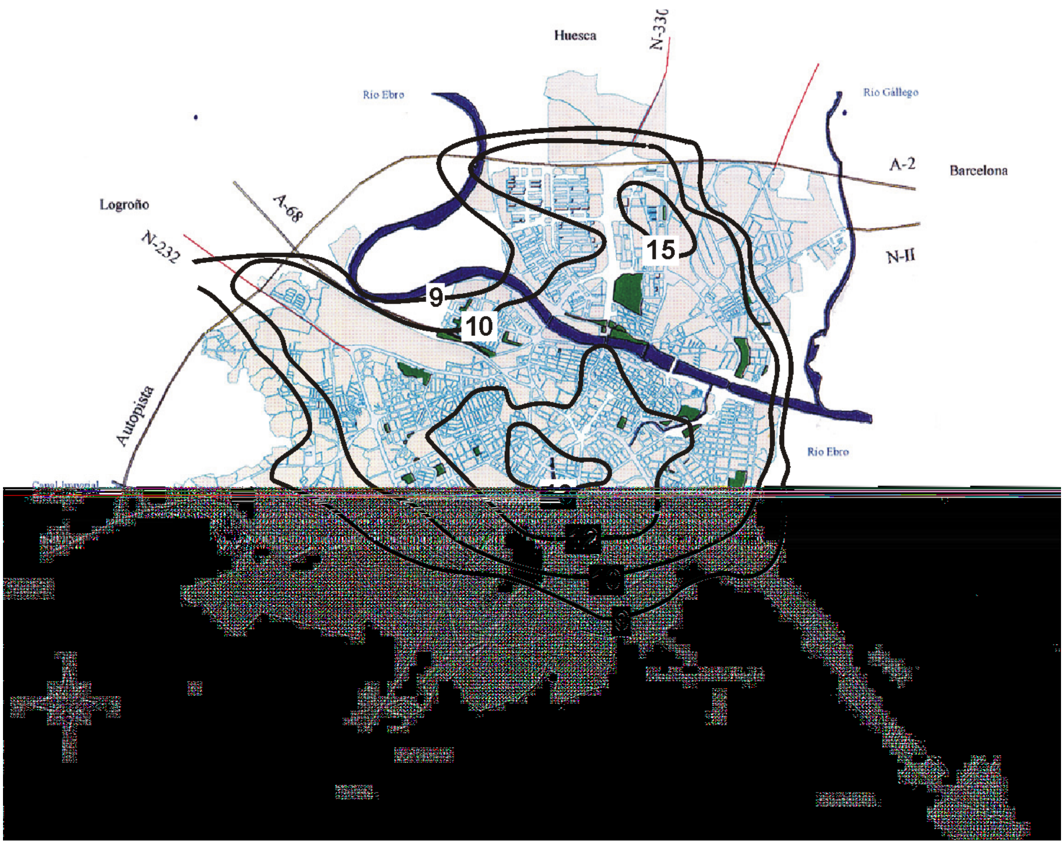

Figure 23: NO_x, total, summer.

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Appendix A

KILDER Air Pollution Modelling System

Introduction

The KILDER dispersion modelling system has been in use at the Norwegian Institute for Air Research (NILU) for more almost 20 years. It has been gradually developed by active use at NILU, and the most commonly used programmes are included in this report. Some of the programs were been transferred into English versions for planning use in Bilbao, Spain in 1988. These and some more programs were transferred to PC-versions for Central Pollution Control Board (CPCB) in Dehli, India in May 1992.

The basic units are two Gaussian dispersion models, POI-KILD and ARE-KILD for calculating long-term ground-level concentrations over an area from point and area sources, respectively. The system also includes 3 programs for statistical evaluation of meteorological and air quality data: WINDFREC, STABFREC and METFREC. The KILDER modelling system is, however, more than two dispersion models. Today about 30 different supporting programs are available (some of them only in Norwegian). The KILDER system has also been used in air pollution modelling for URBAIR in the mega-cities Bombay, Jakarta, Manila and Kathmandu and in Pecs, Hungary, Ostrava, the Czech Republic and Guangzhou, China.

One major feature in the KILDER system is that the file structure is based upon binary files with data fields. The data fields are matrixes with different types of values and they may be read into the computer or calculated in different programs. As the files are binary we can not use an editor to look at them, and it is very difficult to change values, which means that this is a safe file structure. The programs are originally written to serve different purposes, so one might in some cases get questions that may seem to be irrelevant for the actual case. For model calculations you need hourly emission fields, whereas an emission survey report needs annual emission fields.

Another advantage is that the system consists of a series of programs, which are making small steps. In an emission survey the input data may be very deficient, and we have to use other data instead. We may for instance have an estimate of the total consumption of fuels for the area, but will distribute this according to the population distribution. It will then be possible take into account different fuel use in different regions by using various consumption per capita for the regions.

The examples to the programs are not real; some are taken from different studies, adjusted to fit the format of this report better, some are just examples. It would be nice if we could follow the calculations for one region through all the programs, but the cities and the data sources are all so different that this has not been possible. This is at the same time the strength of the KILDER system, it is so flexible that the programs may utilise the data that are available for the preparation of the fields.

The programs can operate in different modes: interactive or as a batch job. When running interactive, the program asks questions to the **terminal**, otherwise the program reads the input data from a **run-file**. It is possible to read some of the data from a separate file, such as fixed information about the model area and the stack and emission data. All meteorological data, such as wind speed, inversion height and the meteorological frequency matrix are read from a separate file. The input records are read in free format, unless a format is specified.

The output of the programs is given in data fields with concentration values together with the printout. It is possible to run the programs separately for different source categories, or even to use different meteorological data for the sources in separate sub-regions of the area. With SUM-FIE we get the total concentration fields. The values are calculated for points located in the centre of each grid. Due to the need of a model which can work for several different areas, the models are using variable dimensioning in the source code, limited to a grid of KX*KY=3500 points, but this can easily be changed in the program code if necessary.

THE GAUSSIAN PLUME EQUATION

The Gaussian plume equation calculates the downwind concentration of an inert gas being continuously emitted from a single source. When applying sector averaging it is assumed that the cross wind concentration distribution is constant within an regular sector corresponding to the resolution in the wind direction data.

Normally a joint frequency distribution of 4 stability classes, 4 wind speed classes and 12 wind directions (30° sectors) is used. The Gaussian dispersion formula for the ground level concentration with sector averaging in n sectors and with emissions from p point sources can then be expressed as follows:

$$c(x,y,0) = n/2\pi \sum_{i=1}^{p}\sum_{k=1}^{12}\sum_{l=1}^{4}\sum_{m=1}^{4} f(k,l,m) * Q_i * D(x_i,u) * S(p,k) * (1.0 - P), \qquad (2)$$

where the dispersion function $D(x_i,u)$ is defined as:

$$D(x_i,u) = \sqrt{2/\pi} * (1+a)/2 * \exp\left(H/\sigma_z)^2\right) / \left(U_s * x_i * \sigma_z\right), \qquad (3)$$

the sector function S(p,k) as

S(p,k)	=	1 if receptor point is within sector k downwind of source p 0 otherwise
P	=	fraction of the plume that penetrates an elevated stable layer
f(k,l,m)	=	the frequency of occurrence for wind sector k, wind speed class l and stability class m
(x,y,0)	=	location of the receptor point given in Cartesian coordinates with the origin at ground level at the source location and x-axis parallel to wind direction. Normally in the centre of each square.
x_i	=	distance from the source to the receptor (m)
Q_i	=	continuous source emission rate (kg/h or g/s)
H	=	effective plume height (m)

h_s = stack height

α = ground level reflection coefficient

n = number of sectors = 12

σ_z = standard deviation of the vertical concentration distribution

U_s = mean transport wind speed

Figure 1 shows the geometry of a single point source.

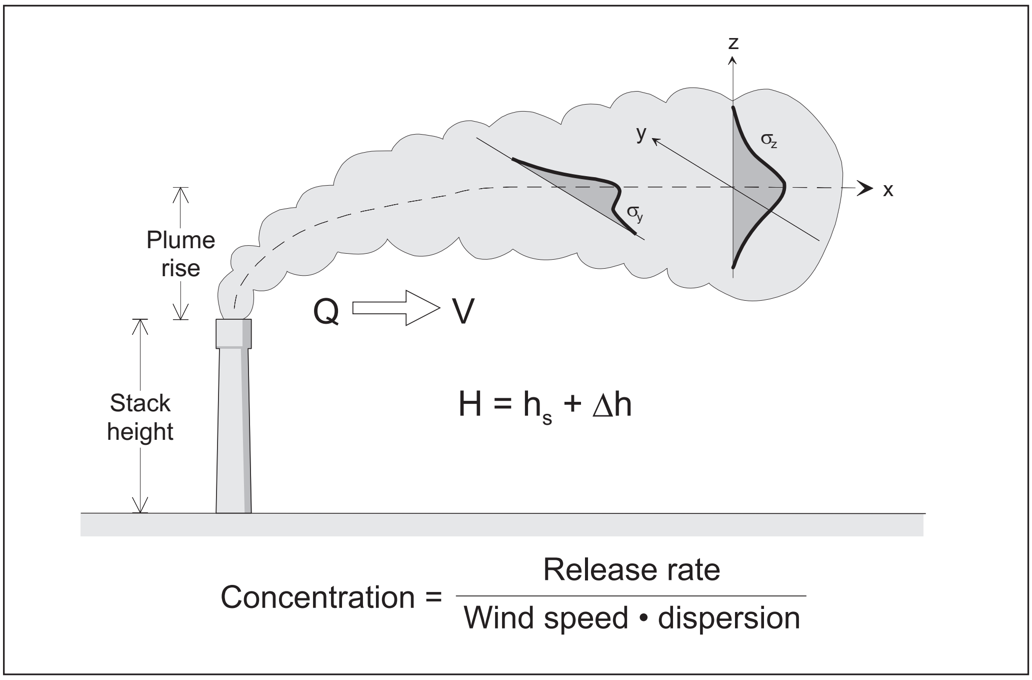

Figure 24: Gaussian point source geometry.

1.1 Wind speed

The mean transport wind speed should be representative of the conditions throughout the vertical interval in which the plume is dispersing. The wind speed in the lower atmosphere varies with height above ground. Since wind measurements are generally performed near ground level (10 m above ground), an adjustment for the exptected height range of dispersion has to be made. The variation of wind speed with height depends also upon the atmospheric stability.

The height dependency of the wind speed is described by a power law:

$$\bar{u}(z) = \bar{u}(z_o)\left(\frac{z}{z_o}\right)^m \qquad (1)$$

with

- z = height above ground,
- z_o = reference height above ground,
- $\bar{u}$ = time averaged wind speed,
- m = wind profile exponent (corresponds to RN in the .MET-file).

The mean transport speed representative of an appropriate height range, e.g. from the effective source height (H) to ground level (for dispersion calculations), may then be calculated by integration:

$$\bar{u} = \frac{1}{\Delta z}\int \bar{u}(z)\,dz = \frac{1}{(z_2 - z_1)}\int_{z1}^{z2} \bar{u}(z_o)\cdot\left(\frac{z}{z_o}\right)^m dz\,, \qquad (9)$$

Several empirical values of wind profile exponents (m) for different turbulence conditions have been published. The wind profile exponents are user input parameters, and in the NILU models the following values have been applied as standard values:

Stability class	m
Unstable	0.20
Neutral	0.28
Slightly stable	0.36
Stable	0.42

1.2 Atmospheric stability

The diffusion of air pollutants in the lower atmosphere is strongly influenced by the local atmospheric stability. The diffusion of effluents is more rapid in the unstable than in the stable atmosphere.

The stability of the atmosphere can be derived from vertical and horizontal turbulence measurements, or from measurements of the vertical temperature profile and wind speed. Estimates of the net radiation or cloud cover, mixing height, and solar elevation have also been used. For practical reasons the turbulence situations of the atmosphere are usually described by a discrete set of stability classes.

Different turbulent classification schemes have been developed and used. Pasquill defined 6 turbulence classes:

A = extremely unstable
B = moderately unstable
C = slightly unstable
D = neutral
E = slightly stable
F = moderately stable

The meteorological data used to determine the turbulence type are usually the surface wind speed, daytime insolation, and nigth-time cloudiness.

In the NILU data input for dispersion models, the three unstable classes have been combined into one. The stability classes are usually defined by vertical temperature gradients and by direct measurements of the standard deviation of the horizontal wind direction fluctuations, where such data are available. The stability classes are defined as follows:

Stability class	Temperature gradient dT (deg/100 m)	Corresponds to:	
		Pasquill	Brookhaven
Unstable	dT < -1	A+B+C	B_1+B_2
Neutral	-1 ≤ dT < 0	D	C
Slightly stable	0 ≤ dT < 1	E	-
Stable	dT ≤ 1	F	D

1.3 Diffusion parameters

A main assumption for solving the diffusion equation is th existence of a Gaussian normal distribution of the plume concentrations perpendicular to the transport direction. The diffusion parameter σ_y and σ_z are defined as the standard devitations of the concentration distributions in the lateral and vertical, respectively. They are functions of the downwind distance from the emission source and of the stability of the atmosphere. The standard deviations have been determined from tracer experiments carried out during different wind and turbulence conditions.

The most appropriate set of diffusion parameters should be selected for each particular application. The choice will be dependent upon source height, surface roughness and, in some cases, averaging time or transport distance. A set of different parameters has been evaluated at NILU and represents the basis for our selection of stability classes.

When direct turbulence measurements are not available, the following form of diffusion parameters is used:

$$\sigma_y(x) = ax^P, \sigma_z(x) = bx^q .$$

The most commonly used coefficients are listed in the Table 1 below, and apply to averaging times of up to one hour.

Table 44: Commonly used dispersion coefficients applicable for different source types and surface roughness.

Source and surface specifications	Coefficien	Unstal	Neutr	Slightly stab	Stab
Surface and low sources.	a	1.7	0.91	1.02	-
Rought surface, urban area	p	0.72	0.73	0.65	-
Ref.: Mc Elroy, J.L.	b	0.08	0.91	1.93	-
Pooler, F., 1968	q	1.2	0.70	0.47	-
High stacks, smooth to medium	a	0.36	0.32	0.31	0.3
rough surface.	p	0.86	0.78	0.74	0.7
Ref.: Smith, M., 1968	b	0.33	0.22	0.16	0.0
(Brookhaven)	q	0.86	0.78	0.74	0.7
Sea surface.	a	0.01	0.05	0.127	-
Ref.: Raynor et al., 1977	p	1.19	0.87	0.783	-
	b	0.25	0.53	0.167	-
	q	0.63	0.41	0.578	-

Stack downwash

An effluent emitted vertically from a stack rise due to its momentum or can be brought downward by the low pressure in the wake of the stack, which occurance depends on the ratio of the exit gas velocity, W_s, to the crosswind velocity, U.

The physical stack height is modified according to Briggs (1974):

$$h_s = \begin{cases} h_s + 2(W_s / U - 1.5)D_s & for\ W_s < 1.5\ U \\ h_s & for\ W_s \leq 1.5\ U \end{cases} \quad (5)$$

where h_s is the physical stack height, W_s is the exit gas velocity and D_s is the inside stack-top diameter. The modified stack height h_s is further used to calculate the effective plume height.

1.4 Plume rise equations

The plume rise due to momentum or buoyancy is estimated using Briggs algorithm (Briggs 1969, 1971 and 1975). The calculated values of ΔH_b in this chapter, and h_s in chapter 4.3 are further used to evaluate the effects of buildings, penetration and topography in following chapters to end up with the final plume height, H.

1.4.1 Neutral-Unstable Momentum Rise

Regardless of the atmospheric stability, neutral-unstable momentum rise is calculated. The plume rise is calculated as follows:

$$\Delta H_m = 3 D_s W_s / U. \quad (6)$$

This equation is most applicable when W_s/U is greater than 4. Since momentum rise occurs quite close to the point of release, the distance to final rise is set equal to zero.

1.4.2 Neutral-Unstable Buoyancy Rise

The value of the buoyancy flux parameter, F (m^4/s^3) is needed for computing the distance to final rise and the plume rise.

$$F = (g W_s D_s^2\ \Delta T) / (4 T_s) \quad (7)$$

where $\Delta T = T_s - T_a$, T_s is the stack temperature (K), and T_a is the ambient air temperature (K).

The distance to final rise x_f (in kilometres) is the distance at which atmospheric turbulence begins to dominate entrainment.

For F less than 55,

$$x_f = 0.049 F^{5/8}. \quad (8)$$

For F equal to or greater than 55,

$$x_f = 0.119F^{2/5}. \quad (9)$$

The plume rise, ΔH (in metres), is determined from the equations:

For F less than 55,

$$\Delta H_b = 21.425F^{3/4} / U. \quad (10)$$

For F equal to or greater than 55,

$$\Delta H_b = 38.71F^{3/5} / U. \quad (11)$$

If the nutral-unstable momentum rise (previously calculated from Eq. 6) is higher than the neutral-unstable buoyancy rise calculated here, momentum rise applies and the distance to final rise is set equal to zero.

1.4.4 Stability Parameter

For stable equations, the stability parameter s is calculated from the equation:

$$s = g(\sigma\theta / \sigma z)T_a. \quad (12)$$

As an approximation $\sigma\theta / \sigma z$ is taken as 0.02 K/m for the light stable class, and 0.035 K/m for the stable class.

1.4.4 Stable Momentum Rise

When the stack gas temperature is less than the ambient air temperature, it is assumed that the plume rise is dominated by momentum. The plume rise is then calculated by using the equation:

$$\Delta H_m = 1.5\left[(W_s^2 D_s^2 T_a) / (4T_s U)\right]^{1/3} s^{-1/6}. \quad (13)$$

This value of ΔH_m is compared with the value for neutral-unstable momentum-rise (Eq. 6) and the lower of the two values is used as the resulting plume height.

1.4.5 Stable Buoyancy Rise

For situations where $T_s \geq T_a$, buoyancy is assumed to dominate. The distance to final rise (in kilometres) is determined by the equation:

$$x_f = 0.0020715Us^{-1/2}. \quad (14)$$

The plume rise is determined by:

$$\Delta H_b = 2.6\left[(F / U \cdot s)\right]^{1/3} . \qquad (15)$$

The stable buoyancy rise for calm conditions is also evaluated:

$$\Delta H_b = 4F^{1/4} s^{-3/8} . \qquad (16)$$

The lower of the two values obtained from Eqs. 15 and 16 is taken as the plume rise.

If the stable momentum rise is higher than the stable buoyancy rise calculated here, momentum rise applies and the distance to final rise is set equal to zero.

1.5 Building effects

Briggs (1974) has outlined a useful procedure for estimating the effective height of emission incorporated building-induced disturbances to the flow. The procedure is as follows:

1. Calculate the following height h:

   $$h = h_s + \Delta H_m$$

   where ΔH_m is the momentum plume rise, eqs. (6) or (13).

   If stack downwash occurs, $h' = h_s$ from Chapter 3.4.

   Let L_b be the smaller of the frontal building dimensions H_b or W_b.

   a) If h' is greater than H_b+1.5 L_b, the plume is above the region of building influence. continue to the next chapter to check for penetration by using H_e=h'+ΔH as the effective plume height. ΔH is the plume rise from chapter 3.5.

   b) If h' is less than H_b, set

   $$h''=h'-1.5\ L_b \qquad (17)$$

   c) If h' is between H_b and H_b+1.5 L_b, set

   $$h''=2h'-(H+1.5\ L_b) \qquad (18)$$

For the cases b) and c) the plume may remain aloft or may be entrained into the wake cavity and become essentially a ground level source.

If h'' is greater than 0.5 L_b, the plume remains elevated and concentrations can be calculated by using standard formulaes with modified stack height equal h'', and effective plume height h_e=h"+ΔH. Continue to the next chapter to check for penetration by using h_e as the effective plume height.

If h" is less than 0.5 L_b, the plume is trapped in the cavity zone and should be treated as a ground source with initial dimensions equal the projected frontal area of the building, A.

For the cases b) and c), where the plume is influenced by the buildings, an additional dispersion factor is combined with the standard dilution factor as follows (Briggs, 1970).

$$\sigma_y = \left(\sigma_y^2 + cA/\pi\right)^{1/2} \tag{19}$$

$$\sigma_z^2 = \left(\sigma_z^2 + cA/\pi\right)^{1/2} \tag{20}$$

where c = 1.0 and A = $H_b W_b$.

In POI-KILD the building effects are taken into account, whereas in ARE-KILD these are included in the box heights as a measure of the initial turbulence. Thus, in the stack file in POI-KILD the height and width of the nearest buildings (within 3*h_s m) should be given in SKOR(8) and SKOR(9).

1.6 Plume penetration

A buoyant plume rising into a well-mixed layer trapped by stable air may partially or completely penetrate the evelvated stable layer. Tom compute ground level concentrations for this situation, the fraction of the plume that penetrates the stable layer is first estimated and the the emission rate, Q_s, and effective plume height, h_e, for the material remaining within the mixed layer are modified.

The fraction P of the plume that penetrates the elevated stable layer is estimated as follows (Weil and Brower, 1984):

1. No penetration:

$$P = 0 \; if \; \frac{Z_i^{'}}{\Delta H} \geq 1.5 \tag{21}$$

2. Total penetration:

$$P = 1 \; if \; \frac{Z_i^{'}}{\Delta H} \leq 0.5 \tag{22}$$

3. Partial penetration:

$$P = 1.5 - \frac{Z_i^{'}}{\Delta h} \; if \; 0.5 < \frac{Z_i^{'}}{\Delta h} > 1.5 \tag{23}$$

where Δh is the predicted plume rise and $Z_i^{'} = Z_i - h_s$, where z_i is the height of the stable layer aloft, and h_s is the stack height.

The plume material remaining within the mixed layer is assumed to contribute to ground level concentrations. The modified source strength, Q is then:

$$Q = Q_s(1 - P) \qquad (24)$$

where Q_s is the emission rate on top of the stack.

To modify the effective plume height for plumes trapped within the mixed layer, it is assumed that the plume rise due to penetration, ΔH_p, is linearly varying between 0.62 $Z_i^{'}$ for total penetration.

Thus for partial penetration (0 < P < 1):

$$\Delta H_p = (0.62 + 0.38P)Z_i^{'} \qquad (25)$$

The modified plume height to be used further, h_m, is the lowest value of the height in the unlimited atmosphere, h_e, from chapter 3.6, and the height due to penetration, such as:

$$h_m = \min\left(h_e, h_p\right), h_p = h_s^{'} + \Delta H_p \qquad (26)$$

Continue to the next chapter to check for terrain effects by using h_m for the effective plume height.

1.7 Topography

The effect of elevated terrain on the ground level concentrations is included by reducing the effective plume height, h_m, assuming:

$$H = h_m - \Delta H_t, \Delta H_t = k \cdot h_t \qquad (27)$$

where h_t is the height of terrain above stack base level and k is a terrain factor (0 < k < 1) dependent upon steepness, distance from source, stability, etc.

Table 45: Terrain factor, k, to evaluate the effect of a hill on a source with stack height h_s.

Distance (x)	k
0 < x ≤ 5 h_s	0.7
5 h_s < x ≤ 10 h_s	0.5
10 h_s < x ≤ 20 h_s	0.3
20 h_s < x ≤ 30 h_s	0.1
30 h_s < x	0.0

Program METFREC

General description of the program.

This program presents joint frequency distribution of wind speed, wind direction, stability and air quality for four wind classes, 12 or 16 wind sectors and four stability classes for a given period. The output from METFREC is used as input to the dispersion models POI-KILD and ARE-KILD. The program also calculates average values for a concentration variable in the same groups. The following data are input for the program:

- Stability parameter (variable 1 (and 2))
- Wind direction (variable 3)
- Wind speed (variable 4)
- Concentration parameter (optionally variable 5, see later).

The stability parameter and its limits should be the same as in STABFREC.

The results from METFREC are given in two parts:

The first part presents a joint frequency distribution matrix with the occurrence in percent within four classes of wind speed and stability and 12, 16 or 36 wind direction sectors. The values of the line "Total" gives the occurrence in percent of each stability class in each wind class for all wind directions. The values in the column "Rose" gives the occurrence in percent of winds blowing from this sector for all classes of wind speed and stability. If the program is run with 12 or 16 sectors, the frequency distribution matrix may be written to a special file which may be prepared as a meteorological input file to the dispersion models POI-KILD and ARE-KILD.

The second part of the program presents in the same way average and maximum values of concentrations or other variables, sorted into boxes of different meteorological conditions related to the wind/stability classification given in the first part. The fifth variable may be a SO_2-concentration, but can also be other variables as turbulence or mixing height.

The program dialogue and results.

The program METFREC is an interactive program with a dialogue with the terminal, but the input may also be read from a batch file. The questions are written in `Courier`, the answers written in **bold.** The results are written to a user-specified result-file. The example below is a typical input sequence for the program. The number of variables will vary with the data. Instead of using the temperature difference as a stability parameter you may use another variable, with other limits for the stability classes.

Program TRA-EMIS

The program is normally run interactive, and it reads one or more fields with traffic work from TRA-WORK and calculates emission fields.

Input data to TRA-EMIS

KX, KY,NTR	Grid dimension, number of points eastward and northward and the number of traffic fields (max. 4)
INFILE	Traffic work file (with apostrophes and .FLD).
ITR	Field number for the first traffic work field. (Normally 2 for files from TRA-WORK, as the first field is the road length.)
OUTFI	Name of the output files (with apostrophes) The data fields will be written binary to the file OUTFI.FLD, the output is written to the file OUTFI.PRN
INFAK	Emission factor file (with apostrophes and .DAT)
(IVE(I), I=1,NTR)	Vehicle type codes on the emission factor file

Emission factors for NCOMP compounds are read from the file INFAK (with apostrophes and .DAT), see the separate description of the emission factor file. The program will prepare NCOMP fields with emissions as a sum of the contributions of each vehicle type.

Program CONS-EMI

From the **consumption** fields that was created by CONS-FIE, **emission** fields are created by CONS-EMI. The program is run interactive.

There are some questions by the program which may seem senseless, but they have their use and their history. Consumption fields will very often tell about the annual consumption of fuels. It is useful to calculate annual emissions, by the use of emission factors. But as an input for model calculations hourly emissions are needed, in kg/h. In Norway most of the fuel is used during winter, and the major pollution problems are due to winter situations with bad dispersion conditions. Therefore we need winter emissions. In hourly model calculations the emissions from heating is adjusted by the hourly temperature and degree-days.

Other places there may also be great seasonal variations in the consumption, and it is necessary to take this into account when preparing hourly emissions.

Input data to CONS-EMI

KX, KY,NCOMP	Grid dimensions, number of points eastward and northward and number of compounds (max 6)
INFILE	File with consumption figures (with apostrophes and .FLD)
INFAK	File with emission factors (with apostrophes and .DAT)
OUTFI	Name of the output files (with apostrophes). The data fields will be written binary to the file OUTFI.FLD, the output is written to the file OUTFI.PRN

NFU, (IFU(I), I=1, NFU)

NFU	Number of fuel types/consumption fields (max. 8)
IFU	Fuel type code from emission factor file

IUV	IUV=0	Yearly emissions
	IUV=1	Average hourly emissions shall be calculated

(PALL(J), J=1,NFU)

% of the total consumption allocated. This should be 100 % from CONS-FIE, but we have the opportunity to adjust this by multiplying the data with 100./PALL(J).

If IUV = 1, then:

(PPER(J), J=1,NFU)	% of the total consumption that is used during the period

Program POI-EMIS

In the program POI-KILD we calculate concentrations from point sources. All informations about the point sources (name, position, stack parameters and emissions) are collected in a **stack-file** INSTA, see the description for POI-KILD.

In some cases we start with informations about activity data as **fuel consumption** or **production** instead of emission data. The program POI-EMIS is prepared as a tool for calculating average hourly emissions from such consumption data, especially when we have a series of different consumption data sets. For this you have to prepare a stack-file as described for POI-KILD, see also the example to this.

In POI-EMIS the stack-file INSTA is read and copied to a new stack-file OUTFI.DAT until two dummy lines preceding the source data. For each source the emissions are calculated, using consumption data, period length and emission factors. The program uses the same emission factor file as in CONS-EMI, see the separate description. If the emissions of all the compounds are less than certain limits, the emissions are collected in an **area source** file OUTFI.FLD and OUTFI.PRN. Otherwise they are written together with the other source data to OUTFI.DAT, according to the POI-KILD format.

The fuel consumption data may be for a year or a shorter period, and the program calculates the average emission rate kg/h.

Input data to POI-EMIS

KX, KY, NCOMP	Grid dimensions, number of points eastward and north-ward and number of compounds (max 6)
INSTA	Input file with stack and consumption data (with apo-strophes and .DAT)
OUTFI	Name of the output files (with apostrophes) Stack data and point source emissions are written to OUTFI.DAT
	The area emission fields (if any) will be written binary to the file OUTFI.FLD, the output is written to the file OUTFI.PRN
PERIOD, PLACE	Both with apostrophes
ICON	We may have different sets with consumption data at the file (max. 5), we want to use no. ICON
NDAY	Number of days in the data period
INFAK	Emission factors are read from INFAK (with apostrophes and .DAT).
(QLIM(I), I=1,NCOMP)	Limits for point source emissions (kg/h)

Consumption data

The preliminary stack-file INSTA contains both data about the stack and the consumption or other activity. Instead of the line with

STACK, (SKOR(I), I=1,8), ICOD, (EM(I), I=1 NCOMP),
the program reads
STACK, SKOR(I), I=1, 2), SKORTE, ICOD, IFU, (CON(I), I=1, ICON).

STACK	Stack (factory) name A10 (without apostroph)
SKOR (1), (SKOR(2)	UTMX (km), co-ordinates of the stack UTMY (km)
SKORTE	Text, corresponding to STACK (3) -- STACK (9), within apostrophes.
ICOD	Source group code 1-9
IFU	Fuel type code, according to the emission factor file.
CON	Consumption data sets, with units corresponding to the emission factor file.

Emission factors are read from the file INFAK (with apostrophes and .DAT), see the separate description of the emission factor file.

Stack data and point source emissions are written to the file OUTFI.DAT, the area emission fields (if any) will be written binary to the file OUTFI.FLD, the output is written to the file OUTFI.PRN.

NDAY	Number of days in the period (365, 182 or other)
PERIOD	New period (with apostrophes) The period for the emission data may be different from the consumption data

PLACE and SOURCE will be taken from INFILE, PERIOD from INFILE if IUV = 0, and DATE is the current date.

Emission factors are read from the file INFAK.DAT (with apostrophes and .DAT). See the separate description of the emission factor file.

The emission factors will vary from place to place, depending on access to "clean" fuels the burner type and many other factors. The SO_2-factor will be 20 * %S * ρ, where %S is the sulphur content and ρ is the density of the fuel.

To calculate annual emission fields to file EMIS-DOM, IUV is set to 0, but PPER, NDAY and PERIOD is not read.

ARE-KILD, dispersion calculations for area sources

An area source represents the emission from several small sources within a grid square, mostly from domestic heating, small industries and road traffic. The emission field is often calculated from fields with oil, wood or coal consumption or traffic work.

The program ARE-KILD calculates sector averaged long term concentrations at ground level in a grid of receptor points from sources in an emission field given in the same grid system.

In the program the pollution contribution from an area source is taken into account by considering 100 point sources evenly distributed over the square-km (Fortak, 1970). Each area source is assigned to a box class, which defines the height of the initial vertical turbulence elements, which again is a function of the average building height. The dispersion from an area source is tabulated as a function of distance, wind speed, stability and box class. Actual concentration values are calculated by linear interpolation between tabulated values and multiplied by the emission.

The vertical standard deviation σ_z is calculated from:

$$\sigma_z^2 = \sigma_{z_o}^2 + H_b^2 \cdot F_a$$

where

σ_{z_o} = a * x^P

H_b = box height

F_a = wind speed correction factor = 0.5 * $\left(1.0 + 0.7 / \bar{u}\right)^2$

$\bar{u}$ = mean wind speed for the wind speed class.

The result from the program will be two separate data fields, one with the total concentration, and one with the concentration contribution from emissions within a square to the square itself.

Input data for ARE-KILD

The program ARE-KILD gets it data from different sources; interactive from the terminal or from a .RUN-file, from a file with constant data, and from a METFIL-file with meteorological data (as described in separate chapter). To run the program for the first time it may be run interactive to perform a .RUN-file with all the answers for the next calculations.

Input file INFI

This file includes all information that shall be constant during a set of computations. The program gives no dialogue when reading from this file, as the file is already prepared and the questions answered. Nevertheless, we will use questions in the preparing of the file. The file will be read with a line that begins with START in columns 1-5. This means that we may put useful comments at the beginning of the file. The data at the file is read in different subroutines.

The program asks for:

TEXT One line with text as a heading for the calculations

ISIZE Grid size in meter

ANORTH It is possible to rotate the grid area. ANORTH tells the direction of the y-axis of the grid (in degrees), normally 0.0

BACKG Background concentration which may be added.

For a composite calculation with different source groups the background should be added when making the sum of the data fields in SUM-FIELD.

IDISP Selection of dispersion parameters:
1: McElroy-Pooler
2: Brookhaven
3: New values

If IDISP=3, the program reads:

SIGM (CZA(I),I=1,4) (PZA(I),I=1,4)	New name and dispersion parameters

INBOX, JFIE
Box codes are field no. JFIE on the file INBOX (with apostrophes and .FLD).

INEMIS, IFILE
The emission field is field no. IFILE at the file INEMIS (with apostrophes and .FLD).

IKO It is possible to run for selected parts of the emission field.
IKO=1 uses the whole emission field.
IKO=2 uses "splitted" emission field.

If IKO=2, then:

INCODE, IFIE
A field with area codes is read as field no. IFIE at the file INCODE (with apostrophes and .FLD).

NCOD, (IFAK(I), I=1, NCOD)
Factors 0/1 for which area codes that shall be included in the calculations. If we want to use one meteorology file for the northern part of the area and another for the southern, we prepare a data field (by INP-FIE) with 1 and 2 in the different areas. The computations are first made for area 1 using a METFIL1 AND IFAK=1 and 0, next for area 2 with a METFIL2 and IFAK=0 and 1.

SCAL,QL Emissions have to be multiplied by SCAL to have the unit kg/h.
The program is dimensioned for up to 500 area sources. In order to reduce the computer time somewhat area with emissions less than QL kg/h may

be excluded. If the emissions from these area sources represents more than 5% of the total area emissions, QL is divided by two, until the 5% limit is satisfied.

In the routine CQCALC the program gets information about the boxes:

NBOX Number of box classes, max. 9.

(HBOX(I), I=1,NBOX)
Height of each box class. This should be a measure for the height of the initial turbulence elements in each area source box, normally 1.2 * average building height in the square.

(HEMI(I), I=1,NBOX)
Height of emission for each box class. For traffic emissions this will be 1-2 m, for domestic heating the box height.

The OUTFI.FLD-file now contains two data fields. The first field gives the total long term concentration, whereas the second gives the concentration from one grid element to itself. This gives us an opportunity to use other models to calculate the local contribution.

POI-KILD, dispersion calculations for point sources

The program POI-KILD calculates sector averaged long term average concentrations at ground level in a grid of receptor points, with emission from several point sources, taking into account data on dispersion, topography, buildings and penetration through an upper stable layer. The program is dimensioned for 80 sources, but this can be easily increased. Another possibility is to split the sources into different source groups, make separate calculations for each source groups, and add the results by SUM-FIE.

Input data for POI-KILD

The program POI-KILD gets its input data from different sources; interactive from the terminal or from a RUN-file, from a file with **stack data**, and from a METFIL-file with meteorological data (described in separate chapter). To run the program for the first time it may be run interactive to perform a .RUN-file with all answers for the next calculations.

Stack-file INSTA

All stack data are read from the file INSTA (which should be of type .DAT). At this file all other data which should remain constant are collected, whereas data which varied from one run to another should be read interactive from a .RUN-file.

The program does not give a dialogue when reading from the file INSTA, as the file is already prepared and the questions answered. Nevertheless, questions will be useful in preparing the file. The file is read until a line that begins with START in columns 1-5. This means that we may put useful comments at the beginning of the file. The data at the file is read in different subroutines.

After the line with START the program reads:

TEXT	One line with a heading for the computations (A80)
ISIZE	Grid size in meter (integer).
UTMX, UTMY	Co-ordinates for south-west corner of the grid array (real).
ANORTH	Direction of the Y-axis (in degrees, counter- clockwise, normally =0 (real).

We may perform calculations for standard components. 1=SO_2, 2=NO_x, 3=CO, 4=Particles, 5=HC and 6=Other. The program asks if this is OK, Y/N.

If YN=N, the program reads new component names.

NCOMP, (LCOMP(I), I=1,NCOMP)

The number of components, and their names (in apostrophes) (max. 6). The calculations are carried out for component no. ICOMP, which is read interactive, see page 4.

BACKG Background concentration of component no. ICOMP may be added to the result. For a composite calculation with different source groups the background should be added when making the sum of the data fields

TOP Do you want to correct for topography? Y/N

If TOP=Y, the program asks for

TOPFIL Name of the topography field (with apostrophes and .FLD)

DGR Standard ground level reflection factor ALPHA = 1.0 OK? Y/N

If DGR=N, the program asks for

ALPHA Ground level reflection factor, which is the relative amount of inert gas reflected from the surface by impaction. Can be used to estimate the effect of deposition on concentrations.

DHL It is possible to use different dispersion parameters for high and low sources (Brookhaven/McElroy-Pooler) if we read IDISP=3 in the routine SIGMA (see below). Standard limit between high and low sources = 50 m OK? Y/N.

If DHL=N, the program asks for

HL New limit for distinguishing between high and low sources. Sources with effective stack height >HL will use one set of dispersion parameters for high sources, other for low sources.

IDISP Selection of dispersion parameters:

1: McElroy-Pooler
2: Brookhaven
3: McElroy-Pooler for low sources, Brookhaven for high sources with effective stack height >HL
4: New values

If IDISP=4, the program asks for

SIGL
(CZL(I), I=1,4)
(PZL(I), I=1,4)

Name and dispersion parameters for low sources

$\sigma_z\ (low) = CZL \cdot X^{PZL}$

SIGH
(CZH(I), I=1,4)
(PZH(I), I=1,4)

Name and dispersion parameters for high sources

$\sigma_z\ (high) = CZH \cdot X^{PZH}$

JEM, ITT JEM=1: Emission in g/s
=2: Emission in kg/h
ITT =1: Temperature in degrees C
=2: Temperature in degrees K

The program reads two dummy lines with heading for the stack data, and then reads the stack data, until the end of the file. In the example file these lines are used to show the variable names, and the format. A line beginning with an asterisk (*) is not read by the program.

STACK,(SKOR(I), I=1,8), ICOD,(EM(I), I=1,ICOMP)

Format: (A10,9F7.2,I2,6F7.2)

STACK	Stack (factory name) A10 (without apostrophes)
SKOR(1)	UTMX (km)
SKOR(2)	UTMY (km)
SKOR(3)	Stack base (m.a.s.l)
SKOR(4)	Stack height (m)
SKOR(5)	Stack diameter (m)
SKOR(6)	Gas temperature ° C or K, according to index ITT
SKOR(7)	Gas velocity (m/s)
SKOR(8)	Building height (default 10 m)
SKOR(9)	Building width (default 30 m)
ICOD	Source group code 1-9 (default=1),
EM	Emission data for max. 6 compounds, unit: see JEM. The calculations are performed with emission EM(ICOMP).

All data SKOR(1)-STACK(7) must be present, otherwise the program skips the source and gives a warning message.

For the building dimensions the program uses default height=10 m and width=30 m. For McElroy-Pooler dispersion parameters no building turbulence is calculated.

Program EXPO-FIE

This program reads concentration fields from a number of source groups together with a population distribution field. In its first phase the sum of the concentration values is calculated, together with a background value. If the concentration in a square is above certain limits, the corresponding population is counted. In the next phase the concentration from each source group is successively increased and reduced by +/- 10% and 25%, and new exposure figures are calculated.

The program is normally run interactive.

Input data to EXPO-FIE

KX, KY, NF	Grid dimension, number of points eastward and northward number of concentration fields (max. 8)
POPFILE	Population file name (with apostrophes and .FLD)
OUTFILE	Output file name (with apostrophes). The output will be written to OUTFILE.PRN
IPER	IPER=1: Output as persons, 2: Percentage of the total population
BACKGR	Background concentration ($\mu g/m^3$)

For NF fields is read:

KFILE, KREC, FACT
File name (with apostrophes and .FLD), record number and scale factor. If the file is the same as previous, enter 'SAME'

ILI, NLIM	ILI= 1: read start value and increments, 2: read values NLIM: number of limits (max. 20)

If ILI=1, then:

LIM, DLIM	Start value LIM and increment DLIM (may be negative)

If ILI=2, then:

(CLIM(I), I=1,NLIM)	Limit values

Program SUM-FIE

In the program SUM-FIE we may calculate a sum of different fields. It is normally run interactive.

Input data to SUM-FIE

KX, KY	Grid dimensions, number of points eastward and northward
NFIELD, NCOMP	Number of NFIELD fields (max. 12), each with NCOMP components
IPR, ISF	IPR=0 No print-out of single fields IPR=1 Print-out of single fields **before** scaling IPR=2 Print-out of single fields **after** scaling ISF=1 makes a new .FLD file

For NFIELDS we read for component no. 1:

KFILE, KREC, FAK	File KFILE (with apostrophes and .FLD). If this is the same as previous, put 'SAME' as the file name. Record number KREC at the file. The data should be multiplied by FAK.
BACKGR	Background value for component no. 1
COMPS, UNIS	COMPS = compound for the sum field (with apostrophes) UNIS = unit of the sum (with apostrophes) If you enter 'SAME' you will get the same as for the **last** field
SUMSO	SUMSO = source for the sum (with apostrophes), Ex.: SUM NOX TRAF', 'SUM SO2 OIL'
OUTFILE	Name of the output files (with apostrophes) Output is written to the file OUTFI.PRN If ISF=1 data fields will be written binary to the file OUTFI.FLD

For the following components (J= 2 to NCOMP) we read:

(KREC(N), N=1, NFIELD)	Record numbers for component J at the different files
(FAK(N), N=1, NFIELD)	New scale factors
BACKGR	Background value for component no. J
COMPS, UNIS	COMPS = compound for the sum field (with apostrophes) UNIS = unit of the sum (with apostrophes) If you enter 'SAME' you will get the same as for the **last** field

A new notation for PERIOD and PLACE will be taken from the last field.

Appendix B

Monitoring Network Description

REMOTE STATION PICARRAL

Name:	El Picarral	Kind of station:	Local		
Station Code:	50297026	Place:	C/ S. Juan de la Peña (frente a SAICA)		
Longitude:	00º 52' 16" W	Latitude:	41º 40' 13" N	Altitude:	195 m
Zone:	Urban	Kind:	Residential-Light Industry	Traffic:	Moderate
Distancie to nearest obstacle:			5,2 m		
Distancie to nearest traffic way:			6 m		

Compounds	Method	Height	Date of installation
SO2	Ultraviolet Fluorescence (UVF)	2,6 m	May 1990
PST	Beta Absorption	3,5 m	January 1995
NO2	Chemical Luminiscence	2,6 m	May 1990
CO	Infrared Absorption (IR)	2 6 m	January 1995
SH2	Ultraviolet Fluorescence (UVF)	2,6 m	May 1990

REMOTE STATION MIGUEL SERVET

Name:	Miguel Servet		Kind of station:	Local	
Station Code:	50297027	Place:	C/ Miguel Servet C/ C. de Caspe		
Longitude:	00° 52' 14" W	Latitude:	41` 38' 50" N	Altitude:	202 m
Zone:	Urban	Kind:	Residential-Commercial	Traffic:	Intense
Distance to nearest obstacles:			10 m		
Distancie to nearest traffic way:			2 m		

Compounds	Methods	Height	Date of installation
SO2	Ultraviolet Fluorescence (UVF)	2,6 m	May 1990
PST	Beta Absorption	3,5 m	January 1995
NO2	Chemical Luminiscence (CHL)	2,6 m	May 1990
CO	Infrared Absorption (IR)	2 6 m	May 1990
O3	Ultraviolet Absorption (UVA)	2,6 m	January 1995
Pb	Atomic Absorption	3 5 m	May 1990

REMOTE STATION LUIS VIVES

Name:	**Luis Vives**		**Kind of station:**	**Local**	
Station Code:	**50297028**	**Place:**	**C/ Luis Vives-Supervía**		
Longitude:	**00º 53' 38" W**	**Latitude:**	**41º 38' 1" N**	**Altitude:**	**214 m**
Zone:	**Urban**	**Kind:**	**Residential**	**Traffic:**	**Intense**
Distancie to nearest obstacles:			**8 m**		
Distancie to nearest traffic way:			**6 m**		

Compounds	Method	Height	Date of installation
SO2	Ultraviolet Fluorescence (UVF)	2,6 m	May 1990
PST	Beta Absorption	3,5 m	January 1995
NO2	Chemical Luminiscence (CHL)	3,5 m	May 1990
CO	Infrared Absorption (IR)	2 6 m	May 1990
O3	Ultraviolet Absorption (UVA)	2,6 m	January 1995

REMOTE STATION ROGER DE FLOR

Name:	**Roger de Flor**		**Kind of station:**	**Local**	
Station Code:	**50297029**	**Place:**	**C/ Roger de Flor/Av. Madrid**		
Longitude:	**00º 54' 59" W**	**Latitude:**	**41° 39' 49" N**	**Altitude:**	**212 m**
Zone:	**Urban**	**Kind:**	**Fuentes Móviles**	**Traffic:**	**Intense**
Distance to nearest obstacle:			**3 m**		
Distance to nearest traffic way:			**3,5 m**		

Compounds	Method	Height	Date of installation
SO2	Ultraviolet Fluorescence	2,6 m	May 1990
PST	Beta Absorption	3,5 m	January 1995
NO2	Chemical Luminiscence (CHL)	2,6 m	May 1990
CO	Infrared Absorption (IR)	2,6 m	May 1990
O3	Ultraviolet Absorption (UVA)	2,6 m	May 1990

Meteorological data:
T, DD, VV, P HR, RS, R
- Temperature – Wind Velocity – Solar Radiation
- Atmospheric Pressure - Precipitation
- Wind Direction –Relative Humidity

REMOTE STATION AVDA. DE NAVARRA

Name:	Av. de Navarra		Kind of station:	Local	
Station Code:	50297030	Place:	Av. de Navarra, corner with Av. de Madrid		
Longitude:	00º 54' 00" W	Latitude:	41° 39' 20" N	Altitude:	207 m
Zona:	Urbana	Kind:	Mobil sources	Traffic:	Intense

Distancie to nearest obstacle: 1,5 m

Distancie to nearest traffic way: 3 m

Compounds	Method	Height	Date of installation
SO2	Ultraviolet Absorption (UVA)	2,6 m	May 1990
PST	Beta Absorption	3,5 m	January 1995
NO2	Chemical Luminiscence (CHL)	2,6 m	May 1990
CO	Infrared Absorption (IR)	2,6 m	January 1995
O3	Ultraviolet Absorption (UVA)	2,6 m	January 1995
Pb	Atomic Absorption	3,5 m	May 1990

REMOTE STATION PARANINFO

Name:	Paraninfo		Kind of station:	Local	
Station Code:	50297031	Place:	C/ Gran Vía (Paraninfo)		
Longitude:	00° 53' 02" W	Latitude:	41° 38' 54" N	Altitude:	208 m
Zone:	Urban	Kind:	Residential	Traffic:	Moderate

Distance to nearest obstacle: 2 m

Distance to nearest traffic way: 3,5 m

Compounds	Method	Height	Date of installation
SO2	Ultraviolet Fluorescence (UVF)	2,6 m	May 1990
PST	Beta Absorption	3,5 m	January 1995
NO2	Chemical Luminiscence (CHL)	2,6 m	May 1990
CO	Infrared Absorption (IR)	2,6 m	January 1995
O3	Ultraviolet Absorption (UVA)	2,6 m	January 1995
Pb	Atomic Absorption	3,5 m	May 1990

Meteorological data:
T, DD, VV, P, HR, RS, R
- Temperature – Wind velocity – Solar Radiation
- Atmospheric pressure - Precipitation
- Wind direction - Relative Humidity

REMOTE STATION JAIME FERRAN

Name:	Jaime Ferrán	Kind of station:	Local

Station Code:	50297032	Place:	C/ Jaime Ferrán / Cl Franklin		
Longitude:	00° 51' 51" W	Latitude:	41º 40' 27" N	Altitude:	196 m
Zone:	Suburban	Kind:	Light industry	Traffic:	Very light

Distancie to nearest obstacle: 4 m

Distancie to nearest traffic way: 3 m

Compounds	Methods	Height	Date of Installation
SO2	Ultraviolet Fluorescence (UVF)	2,6 m	May 1990
PST	Beta Absorption	3,5 m	January 1995
NO2	Chemical Luminiscence (CHL)	2,6 m	May 1990
CO	Infrared Absorption (IR)	2,6 m	January 1995
O3	Ultraviolet Absorption (UVA)	2,6 m	January 1995
Pb	Atomic Absorption	3,5 m	January 1995

MOBILE UNIT

Name: Mobiel unit   Kind of station:

Station Code: Place:

Longitude: Latitude: Altitude:

Zone: Kind: Traffic:

Distance to nearest obstacle:

Distance to nearest traffic way:

Compounds	Method	Height	Date of installation
SO2	Ultraviolet Fluorescence (UVF)	3 m	January 1991
PST	Beta Absorption	3,5 m	January 1995
NO2	Chemical Luminiscence (CHL)	3 m	January 1991
SH2	Ultraviolet Fluorescence (UVF)	3 m	January 1991
NH	Chemical Luminiscence (CHL)	3 m	January 1991
Pb	Atomic Absorption	3,5 m	January 1995
CO	Infrared Absorption (IR)	2,6 m	Jaunary 1995
Pb	Atomic Absorption	3,5 m	January 1995
03	Ultraviolet Absorption (UVA)	2,6 m	January 1995

Appendix C

Monitoring Network Description

OZONE

The Royal Decree 1494/1995, of 8 of September, of atmospheric environmental protection establish the air quality criteria for ozone. Those criteria are:

1. Threshold of health protection.

Average concentration in 8 hours: 110 $\mu g/m^3$

2. Threshold of vegetation protection.

Average concentration in 1 hours: 200 $\mu g/m^3$ N

Average concentration in 24 hours: 65 $\mu g/m^3$ N

3. Threshold of information to population.

Average concentration 1 hour: 180 $\mu g/m^3$ N

4. Threshold of alert to population.

Average concentration in 1 hour: 360 $\mu g/m^3$ N

SULPHUR OXIDES AND TOTAL SUSPENDED PARTICLES

In accordance with Royal Decree 1613/1985, of 1 of Octuber, the values are:

SO_2 and T. S. P.
Limit values for sulphur dioxide and suspended particles in µg/m^3 N.

Period of time		Associated value for suspended particles *	
	Limit value for sulphur dioxide	Standard smoke method	Gravimetric method
Annual	80	> 40	>150
	120	< 40	<150
	Mediana of the daily mean values registered during the annual period.		
Winter	130	> 60	> 200
	180	< 60	< 200
	Mediana of the daily mean values registered during the winter period.		
Annual	250 It should not be exceeded during more than 3 consecutives days	> 150	> 350
	180 It should not be exceeded during more than 3 consecutives days	<150	< 350
	98 percentile of the all daily mean values registered during the annual period .		
* Both methods can be used.			

TSP

Limit values for suspended particles in µg/m^3 N.

Period of time	Limit value for suspended particles *	
	Standard smoke method	Gravimetric method
Annual	80 (Mediana of the daily mean values registered during the annual period.)	150 (Arithmethic average of the daily mean values registered during the annual period)
Winter	130 (Mediana of the daily mean values registered during the winter period.)	
Annual	250 (98 percentile of all daily mean values registered during the annual period)	300 (95 percentile of all daily mean values registered during the annual period)
	It should not be exceeded during more than 3 consecutives days	
* Both methods can be used.		

SO_2

Guide values for sulphur dioxide in µg/m^3 N.

Period of time	Guide value for SO2
Annual	40 – 60 (Arimethic average of the daily mean values registered during the year.)
24 hours	100 –150 (Daily mean value)

TSP

Guide value for suspended particles (standard smoke method) in µg/m^3 N.

Period of time	Guide value for suspended particles.
Annual	40 – 60 (Arimethic average of the daily mean values registered during the year.)
24 hours	100 -150 (Daily averaged value)

SO_2 and T. S. P.

Reference values for state of emergency.

Product of concentrations of SO2 and suspended particles in µg/m^3 N.	Emergencies		
	1. degree	2. degree	Total
1 day average	160.10^3	300.10^3	500.10^3
3 days average	125.10^3	250.10^3	420.10^3
5 days average	115.10^3	230.10^3	
7 days average	110.10^3		

Nitrogen oxides

The Royal Decree 717/1987, of 27 of March, of atmospheric environmental protection establish the criteria of air quality for nitrogen dioxide.
These criteria are:

Limit values for nitrogen dioxide in µg/m^3 N.

Period of reference	Limit values for nitrogen dioxide
	200
	98 percentile calculated from the averaged values per hour or period under one hour, registered during throughout all year

Guide values for nitrogen dioxide in µg/m^3 N.

Period of time	Limit values for nitrogen dioxide
Year (composed of one hour or under one hour period units)	50
	50 percentile calculated from the averaged values per hour or period under one hour, registered during throughout all year
	135
	98 percentile calculated from the averaged values per hour or period under one hour, registered during throughout all year

Reference values for state of emergency for nitrogen dioxide in µg/m^3 N.

Period of time	Emergencies		
	First grade	Second grade	Third grade
1 Hour	957	1270	1700
24 Hours	565	750	1000
7 Days	409	543	724

Appendix D

Traffic, Industrial and Domestic Emission Data

TRAFFIC

MAP OF : SO2 UNIT: KG/DAY SOURCE: TRAFFIC
PERIOD : 1996 PLACE: ZARAGOZA GRID SIZE: 500 METER
CREATED: 2000/03/13 12.55 FILE: TRAFFIC.FLD
MAXIMUM VALUE IS 4.2770E+00, IN (2,11)
SUM= 1.91003E+02 SCALE FACTOR: 1.0E-03

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	.	.	.	.	.	2030.	1624.	.	.	125.	.	481.	.	.	.	.	.
J=14	.	.	.	.	.	.	609.	2891.	2086.	2932.	2277.	4151.	2246.	1253.	1078.	.	.
J=13	.	.	.	.	.	.	.	365.	650.	1713.	1432.	517.	713.	403.	118.	.	.
J=12	.	.	.	.	.	.	.	26.	541.	1344.	1511.	546.	685.	65.	317.	1106.	1364.
J=11	.	4277.	949.	1746.	.	.	44.	67.	427.	1766.	2826.	1486.	2068.	1548.	.	.	.
J=10	.	.	1040.	2109.	1130.	.	629.	682.	2481.	2793.	1696.	941.	884.	1729.	460.	.	.
J= 9	.	.	317.	1815.	4248.	1498.	2009.	3274.	664.	1266.	2363.	1477.	1549.	300.	1830.	.	.
J= 8	.	.	199.	456.	2056.	1121.	1743.	1572.	1822.	247.	2289.	1991.	1086.	2371.	482.	.	.
J= 7	.	.	.	508.	2319.	577.	1712.	2216.	2983.	2809.	2577.	793.	3379.	2009.	711.	.	.
J= 6	.	958.	1035.	993.	45.	2435.	2064.	1388.	3160.	2623.	3305.	1647.	1855.	582.	64.	.	.
J= 5	.	61.	440.	190.	323.	1346.	582.	1841.	2925.	919.	1904.	1953.	1277.	1260.	51.	.	.
J= 4	.	2.	58.	265.	.	336.	2156.	2574.	241.	1156.	1916.	659.	44.	192.	879.	.	.
J= 3	56.	77.	124.	242.	115.	194.	1820.	23.	292.	333.	915.	126.	48.	.	.	755.	.
J= 2	12.	.	.	12.	259.	618.	1607.	487.	70.	72.	48.	108.	34.	.	.	.	.
J= 1	.	.	.	.	.	716.	76.	433.	12.	.	.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

MAP OF : PST UNIT: KG/DAY SOURCE: TRAFFIC
PERIOD : 1996 PLACE: ZARAGOZA GRID SIZE: 500 METER
CREATED: 2000/03/13 12.55 FILE: TRAFFIC.FLD
MAXIMUM VALUE IS 5.7440E+00, IN (5, 9)
SUM= 2.56383E+02 SCALE FACTOR: 1.0E-03

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	.	.	.	.	.	2746.	2196.	.	.	169.	.	581.	.	.	.	.	.
J=14	.	.	.	.	.	.	824.	3497.	2821.	3965.	3079.	5614.	3038.	1516.	1304.	.	.
J=13	.	.	.	.	.	.	.	442.	879.	2316.	1937.	699.	964.	487.	143.	.	.
J=12	.	.	.	.	.	.	.	32.	731.	1817.	2043.	738.	926.	88.	428.	1495.	1845.
J=11	.	5174.	1283.	2361.	.	.	59.	91.	577.	2389.	3822.	2009.	2796.	2093.	.	.	.
J=10	.	.	1406.	2852.	1367.	.	761.	922.	3355.	3777.	2294.	1272.	1195.	2338.	622.	.	.
J= 9	.	.	429.	2454.	5744.	2026.	2717.	4427.	898.	1712.	3195.	1998.	2095.	405.	2475.	.	.
J= 8	.	.	269.	616.	2780.	1516.	2357.	2126.	2464.	334.	3096.	2692.	1468.	3207.	652.	.	.
J= 7	.	.	.	687.	3136.	781.	2315.	2996.	4033.	3799.	3485.	1072.	4570.	2717.	961.	.	.
J= 6	.	1296.	1400.	1343.	61.	3293.	2791.	1876.	4273.	3548.	4469.	2227.	2509.	787.	86.	.	.
J= 5	.	83.	596.	256.	437.	1820.	788.	2490.	3955.	1243.	2574.	2642.	1727.	1703.	68.	.	.
J= 4	.	3.	79.	359.	.	455.	2915.	3481.	326.	1564.	2591.	891.	60.	259.	1189.	.	.
J= 3	76.	105.	168.	328.	155.	262.	2461.	31.	395.	450.	1237.	170.	65.	.	.	913.	.
J= 2	17.	.	.	16.	350.	836.	2174.	659.	95.	97.	65.	146.	46.	.	.	.	.
J= 1	.	.	.	.	.	968.	103.	586.	17.	.	.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

MAP OF : NOX UNIT: KG/DAY SOURCE: TRAFFIC
PERIOD : 1996 PLACE: ZARAGOZA GRID SIZE: 500 METER
CREATED: 2000/03/13 12.55 FILE: TRAFFIC.FLD
MAXIMUM VALUE IS 1.0994E+02, IN (2,11)
SUM= 4.84399E+03 SCALE FACTOR: .1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	.	.	.	.	.	514.	411.	.	.	32.	.	124.	.	.	.	.	.
J=14	.	.	.	.	.	.	154.	743.	529.	743.	577.	1052.	569.	322.	277.	.	.
J=13	.	.	.	.	.	.	.	94.	165.	434.	363.	131.	181.	104.	30.	.	.
J=12	.	.	.	.	.	.	.	7.	137.	340.	383.	138.	173.	17.	80.	280.	346.
J=11	.	1099.	240.	442.	.	.	11.	17.	108.	448.	716.	376.	524.	392.	.	.	.
J=10	.	.	263.	534.	290.	.	162.	173.	629.	708.	430.	238.	224.	438.	117.	.	.
J= 9	.	.	80.	460.	1076.	380.	509.	829.	168.	321.	599.	374.	393.	76.	464.	.	.
J= 8	.	.	50.	115.	521.	284.	442.	398.	462.	63.	580.	504.	275.	601.	122.	.	.
J= 7	.	.	.	129.	587.	146.	434.	561.	756.	712.	653.	201.	856.	509.	180.	.	.
J= 6	.	243.	262.	252.	11.	617.	523.	352.	801.	665.	837.	417.	470.	147.	16.	.	.
J= 5	.	16.	112.	48.	82.	341.	148.	467.	741.	233.	482.	495.	323.	319.	13.	.	.
J= 4	.	.	15.	67.	.	85.	546.	652.	61.	293.	485.	167.	11.	49.	223.	.	.
J= 3	14.	20.	31.	61.	29.	49.	461.	6.	74.	84.	232.	32.	12.	.	.	194.	.
J= 2	3.	.	.	3.	66.	157.	407.	123.	18.	18.	12.	27.	9.	.	.	.	.
J= 1	.	.	.	.	.	181.	19.	110.	3.	.	.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

FACTORIES.

firm name	X km	Y km	Z m	stack height	exit diam.	exit temp	gas vel	constr. heiwidcode	NOx	CO	CO2	NMVOC	CH4	N20	Part	
RICO FUND1	6.6	5.7		22	2.5	95	19.9		1.7	7.7	1.9	.2	.2	.1	2.557	Steel work
RICO FUND2	6.6	5.7		22	2.5	95	19.9								2.557	Steel work
RICO LAMIN	6.6	5.7		40	1.2	650	2.7								.086	Steel work
RICO LAMIN	6.6	5.7		40	1.2	650	2.7								.152	Steel work
SAICA CALD	6.3	5.25		35	3.42	135	19.3		26.7	120.1	29.4	2.7	2.7	1.0		Paper
ZARAGOZANA	5.45	2.25		12	.4	70	15		.5	2.2	.5	.0	.0	.0		Brewery
ZARAGOZANA	5.45	2.25		12	.8	70	15									Brewery
ZARAGOZANA	5.45	2.25		12	.8	70	15									Brewery
ZARAGOZANA	5.45	2.25		15	.8	100	15									Brewery
ZARAGOZANA	5.45	2.25		15	.6	100	15									Brewery
ZARAGOZANA	5.45	2.25		15	.6	70	15									Brewery
ZARAGOZANA	5.45	2.25		5	.4	70	15									Brewery
EBROACERO'	2.80	1.00		30	1.68	40	13.5		3.4	15.4	3.8	.3	.3	.1		horno de arco
EBROACERO'	2.80	1.00		30	1.68	229	13.6									caldera
AMYLUM IBE	6.05	6.05		10.3	1.2	50	3.93		5.5	24.9	6.1	.6	.6	.2		
AMYLUM IBE	6.05	6.05		10.3	1.2	50	3.93								.365	germen
AMYLUM IBE	6.05	6.05		20.4	1.8	50	1.								.657	gluten
AMYLUM IBE	6.05	6.05		19	1	56	11.0								2.115	recuperador
AMYLUM IBE	6.05	6.05		19	1	56	11.0								.329	secadero gluten
AMYLUM IBE	6.05	6.05		9.5	.6	45	22.8								.805	almidon n
AMYLUM IBE	6.05	6.05		9.5	.6	45	22.8								.402	almidon m
AMYLUM IBE	6.05	6.05		9.5	.6	45	22.8								.338	dextrosa
firm name	X km	Y km	Z m	stack height	exit diam.	exit temp	gas vel	constr. heiwidcode							5.011	

DOMESTIC

MAP OF : SO2 UNIT: KG/DAY SOURCE: HEATING
PERIOD : 1996 PLACE: ZARAGOZA GRID SIZE: 500 METER
CREATED: 2000/03/20 16.13 FILE: WINTER-HEATING.FLD

MAXIMUM VALUE IS 1.2794E+03, IN (11, 8)
SUM= 6.01834E+03 SCALE FACTOR: 1.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=14	.	.	.	.	.	.	.	.	.	.	.	.	18.	14.	.	.	.
J=13	.	.	.	.	.	.	.	.	.	.	.	.	17.	.	.	.	.
J=12	.	.	.	.	.	.	.	.	.	.	.	.	17.	.	8.	19.	17.
J=11	.	17.	17.	17.	.	.	.	.	4.	4.	.	6.	17.	17.	18.	17.	.
J=10	.	.	.	.	54.	.	.	.	20.	4.	8.	28.	26.	17.	17.	.	.
J= 9	.	.	4.	4.	.	.	24.	25.	80.	79.	80.	90.	8.	17.	17.	.	.
J= 8	.	.	17.	17.	17.	7.	84.	55.	85.	88.	1279.	100.	86.	17.	7.	.	.
J= 7	.	.	.	.	7.	17.	26.	30.	108.	115.	195.	78.	89.	15.	15.	.	.
J= 6	.	.	17.	17.	.	13.	629.	38.	147.	103.	129.	78.	42.	20.	15.	.	.
J= 5	.	17.	17.	17.	.	67.	67.	67.	95.	75.	128.	91.	19.	15.	.	.	.
J= 4	.	4.	4.	.	.	67.	67.	67.	4.	31.	30.	23.	15.	15.	7.	.	.
J= 3	4.	4.	4.	4.	.	15.	15.	1.	.	32.	24.	15.	7.	.	.	.	.
J= 2	4.	4.	4.	4.	.	165.	15.	8.	.	7.	7.	15.	7.	.	.	.	.
J= 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

MAP OF : Partículas UNIT: KG/DAY SOURCE: HEATING
PERIOD : 1996 PLACE: ZARAGOZA GRID SIZE: 500 METER
CREATED: 2000/03/20 16.13 FILE: WINTER-HEATING.FLD

MAXIMUM VALUE IS 3.9435E+02, IN (11, 8)
SUM= 1.16790E+03 SCALE FACTOR: .1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=14	.	.	.	.	.	.	.	.	.	.	.	.	29.	23.	.	.	.
J=13	.	.	.	.	.	.	.	.	.	.	.	.	28.	.	.	.	.
J=12	.	.	.	.	.	.	.	.	.	.	.	.	28.	.	14.	32.	28.
J=11	.	27.	27.	27.	.	.	.	.	7.	7.	.	9.	28.	28.	29.	28.	.
J=10	.	.	.	.	89.	.	.	.	41.	7.	14.	65.	55.	28.	28.	.	.
J= 9	.	.	6.	6.	.	.	54.	58.	97.	96.	95.	130.	14.	28.	28.	.	.
J= 8	.	.	28.	28.	28.	12.	110.	154.	120.	124.	3943.	163.	118.	28.	12.	.	.
J= 7	.	.	.	.	11.	27.	61.	72.	188.	211.	431.	94.	129.	24.	24.	.	.
J= 6	.	.	28.	28.	.	21.	1025.	61.	314.	172.	259.	91.	55.	40.	24.	.	.
J= 5	.	28.	28.	28.	.	109.	109.	109.	146.	82.	255.	135.	37.	24.	.	.	.
J= 4	.	6.	6.	.	.	109.	109.	109.	6.	76.	72.	51.	24.	24.	12.	.	.
J= 3	6.	6.	6.	6.	.	24.	24.	1.	.	80.	55.	24.	12.	.	.	.	.
J= 2	6.	6.	6.	6.	.	27.	24.	13.	.	12.	12.	24.	12.	.	.	.	.
J= 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

MAP OF : NOx UNIT: KG/DAY SOURCE: HEATING
PERIOD : 1996 PLACE: ZARAGOZA GRID SIZE: 500 METER
CREATED: 2000/03/20 16.13 FILE: WINTER-HEATING.FLD

MAXIMUM VALUE IS 1.3788E+02, IN (11, 8)
SUM= 1.96728E+03 SCALE FACTOR: .1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
J=15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=14	.	.	.	.	.	.	.	.	223.	223.	223.	330.	42.	30.	.	.	.
J=13	.	.	.	.	.	.	.	.	223.	223.	223.	330.	41.	.	.	.	.
J=12	.	.	.	.	.	.	.	.	223.	223.	223.	330.	41.	.	20.	45.	41.
J=11	.	27.	27.	27.	.	.	114.	114.	10.	10.	223.	12.	41.	41.	42.	41.	.
J=10	.	.	.	33.	89.	.	114.	114.	178.	10.	52.	51.	48.	41.	41.	.	.
J= 9	.	.	43.	43.	.	.	182.	183.	249.	249.	266.	258.	20.	41.	41.	.	.
J= 8	.	.	41.	41.	41.	87.	253.	210.	130.	256.	1379.	268.	255.	41.	87.	.	.
J= 7	.	.	.	.	133.	27.	184.	187.	274.	281.	408.	248.	258.	174.	174.	.	.
J= 6	.	.	41.	41.	.	21.	1025.	169.	310.	270.	294.	247.	126.	178.	174.	.	.
J= 5	.	41.	41.	41.	.	109.	109.	109.	263.	245.	293.	260.	177.	174.	.	.	.
J= 4	.	6.	43.	.	.	109.	109.	109.	6.	188.	187.	181.	174.	174.	87.	.	.
J= 3	6.	6.	6.	6.	.	174.	174.	1.	.	189.	182.	174.	87.	.	.	.	.
J= 2	6.	6.	6.	6.	.	27.	174.	13.	.	193.	87.	174.	87.	.	.	.	.
J= 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

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REPORT SERIES Scientific Report	REPORT NO. OR 33/2000	ISBN 82-425-1193-4 ISSN 0807-7207	
DATE	SIGN.	NO. OF PAGES 112	PRICE NOK 260,-
TITLE Air Pollution Modelling in Zaragoza		PROJECT LEADER Frederick Gram	
		NILU PROJECT NO. E-100087	
AUTHOR(S) Frederick Gram and Jorge Martinez Chamorro		CLASSIFICATION * A	
		CONTRACT REF.	
REPORT PREPARED FOR Norwegian Institute for Air Research			

ABSTRACT
Concentrations of SO_2, particles and NO_x in Zaragoza has been modelled, using programs in the KILDER Air Pollution Modelling System. For SO_2 there is a good agreement between calculated winter values and annual mean values. Particles and NO_x gives bad agreement, possibly due to influence at the monitoring station from local raod traffic.

NORWEGIAN TITLE
Modellering av luftforurensning i Zaragoza i Spania

KEYWORDS		
Zaragoza	Air pollution	Modelling

ABSTRACT (in Norwegian)

** Classification A Unclassified (can be ordered from NILU)*
B Restricted distribution
C Classified (not to be distributed)