European Topic Centre on Air Quality

AIR POLLUTION BY OZONE IN THE EUROPEAN UNION

Exceedance of Ozone Threshold Values in 1996 and Summer 1997

By

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October 1997

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PREFACE

This report is based upon data collected by the European Commission under the Directive 92/72/EEC on air pollution by ozone and presented to the European Council in their meeting of October 1997 as two separate reports, one covering the year 1996, the other covering summer 1997. The Commission requested the European Environment Agency to assist in the reporting obligations. The reports were subsequently produced by the European Topic Centre on Air Quality under contract to the Agency. The separate reports are also available in electronic form on the EEA homepage on the Internet (http://www.eea.eu.int). In this topic report the annual 1996 and summer 1997 reports are reproduced in their original form as presented to the Commission. The differences in available data, the set of threshold values, the number of stations, the location of stations, and the status of the information based on validated 1996 data and non-validated 1997 data, justifies such an approach.

A major asset of this report is the timeliness of its delivery. The assessment of ozone episodes in 1997 was based upon data measured only two months earlier, while the normal production time from field measurements to validated assessment reports is rarely less than eighteen months. This timely reporting has only been possible with the support of the individual contact points within each Member State and the efficient communication established.

The harmful effects of tropospheric ozone on human health and well-being as well as damage to ecosystems is now being recognised as a major concern throughout the Member States of the European Union. The European Community has taken steps to deal with the problem through a number of Directives including the 92/72/EEC Directive on ambient ozone and the 96/62/EEC Directive on ambient air quality assessment and management (the Framework Directive) as well as the decision to develop a Community strategy for the reduction of ozone pollution. The measures necessary to combat pollution remain however a responsibility of each Member State and require political decisions with cost implications and consequences for the development of activities in society. In this political process basic and reliable information on the extent and severity of the problem is essential.

It is the intention of EEA to continue yearly reporting and assessment of the ground level ozone situation in Europe in close co-operation with the European Commission.

Gordon McInnes
Programme Manager

SUMMARY

This report summarises the annual information on exceedances of ozone threshold values during 1996 and gives a first evaluation of the observed exceedances of the thresholds during summer 1997 (April-August). According to the Council Directive (92/72/EEC) on air pollution by ozone, Member States have to provide information on ozone levels (statistical parameters, number and duration of exceedances of specified threshold values) on an annual basis before 1 July of the next year. Additionally, exceedances of the threshold values for population information and warning, as set in the Directive, must be reported to the Commission within one month after occurrence. The analysis for the year 1996 presented in this report is based on information made available before 6 August 1997. By then information for the calendar year 1996 had been received from 13 Member States. Data from France was not available. Data from Italy was received at a very late stage and inconsistent with the agreed format and could not be included fully in the report. As weather conditions during August 1997 indicated a high probability of occurrence of exceedances, the preparation of the report on summer 1997 was postponed for two weeks in order to include as far as possible information on the situation in August. All information received not later than 19 September has been included. 14 Member States submitted data; information from France was not available.

From an evaluation of the exceedances and annual statistics, the following conclusions are reached:

- Ozone monitoring data for the year 1996 have been received from 836 stations within 13 EU Member States; for Summer 1997 14 Member States provided information for a total of 1070 stations.

- Spatial coverage and documentation on monitoring data quality need improvement. Depending on the local situation, the ozone monitoring stations are characterised as rural, urban, street or other (e.g. industrial). The present subset of rural stations is not representative for the land area of the EU: the subset is estimated to cover only 40-50% of the area. The geographical coverage of the rural stations is rather adequate in North West Europe but in other regions gaps are noted. The subset of urban stations is insufficient to estimate the exposure of the population living in cities with more than 25 000 inhabitants: the urban stations cover about 30% of the urban population, and hence less than 20% of the total population in the EU.

- The threshold for warning of the public (360 $\mu g/m^3$ as hourly average concentration) was exceeded in two Member States in 1996: Greece, two stations in Athens on 21 May 1996 (361 and 391 $\mu g/m^3$) and in Italy, at stations in Palermo (14 November 1996, 368 $\mu g/m^3$) and in Porto Torres (16 December 1996, 371 $\mu g/m^3$). During summer 1997, one exceedance was observed in the Athens conurbation (station Lykovrissi, 383 $\mu g/m^3$ on 18 June).
- The threshold value for providing information to the population (180 $\mu g/m^3$ as hourly average concentration) was exceeded in 1996 in 12 (out of 13 reporting) EU Member States during a limited number of days; Ireland did not report exceedances.

During Summer 1997 this threshold value was exceeded in all Member States with the exception of Ireland, Finland, Denmark and Sweden. In the Member States where exceedances were observed, the number of days on which at least one exceedance was observed ranged from five in Luxembourg to 49 in Italy. 41% of all stations reported one or more exceedances during the 1997 summer season. An initial estimate was made of the percentage of the urban population which was exposed to at least one exceedance of the population information threshold. From all the cities in which at least one monitoring station was operational, 43% (157 cities) reported one or more exceedances. 25 million people (34% of the population in cities with monitors operational) may have been exposed to these exceedances.

- In 1996, the threshold value set for the protection of human health population (110 $\mu g/m^3$ as 8-hourly average concentration) was exceeded substantially and in all reporting Member States. The subset of urban stations is assumed to give representative values for the exposure of an urban population of about 65 million people. 86% of this population was exposed to ozone levels exceeding the threshold during at least one day; 6% was exposed to exceedances during more than 50 days.

- In 1996 the threshold value of daily average concentrations set for the protection of vegetation (180 $\mu g/m^3$ as hourly average concentration) is exceeded substantially (by up to a factor 3), widely (in all reporting Member States) and frequently (four Member States report exceedances during more than 300 days at one or more of their stations). Exceedances during more than 150 days are estimated for more than 31% of the area for which the subset of rural stations reports representative values. The threshold value of hourly average concentrations was exceeded largely and widely (reported by 10 out of 13 Member States) on a limited number of days: in 44% of the mapped area exceedances were reported during 1- 5 days.

- A limited presentation of the percentile values observed in the period 1989-1996 is given for four Member States for which this information was available. Based on the reported data no conclusive answer concerning a trend in percentile values can be given. For the summer season it is noted that in summer 1997 all relevant indicators (the number of stations which reported an exceedance; the number of exceedances at those stations and maximum concentrations this year) were lower than during the 1995 and 1996 summer seasons. This difference can mainly be attributed to year-to-year weather variability.

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EXCEEDANCE OF OZONE THRESHOLD VALUES IN THE EUROPEAN COMMUNITY IN 1996.

Summary based on the information reported in the framework of the Council Directive 92/72/EEC on air pollution by ozone

Report to the Commission by the European Environment Agency
European Topic Centre on Air Quality

Frank de Leeuw
Esther van Zantvoort

September 1997

research for
man and environment

1. INTRODUCTION

Ozone, O_3, is a strong photochemical oxidant which may cause serious health problems and damage to materials and ecosystems. Human exposure to elevated levels of ozone concentrations can give rise to inflammatory responses and decreases in lung function. Symptoms observed are coughing, chest pain, difficulty in breathing, headache and eye irritation. Both laboratory and epidemiological data indicate large variations between individuals in response to episodic ozone exposure; the effects seem to be more pronounced in children than in adults. Studies indicate that exposure to ozone concentrations in the range 160-360 $\mu g/m^3$ for a period of 1-8 hours, often observed in Europe, reduces various pulmonary functions.

Exposure of ecosystems and agricultural crops to ozone results in visible foliar injury and in reductions in crop yield and seed production. Within the framework of the UN-ECE Convention on Long-Range Transboundary Air Pollution the critical level[1] for ozone is expressed as the accumulated ozone exposure above a threshold of 40 ppb (corresponding to 80 $\mu g/m^3$). Guideline values for this accumulated ozone exposure of 3000 ppb.h and 10,000 ppb.h are given for crops and forest, respectively.

In view of the harmful effects of photochemical pollution in the lower levels of the atmosphere, the Council of Ministers adopted in 1992 Directive 92/72/EEC on air pollution by ozone. The Directive came into force in March 1994. It established procedures for harmonized monitoring of ozone concentrations, for exchange of information, for communication with and alerting of the population regarding ozone and optimizing the action needed to reduce ozone formation.

Article 6 of the Directive specifies how the information on monitoring results must be provided by the Member States to the Commission. Regarding the time frame, two main types of reporting can be distinguished. Information on exceedances of the so-called information threshold (article 6 sub 2) and warning threshold (article 6 sub 3) for the ozone concentration is to be provided within one month after occurrence. Information on exceedances of all threshold values given in Article 6 must be provided within six months following the annual reference period (article 6 sub 1). Article 7 of the Directive stipulates that the Commission shall at least once a year evaluate the data collected under the Directive. The present report gives an overview of ozone monitoring results of 1996. Similar overviews of the 1994 and 1995 annual data have been prepared by the European Topic Centre on Air Quality (de Leeuw *et al.*, 1995; de Leeuw and van Zantvoort, 1996). Prior to the current report an overview on ozone threshold exceedances during Summer 1996 (April-July) was also presented to the Commission (Sluyter and van Zantvoort, 1996).

The data reported here do not cover all ozone monitoring stations in the European Union. For inclusion in this report, the data must satisfy certain criteria stipulated in the Directive, concerning inter alia measuring methods, sampling methods, station siting, quality assurance and documentation. Formats on the transfer of data have been defined by the Expert Group on Photochemical Pollution. This group, established by the

[1] Critical levels are defined as concentrations of pollutants in the atmosphere above which direct adverse effects on receptors, such as plants, ecosystems or materials may occur according to present knowledge (Bull, 1991).

Commission following Article 7 of the Directive, had several meetings to co-ordinate the work within the Member States and the Commission in the framework of the Directive.

Background information on the current experience and knowledge concerning photochemical air pollution, dealing in particular with the phenomenology of ozone, the scientific understanding as based on experiments and theory, and the insights from modelling studies on the relation between ozone levels and precursor emissions, may be found in Borrell and Van den Hout (1995), Derwent and Van den Hout (1995), Barrett and Berge (1996) and in the *Consolidated report on the status of tropospheric ozone pollution in the European Community* (Beck and Krzyzanowski, 1997) which is currently in preparation following Article 8 of the Directive. Some aspects of the ozone phenomenology are briefly discussed in Annex II.

2. DATA REPORTING

2.1 Introduction

According to the ozone directive, the EU Member States have to provide the following information for the annual reference period:

- maximum, median and 98 percentile value of 1h- and 8h- average concentrations;

- the number, date and duration of periods during which threshold values as presented in Table 1 are exceeded and the maximum concentrations recorded during each occurrence.

In addition to this annual report, Member States must inform the Commission on a monthly basis if exceedances of the information and warning threshold values are observed.

Table 1. Threshold values for ozone concentrations (in $\mu g/m^3$)

threshold for	concentration	averaging period
health protection	110	8 h
vegetation protection	200	1 h
“ “	65	24 h
population information	180	1 h
population warning	360	1 h

A group of experts from the Members States have followed the practical implementation of the Directive. Among other items this group discussed procedures for data reporting. The formats for information and data exchanges have been defined in the document “Council Directive 92/72/EEC on air pollution by ozone. Information and data exchange/formats”, Doc.Rev. 11/243/95. In general terms, the requested information consists of two parts:

1. information on stations and measurements techniques (Ozone Directive, article 4.2, indents 1 and 2);
2. information on ozone concentration: annual statistics and threshold exceedances (Ozone Directive, article 6.1).

Based on the experiences in processing the data for the 1994 annual report, the European Topic Centre on Air Quality (ETC-AQ) provided remarks concerning data transmission and suggestions for improvement which were discussed in the Expert Group on Photochemical Pollution. Considering the increasing amount of data requiring processing, as well as the improvement of the transfer of data relating to the implementation of the Directive, the Commission has prepared an update (April 1996) of the data exchange format. The major changes concern the transfer of additional information:

- type of station: definition of the location of stations as recommended in the decision on Exchanges of Information (97/101/EC);
- altitude of stations as recommended by the Expert Group;
- NO_x and VOC data, according to Annex 2.3 of the ozone directive;
- file names: it is recommended to define unique names for all files in order to improve the management and transfer of the data files.

For submission of the 1996 data no further modifications in data requirements and data exchange formats have been made.

2.2 Data handling

According to the Ozone Directive, the requested information over 1996 should have been forwarded to the Commission before 1 July 1997. All data forwarded by the Commission and received at the European Topic Centre on Air Quality (ETC-AQ) before 11 August 1997 has been processed is this report. In this report the definition of the data formats as described in the document Doc.Rev. 11/243/95 and its April 1996 amendment is used as a reference. If necessary, files were converted at the ETC-AQ for further processing.

No information has been received from France. Information from Italy was received more than two months after the formal deadline of 1 July. The received data were, however, not fully in agreement with the standard data format which impeded data analyses. As time and resources were limited, the Italian data has not been included fully in this report. However, as far as possible the Italian data are included in the overview Tables 2-6 and a preliminary survey of exceedances in Italy is presented in Chapter 4.6.

For 1996 information on ozone concentrations (annual statistics and/or exceedance information) was received for 836 monitoring stations. For nearly all stations information was submitted on measurement methods, instruments and calibration procedures. In comparison to 1995, information for a slightly smaller number of stations was received (see Figure 1). Comparison of 1995 and 1996 is hampered by the fact that information from two Member States is missing. If one assumes that in those countries the same number of stations is operational in 1995 and 1996, there is an increase in information, see the bar labelled *96-B* in Figure 1.

Information on NO_x concentrations has been received from 6 Member States (90 stations); 8 Member States reported on NO_2 concentrations (122 stations). Information on Volatile Organic Compounds (VOC) was reported by two Member States at five stations.

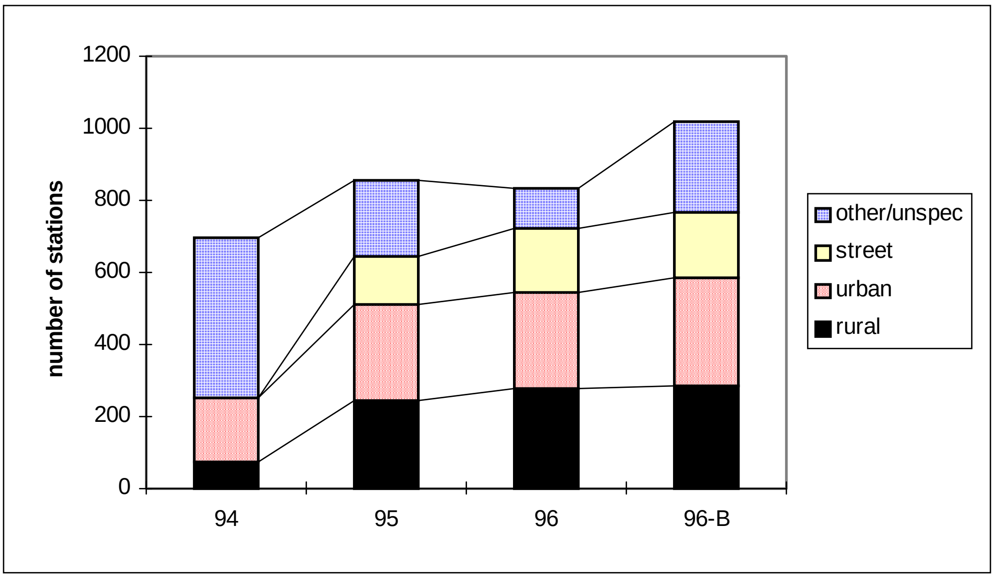


Figure 1. Number of stations reporting ozone data within the framework of the Ozone Directive. The bar “96” refers to the actual 13 reporting Member States; in “96-B” a correction has been made for missing data.

3. SUMMARY OF REPORTED DATA FOR 1996

The location of monitoring stations which are used for the implementation of the ozone directive and which were included in reporting for 1996 is presented in Map 1. In total, information for 836 stations in 13 Member States was received. All reporting Member States use the reference method (UV absorption) as prescribed in Annex V of the Ozone Directive. However, at a limited number of stations the chemiluminescence method is used.

Exceedance of the threshold value of 360 $\mu g/m^3$ for hourly values was observed on 21 May at two stations in Greece and at two Italian stations[2], see Table 2.

Table 2. Observed exceedances of the threshold value of 360 $\mu g/m^3$ for hourly average concentrations, period 1 January - 31 December 1996.

country	station name & city	date, time	max. conc. ($\mu g/m^3$)
Greece	Liosia, Athens Marousi	21 May 1996, 14.00 21 May 1996, 13.00	391 361
Italy	Boccadifa, Palermo Cuile Bo, Porto Torres	14 November 1996, 0.00 16 December 1996, 17.00	368 371

The high ozone levels in Greece are not associated with a widespread episode over Europe but they have a rather local character; for other Member States exceedance of the 180 $\mu g/m^3$ threshold value was not reported on 21 or 22 May. The exceedances in Italy were observed in the winter months when such high levels are unexpected. On 14 November no other Italian station showed ozone levels exceeding 180 $\mu g/m^3$; on 16 December only one station in Naples (400-500 km from Porto Torres) showed an exceedance of the 200 $\mu g/m^3$ threshold value (the maximum observed hourly concentration during that day was 206 $\mu g/m^3$). Investigations of these high concentrations are continuing with the national experts; An explanation of these exceptionally high levels cannot be given here.

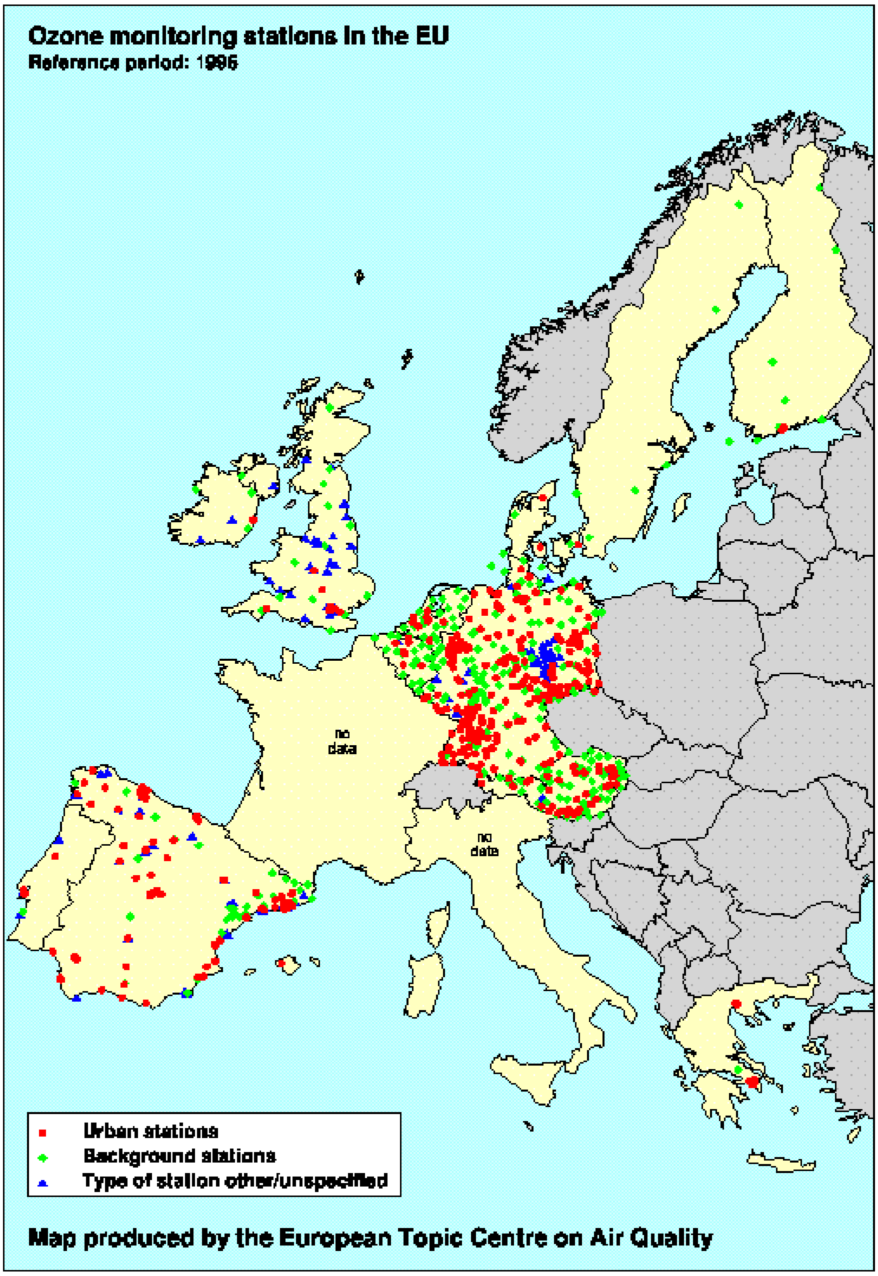
A summary of the maximum concentration measured at any of the reporting stations where exceedance[3] of a threshold value is observed is presented for each Member State in Table 3. When no exceedances of a threshold have been reported by a country this is indicated with a dash (-).

As the number of monitoring stations differs widely from country to country, the absolute number of exceedances is less suitable for comparison. Therefore, the concept of "occurrence of exceedances" introduced in earlier reports is presented here. Occurrence of exceedances is defined as the average number of observed exceedances per country, that is, the total number of exceedances summed over all the stations of a

[2] In the Information document for Summer 1996 (Sluyter and van Zantvoort, 1996) an additional exceedance was reported for the station Settignano in Firenze, Italy (387 $\mu g/m^3$, on 13-7-1996, 9.00). This observation which was based on non-validated data, has not been confirmed in the annual reporting (observed 1h-maximum concentration is 225 $\mu g/m^3$).

[3] In this report exceedances are counted on a daily basis, that is, a day on which at least one 1h- or 8h-concentration exceeds the threshold value, is marked as an exceedance.

country divided by the total number of reporting stations. A summary of occurrence of exceedances is presented in Table 4. There are two additional reasons which hamper a comparison between the Member States. Firstly, the local environment (in particular NO_x sources) influences the ozone levels; the differences between countries partly result from the differences in the ratios of street, urban and rural stations.



Map 1. Location of ozone monitoring stations as reported by Member States in the framework of the Ozone Directive for the reference period 1996.

Table 3. Maximum ozone concentrations (in μg/m³) measured during a period of exceedance of threshold values (reference period 1 January - 31 December 1996). A dash (-) indicates that no exceedances have been observed. For two member states no data is available (na).

	180 (1h)	200 (1h)	360 (1h)	110 (8h-a)	110 (8h-b)	65 (24h)
AT	224	224	-	201	210	185
BE	243	243	-	205	217	141
DE	269	269	-	198	222	183
DK	200	200	-	154	177	125
ES	335	335	-	258	232	210
FI	190	-	-	161	158	146
FR	na	na	na	na	na	na
GB	242	242	-	197	227	182
GR	391	391	391	228	246	142
IE	-	-	-	137	150	128
IT	371	371	371	237	232	166
LU	199	-	-	177	174	152
NL	265	265	-	191	234	130
PT	275	275	-	151	186(c)	147
SE	210	210	-	182	185	166
EU-15(d)	391	391	391	258	246	210

(a) based on three non-overlapping eight hourly values between 0.00-8.00; 8.00-16.00; 16.00-24.00;
(b) based on the eight hourly value between 12.00 - 20.00;
(c) this value contradicts the maximum value reported for the moving 8-h average concentration (169 μg/m³, see Table 6);
(d) France not included.

Secondly, in four member states 20-50% of the reporting stations show a data coverage of less than 75%; this might result in an underestimation of the number of exceedances. Full details on the number of exceedances at the individual stations is presented in Table I.1 of Annex I[4].

The longest period of consecutive days on which thresholds were exceeded and the average length of an exceedance period are presented in Tables I.2 and I.3 of Annex I. Table 5 summarises the number of days on which at least one exceedance has been observed in a Member State. It is clear that the threshold value for protection of vegetation is exceeded almost every day. Histograms based on a daily count of the number of Member States with at least one exceedance are presented in Figure 2; note that a systematic underestimation of the number of days will be found due to data missing from two Member States.

[4] Annex I is only available in computer readable form. In this report a description of the tables in Annex I is provided. Upon request to the ETC-AQ a diskette containing the Annex will be made available (e-mail address: frank.de.leeuw@rivm.nl; fax + 31 30 228 75 31).

For each of the Member States, the lowest and highest 50-, 98- and 99.9-percentile values observed at individual stations with a data-coverage of 75% or more, are presented in Table 6. In this table information on the maximum values is also included. Note that the maximum 8-hourly concentration, as reported in Table 6, is based on a moving average and may therefore differ from the values in Table 3 which are based on fixed 8-hourly periods. Detailed information on the percentile values and maximum concentrations observed at individual monitoring stations is given in Annex I, Table I.4.

Table 4. Occurrence of exceedances (reference period 1 January - 31 December 1996);
n.a. = no information available.

		threshold value (in $\mu g/m^3$)				
	number of stations (c)	180 1h	200 1h	110 8h(a)	110 8h(b)	65 24h
AT	111	0.8	0.1	30.2	34.9	108.5
BE	23	1.6	0.5	16.7	17.2	38.3
DE	369	1.7	0.5	15.6	23.7	56.2
DK	6	0.2	0.2	7.7	12.2	88.0
ES	189	1.1	0.4	17.0	22.6	71.8
FI	10	0.2	0.0	15.3	17.4	129.9
FR	na	na	na	na	na	na
GB	50	1.1	0.3	6.1	8.2	34.9
GR	15	10.6	7.5	36.1	60.4	89.5
IE	6	0.0	0.0	4.6	4.2	93.2
IT	52	7.5	3.5	29.9	28.5	29.8
LU	5	1.6	0.0	28.5	29.8	70.8
NL	38	2.6	1.2	5.8	12.0	27.8
PT	8	1.8	0.8	18.0	18.4	62.0
SE	6	1.0	0.2	18.2	18.5	159.8
EU-15(d)	836	1.5	0.5	17.2	23.5	66.5

(a) based on three non-overlapping eight hourly values between 0.00-8.00; 8.00-16.00; 16.00-24.00;
(b) based on the eight hourly value between 12.00-20.00;
(c) note that small differences in the number of stations reporting for each of the threshold levels may occur;
(d) France and Italy not included.

Table 5. Number of days with at least one exceedance observed at the reporting stations in a Member State. (reference period 1 January - 31 December 1996.

	threshold value (in µg/m³)		
	180 1h	110 8h(b)	65 24h
AT	19	147	363
BE	12	46	157
DE	37	162	361
DK	1	27	169
ES	60	217	366
FI	2	65	320
FR	na	na	na
GB	12	45	266
GR	59	162	239
IE	0	12	252
IT	na	na	na
LU	6	66	166
NL	12	30	120
PT	12	110	264
SE	4	49	287
EU-15[(a)]	126	248	366

(a) France and Italy not included;
(b) based on the eight hourly value between 12.00-20.00.

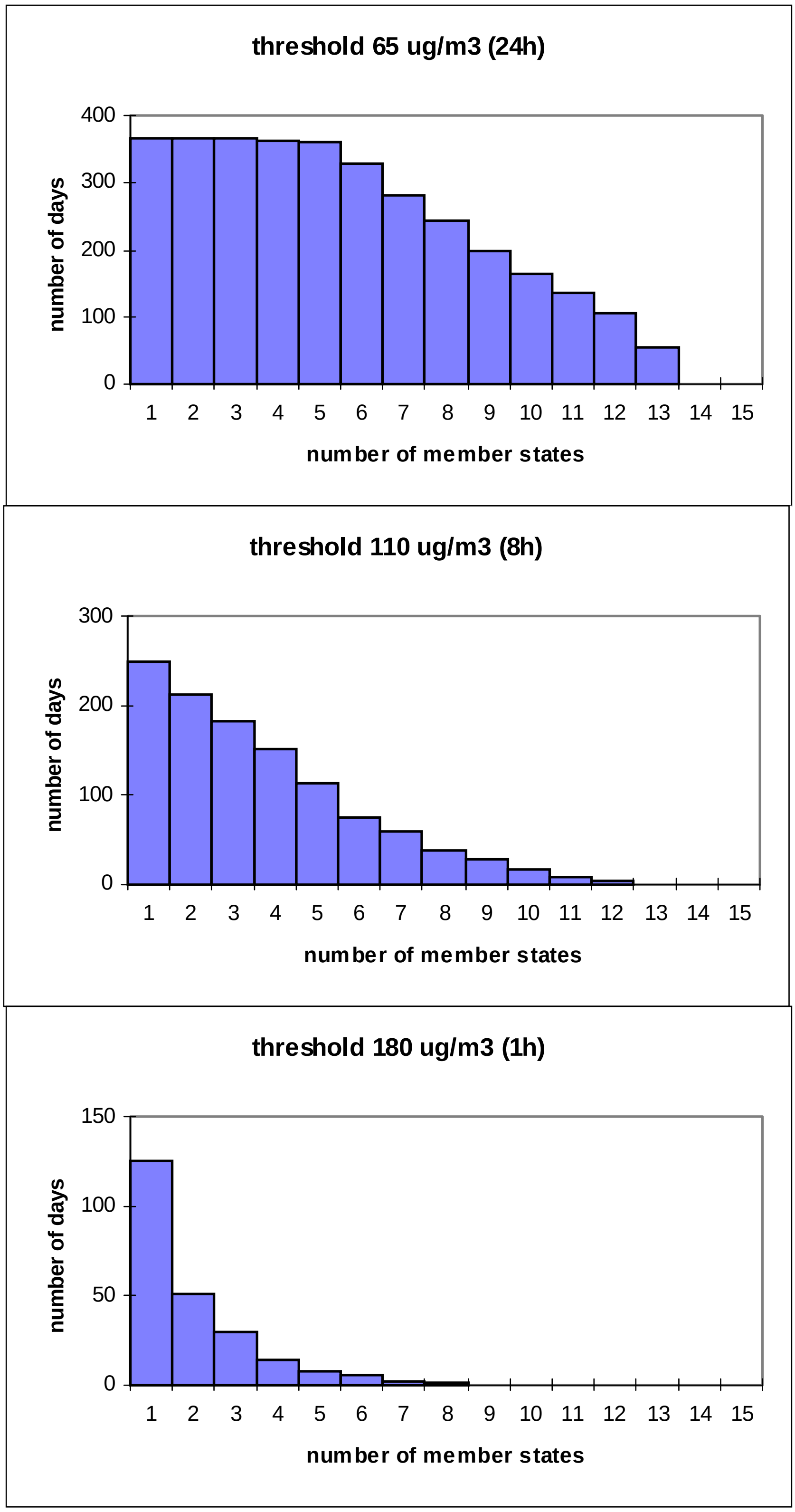


Figure 2. Number of days as function of the minimum number of Member States where at least one exceedance of a threshold value has been observed (for example, on 151 days the threshold value of 110 $\mu g/m^3$ has been exceeded in at least 4 Member States); period 1 January - 31 December 1996. Note that information is available for 13 Member States only.

A further discussion on the reported data for 1996 is given in the following chapters. Percentile values for previous years (1989-1996) have been reported by four Member States and are briefly discussed in paragraph 4.5.

Table 6. Range in reported 50-, 98- and 99.9-percentile values and maximum observed values (based on hourly and moving eight-hourly average concentrations) observed at individual monitoring stations in Member States (in μg/m³), period 1 January - 31 December 1996. For France and Italy no information is available (na); United Kingdom (GB) did not submit statistical information on 8-h average concentrations.

1996	1h-P50		1h-P98		1h-P99.9*		1h-MAX	
range	min	max	min	max	min	max	min	max
AT	13	100	83	151	120	213	129	224
BE	22	49	105	136	159	222	168	243
DE	9	94	67	172	122	213	128	269
DK	45	59	102	116	144	164	151	200
ES	11	90	32	187	55	262	82	335
FI	33	74	82	129	105	164	134	190
FR	na	na	na	na	na	na	na	na
GB	12	68	70	130	112	216	56	242
GR	20	62	87	164	116	301	157	391
IE	47	72	86	106	na	na	124	173
IT	14	74	50	179	106	233	112	371
LU	14	61	77	145	118	183	130	199
NL	15	46	71	121	116	219	133	265
PT	7	94	24	137	62	175	105	275
SE	59	69	99	128	117	183	125	210

1996	8h-P50		8h-P98		8h-P99.9*		8h-MAX	
range	min	max	min	max	min	max	min	max
AT	17	100	77	149	106	203	120	212
BE	23	49	95	134	147	192	145	228
DE	14	93	59	169	107	195	94	230
DK	45	59	98	113	126	161	134	177
ES	11	89	27	178	46	237	39	276
FI	34	74	75	126	99	159	111	164
FR	na	na	na	na	na	na	na	na
GB	?	?	?	?	?	?	?	?
GR	23	64	80	148	105	231	115	258
IE	47	73	80	103	na	na	117	155
IT	na	na	na	na	na	na	120	219
LU	17	61	70	141	102	169	119	179
NL	16	47	65	111	107	199	112	234
PT	14	93	56	135	95	159	55	169
SE	58	69	99	125	115	175	124	192

* additional information submitted on a voluntary basis

4. DISCUSSION

4.1 Geographic coverage of monitoring stations

For 1996 information from 836 stations was received; for nearly all of them geographical coordinates are available. For the interpretation of ozone data it is essential to have an indication of the direct surroundings of the station as the ozone concentration may be strongly influenced by local conditions. For example, the ozone concentrations may be scavenged by locally emitted nitrogen oxides or by enhanced dry deposition as might be the case under a forest canopy; see Annex II for a brief discussion on ozone phenomenology. For nearly all stations information on immediate surroundings is available.

Based on the information submitted on station type and characteristics, Figure 3 shows the partitioning between background (or rural), urban, street and other stations in each of the Member States. Within the European Union the station classification varies strongly: from only rural stations (Sweden) to about 50% urban stations (Denmark, Greece, Germany). A relatively large number of street stations is located in Luxembourg and Spain. There are, however, clear indications that the classification of stations is not uniform over the Member States. Based on the phenomenology of ozone (see Annex II) one expects that ozone concentrations should cluster at low (street), medium (urban) and high levels (rural); the corresponding NO_x concentrations should cluster in reversed order. Although this tendency is shown (see Figure 4), there is a considerable overlap between the sets of stations. Information on NO_x concentrations will be helpful to validate the station classification. For a limited number of stations (7 Member States, 73 stations) both NO_x and ozone statistics are submitted. Figure 4 shows the relation between the yearly average NO_x and the ozone 50-percentile value. The clustering in stations is noted here; this type of graph could guide further harmonisation on classification. Further work on classification of station is being undertaken by ETC-AQ in co-operation with DGXI of the European Commission.

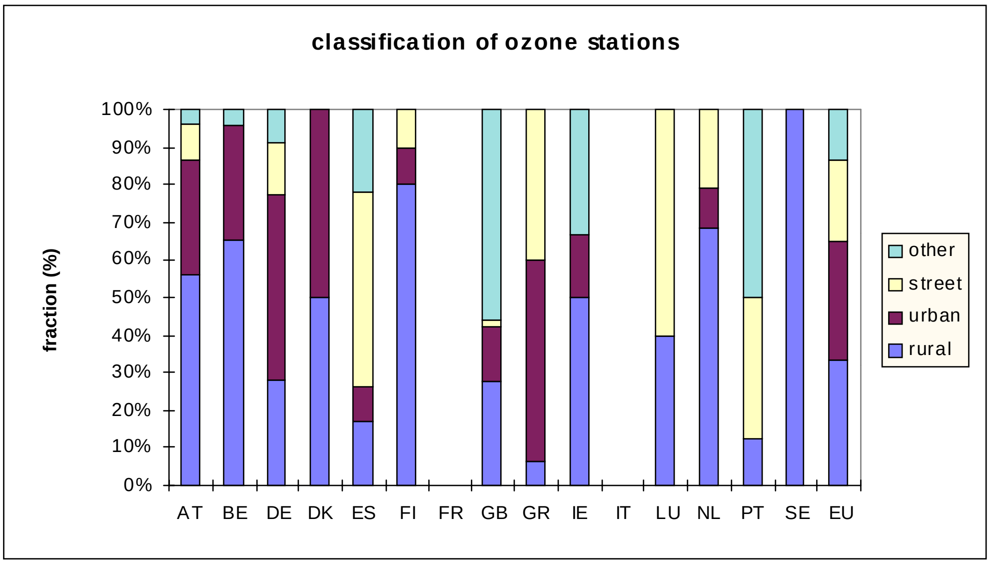


Figure 3. Classification of ozone stations according to their direct surroundings as rural, urban, or street station; 'other' indicates both other station types (e.g. in industrial areas) and stations for which no information of station type is available.

Map 2 shows the location of background monitoring stations. Tentatively, the area for which the measurements at these stations are assumed to be representative is indicated with a circle using a radius of 100 km. This “radius of representativeness” might be different for the various regions in Europe - it might even depend on the wind direction - and should be based on more detailed analysis of the ozone phenomenology at the stations. Although the identification of the background stations is far from complete and the radius of representativeness may differ from the assumed 100 km, Map 2 suggests that the present set of stations covers 40 to 50% of the land area of the EU. As is shown in Map 2 the geographical coverage of background stations is rather adequate in North-West Europe but in other regions (e.g. Greece) gaps are noted; data for France and Italy are lacking but based on the information received for 1995 (de Leeuw and van Zantvoort, 1996), it is assumed that coverage by background stations is inadequate.

It has been attempted to quantify the coverage of the monitoring stations for urban areas as is relevant for population exposure. According to information obtained from the Eurostat population database, there are in the EU about 2000 cities with more than 25 000 inhabitants. It is estimated that from a total EU population of about 362 million, about 195 million people live in these cities with more than 25 000 inhabitants. Summation of the number of inhabitants of all the cities in which at least one ozone station is operational and has been reported to the EC in 1996, leads to a total of approximately 65 million. Hence for only 32% of the total urban population (equivalent to 18% of the total EU population) can an estimate of ozone exposure be made.

Although the uncertainties in the classification of the present set of stations (e.g. the representative radius for the urban and street stations is unknown) preclude any firm conclusion, it is clear that the set of urban stations in the national networks is not representative for the total urban population in the EU. Conclusions concerning the exposure of urban population to high ozone levels should therefore be seen as tentative.

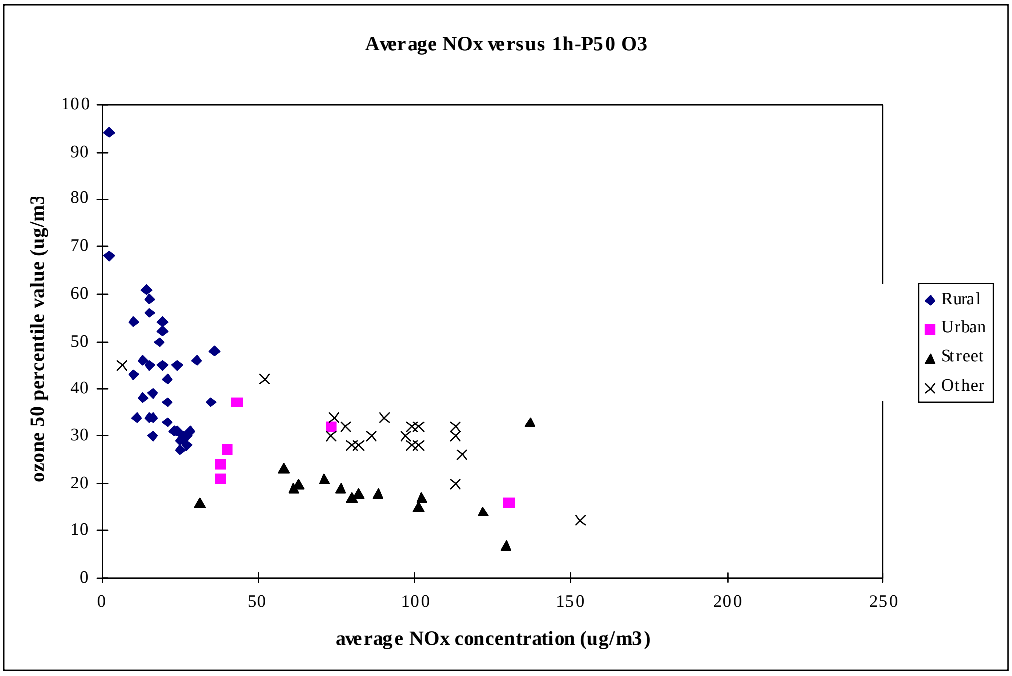
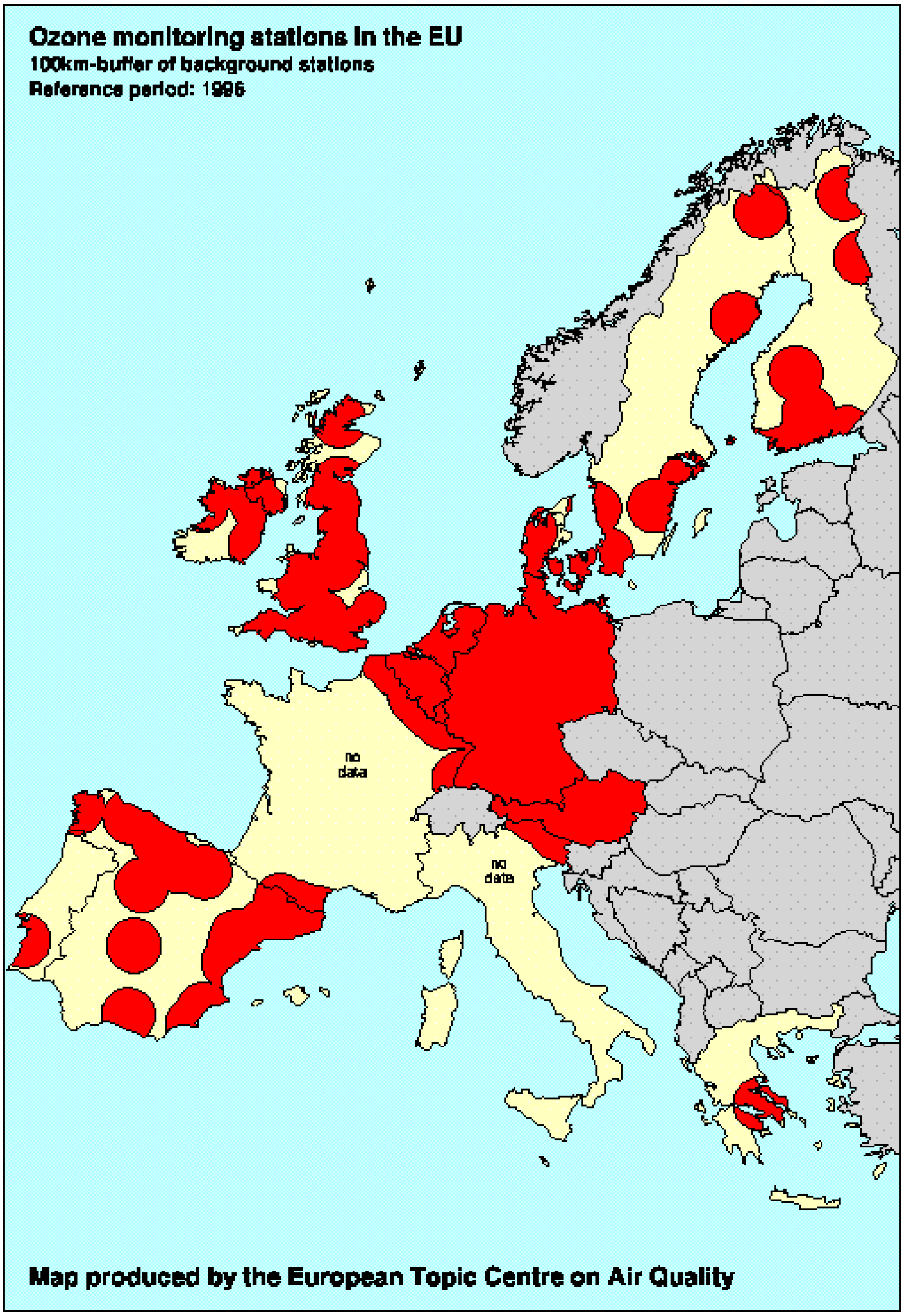


Figure 4. Relation between yearly average NO_x concentration and ozone 50 percentile values at a limited number of stations (period 1 January -31 December 1996).



Map 2. Location of background ozone monitoring stations. Tentatively the area for which the ozone measurements might be representative is indicated with a circle with a radius of 100 km.

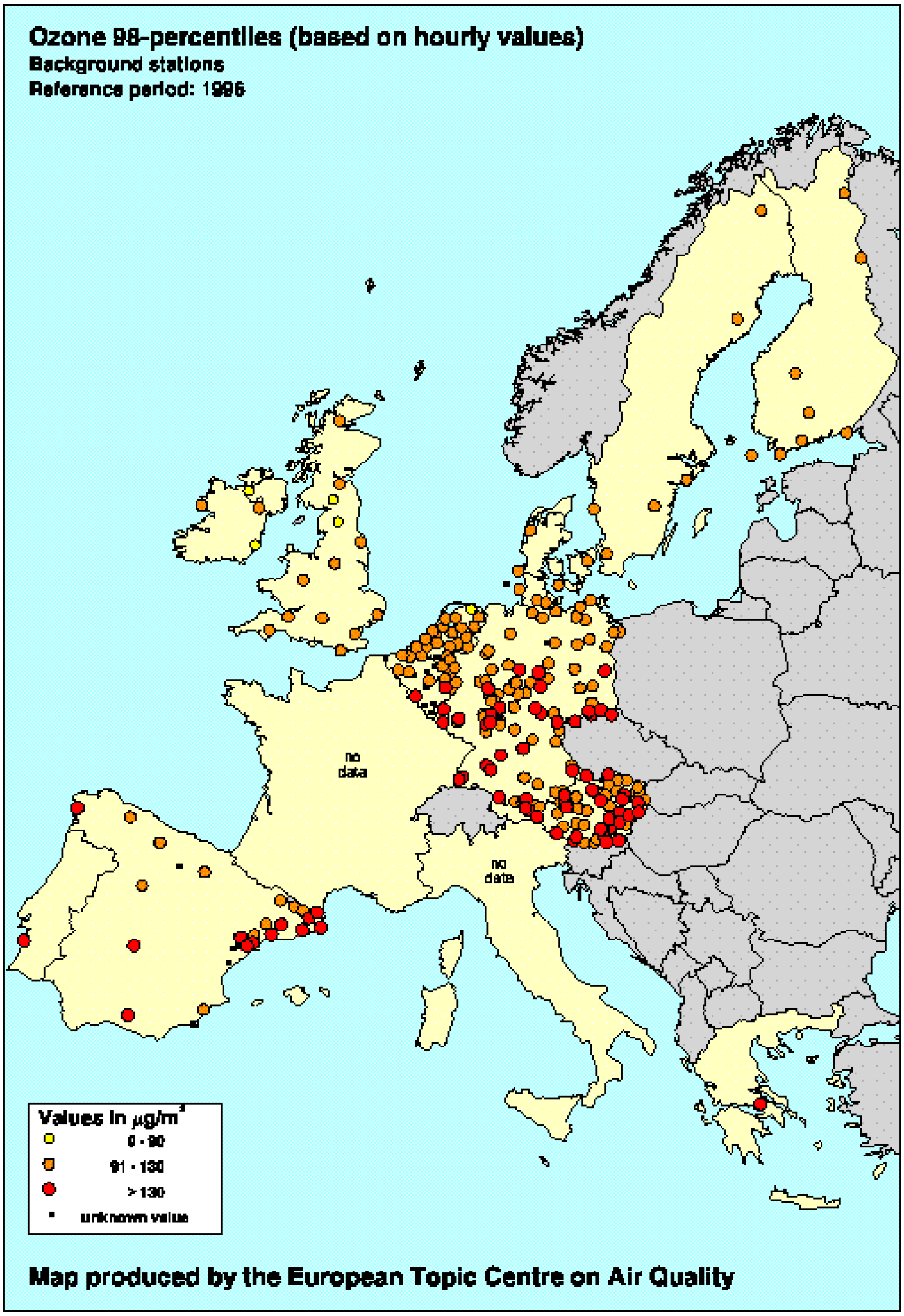
4.2 Annual statistics, 1996

The geographical distribution of 98-percentile values calculated on the basis of hourly concentrations is presented in Map 3 for background stations and in Map 4 for urban, street and other stations.

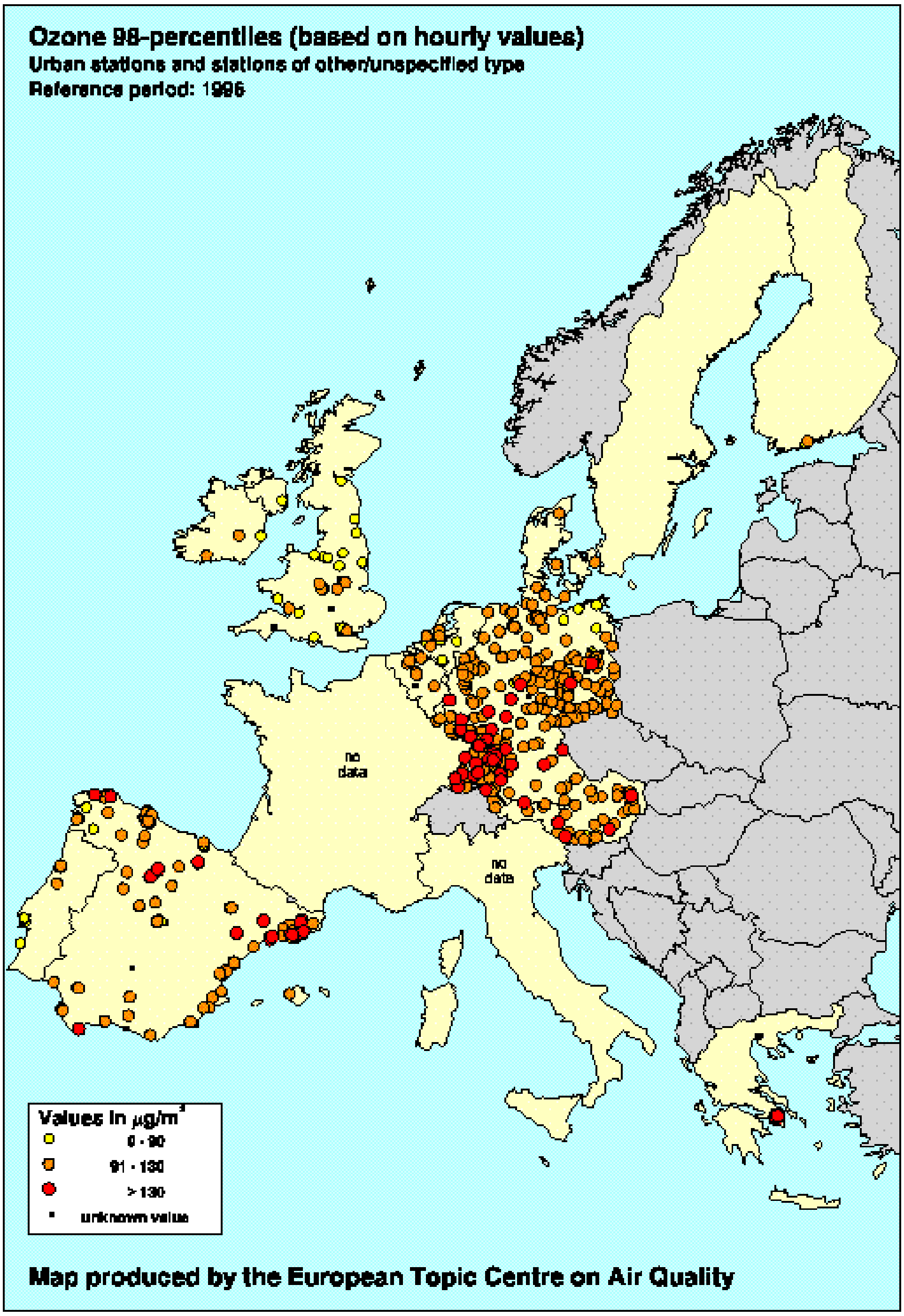
Similar to the observations in previous years (de Leeuw *et al*., 1995; de Leeuw and van Zantvoort, 1996) the 98-percentiles at background stations show in general low values in the Scandinavian countries, and an increase from North-West to Central Europe. In particular for the stations in Austria, the elevated location of the monitoring stations may play a role. Similar patterns have been estimated from measurements made within the framework of EMEP (Hjellbrekke, 1996). However, the relatively low values observed in the EMEP data over the Iberian peninsula are not in agreement with the present observations which might be caused by differences in year, in averaging period and in the set of reporting stations.

For urban and ‘other’ stations (Map 4) no large scale concentration gradient in 98-percentiles is recognized; high values are observed all over the continent. The local conditions (at stations downwind of the urban area relatively high ozone values might be observed whereas at stations with NO_x sources, such as traffic, in their immediate surrounding relatively low ozone levels will be measured, see Figure 4 and Annex II) appears to be more important than European-wide smog episodes.

The 98-percentile values based on moving eight-hourly average concentrations show a strong correlation with the hourly 98-percentile: on average, 8-h percentiles are about 7 $\mu g/m^3$ lower than the corresponding 1h value. However, this relation depends on the type of the stations, see Figure 5; a comparison with previous years also shows that the ratio of 1h and 8h 98-percentile values has a meteorological dependence. The overlap between the ranges spanned by the observations at the three classes of stations suggests that the classification scheme needs further harmonisation. The geographical distribution of the 8-h percentile values is very similar to the distribution of the 1-h percentile values.



Map 3. 98 percentiles (based on hourly concentrations; µg/m³) measured at background stations, period 1 January-31 December 1996.



Map 4. 98 percentiles (based on hourly concentrations; µg/m³) measured at urban, street and other stations, period 1 January-31 December 1996.

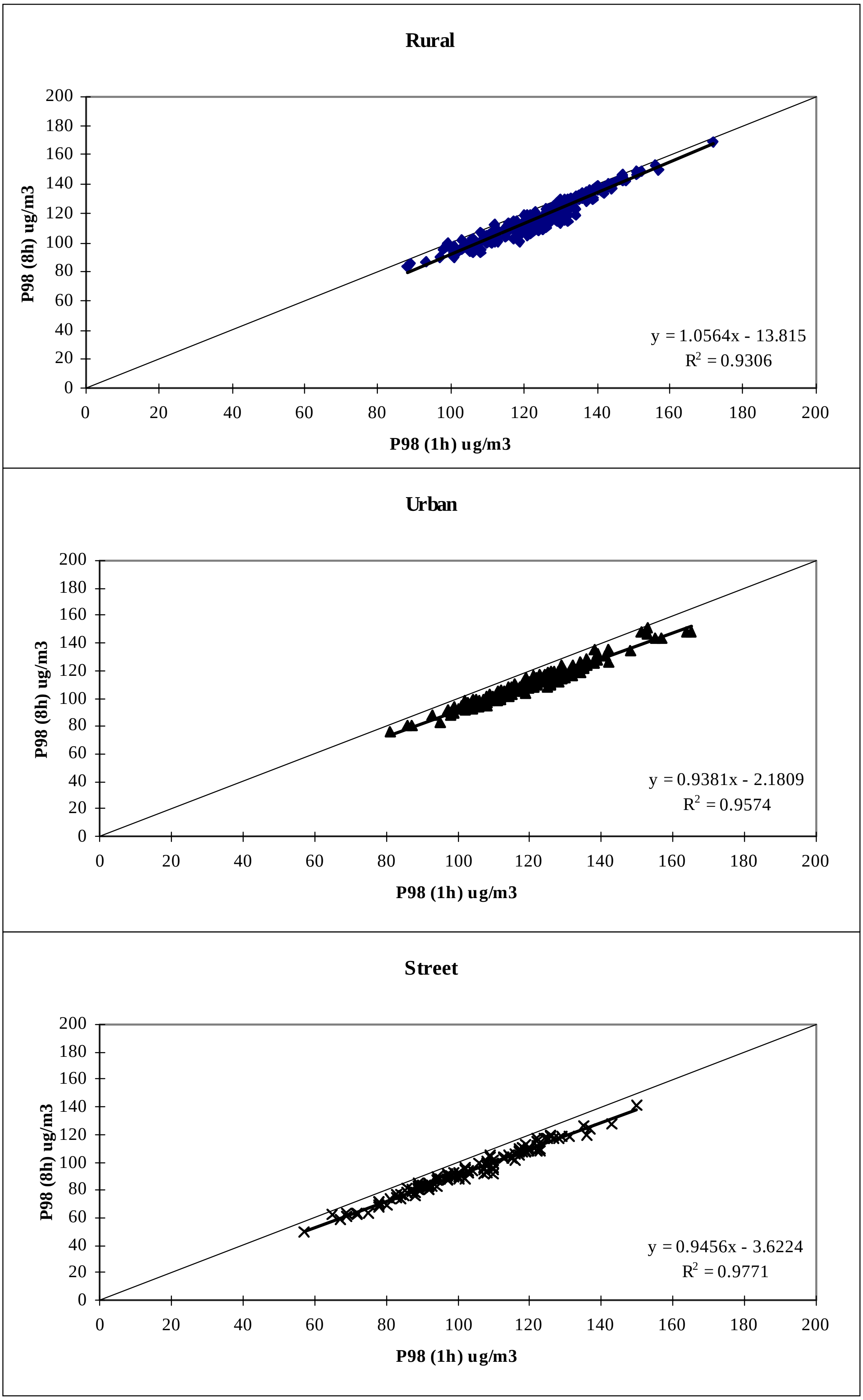


Figure 5. Relation between 98-percentiles values based on hourly concentrations and 8-hourly concentration at all reporting stations (in $\mu g/m^3$; 1 January-31 December 1996).

4.3 Exceedances of thresholds in 1996

4.3.1 Exceedances of the threshold value for protection of human health

The threshold value for protection of human health (110 $\mu g/m^3$) is based on eight-hourly values. According to the Ozone Directive, four eight-hourly periods have to be considered: 0.00-8.00; 8.00-16.00, 16.00-24.00 and 12.00-20.00. Based on the average diurnal profile of ozone (see Annex II) the highest eight-hourly values are generally expected for the 12.00-20.00 period; only exceedances of the threshold values for this period have been considered here.

No clear definition of the time reference (local time or universal time, summer- or winter time) is given. This might lead to inconsistencies between the Member States. The differences between the maximum concentrations quoted for the 8-h concentration between 12.00 and 20.00 (Table 3) and for the moving 8-h average concentrations (Table 6) indicates that small errors might be introduced by the ambiguity on time reference.

In 1996 exceedances of this threshold value have been observed in all reporting countries. In five Member States maximum concentrations exceeding twice the threshold value have been observed (see Table 3).

Figure 6 shows the frequency distribution of eight-hourly ozone concentrations in excess of the threshold value using so-called Box-Jenkins plots. For each Member State the Box-Jenkins plot indicates the minimum (here the minimum is of course 110 $\mu g/m^3$), the maximum, the 25 percentile and the 75 percentile value of the concentrations during exceedance. Although extreme peaks of more than 200 $\mu g/m^3$ are observed in seven out of 13 reporting Member States, Figure 6 shows that, in each Member State, less than 25% of all exceedance concentrations are above 165 $\mu g/m^3$ (that is, above 150% of the threshold value).

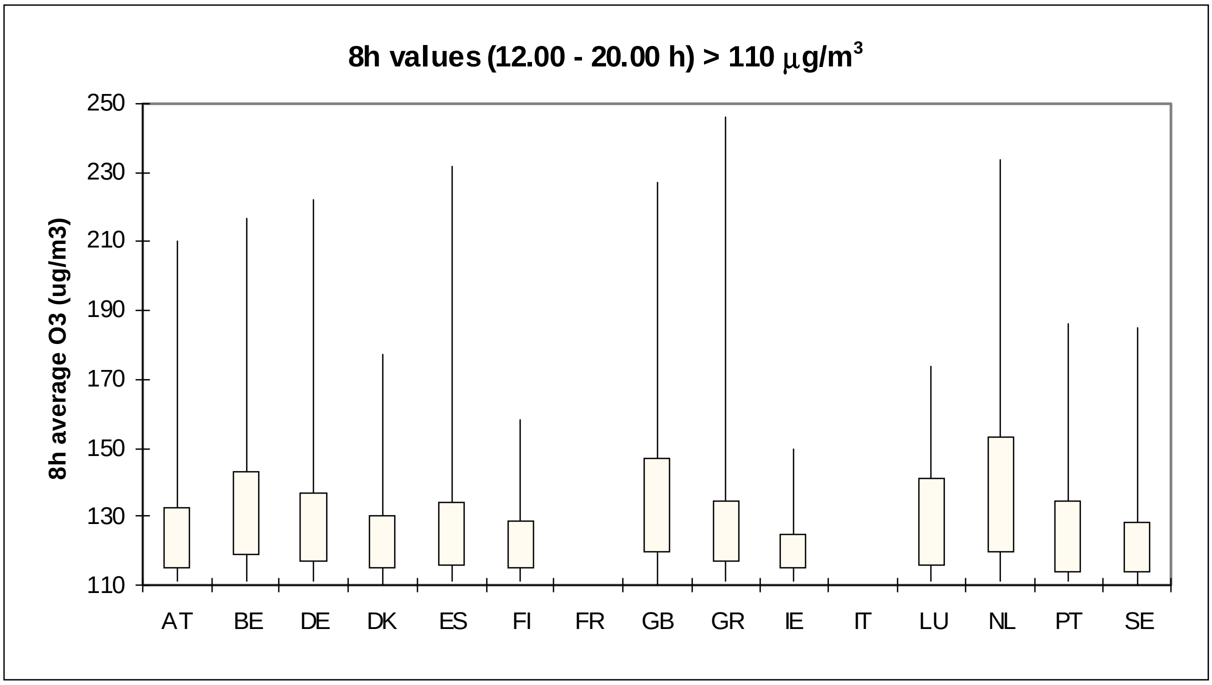
The geographical distribution of the number of days the threshold value was exceeded is shown in Map 5 for background stations and in Map 6 for urban, street and other stations. A comparison of Map 5 and 6 shows that exceedances are more frequently observed at rural stations. This is also demonstrated more clearly in Figure 7 where for each station type (rural, urban and street stations) the average number of exceedances is plotted. The average occurrence of exceedances generally decreases in the order rural - urban - street. Note that ‘other’ stations and stations for which the type has not been specified have been excluded from Figure 7.

Of the total EU urban population, about 65.5 million people live in cities with one or more ozone monitoring stations reporting in the framework of the Ozone Directive. The number of days on which this population is exposed to ozone levels exceeding the 110 $\mu g/m^3$ threshold values ranges from zero days (for 12% of the population, see Figure 8) to more than 50 days (for 6% of the population). The majority (72%) of city dwellers in 1996 is exposed to ozone levels exceeding 110 $\mu g/m^3$ during 1-25 days.

These results should be interpreted with great care. The observations at the present set of urban stations might not be representative for the total urban population; only 32% of the urban population lives in a city “covered” by an ozone monitoring station, and information on urban situation is scarce or even lacking in some Member States (in five Member States the number of operational urban or street monitoring stations is three or less). Although more quantitative conclusions cannot be drawn at this stage, it is likely that a substantial fraction of the urban population is frequently exposed to high ozone levels. Increases in mortality and in hospital admission for chronic obstructive pulmonary diseases are to be expected (Anderson *et al.*, 1997; Sartor *et al.*, 1997; Beck and Krzyzanowski, 1997).

In rural areas the number of exceedances is higher than in urban regions, see Figure 7. It is estimated that in more than 95% of the area for which information is available (see Map 2) the threshold value is exceeded at least on one day in 1996. When *rural population* is defined as the population living in villages and cities with less than 25,000 inhabitants, a total rural population of about 89 million lives within the assumed radius of representativeness of 100 km around rural stations. The fraction of the rural population which is not exposed to 8h ozone levels exceeding 110 $\mu g/m^3$ is less than 2%; slightly less than half of the rural population (about 43 million people) is exposed to high ozone levels on more than 25 days. Similar to Figure 7, Figure 8 demonstrates the higher exposure of the rural population.

Exceedances most frequently occur in the summer months (May-August). In the winter months (January-March and September-December) exceedances have been observed very occasionally.



	AT	BE	DE	DK	ES	FI	FR	GB	GR	IE	IT	LU	NL	PT	SE
#ex	3873	396	8721	73	4114	157	na	403	664	25	na	149	455	129	111
#st	111	23	368	6	182	9	na	49	11	6	na	5	38	7	6

n.a = number of exceedances not available

Figure 6. Frequency distribution of ozone concentrations (eight-hourly values; period 12.00-20.00;
1 January - 31 December 1996) in excess of the 110 $\mu g/m^3$-threshold for hourly values. For each country the total number of observed exceedances is given in row '#Ex', the number of stations is given in row '#St'. Frequency distributions are presented as Box-Jenkins plots indicating the

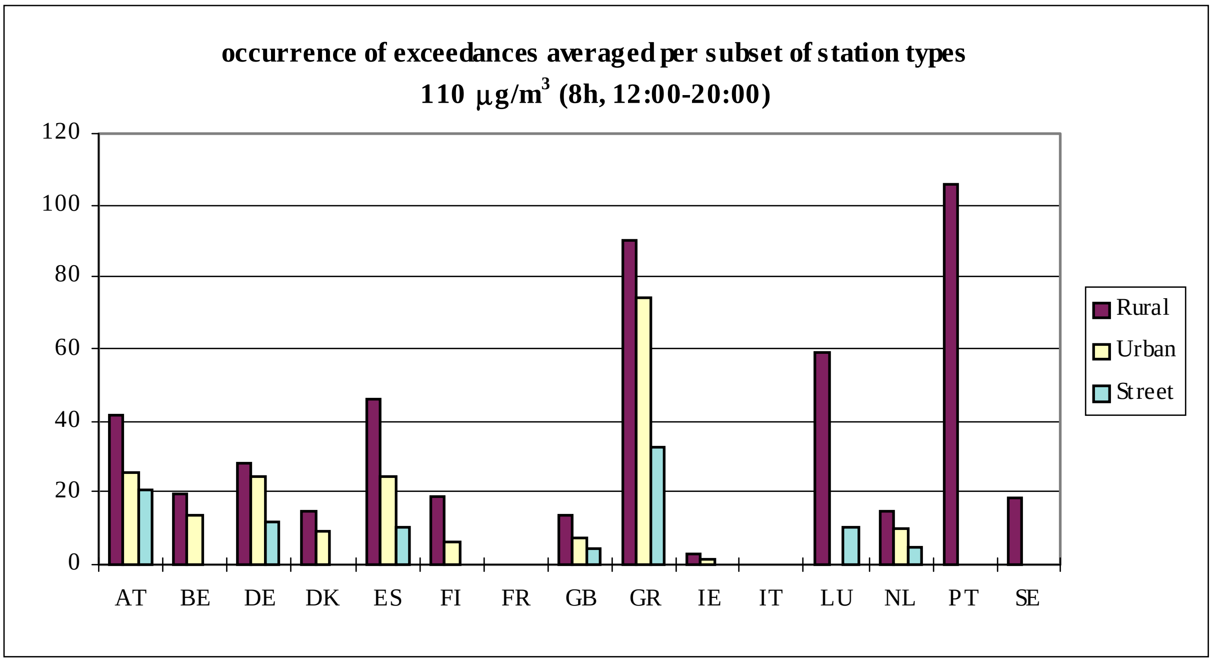


Figure 7. The occurrence of exceedances of the threshold value for protection of human health (110 µg/m^3 for eight-hourly values, period 1 January - 31 December 1996) averaged over all reporting rural, urban, and street stations.

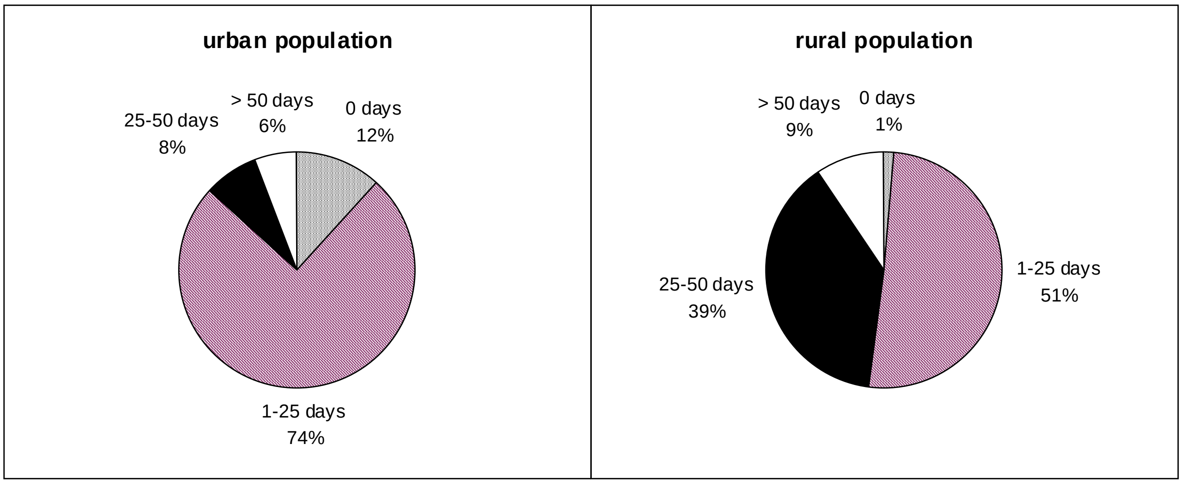
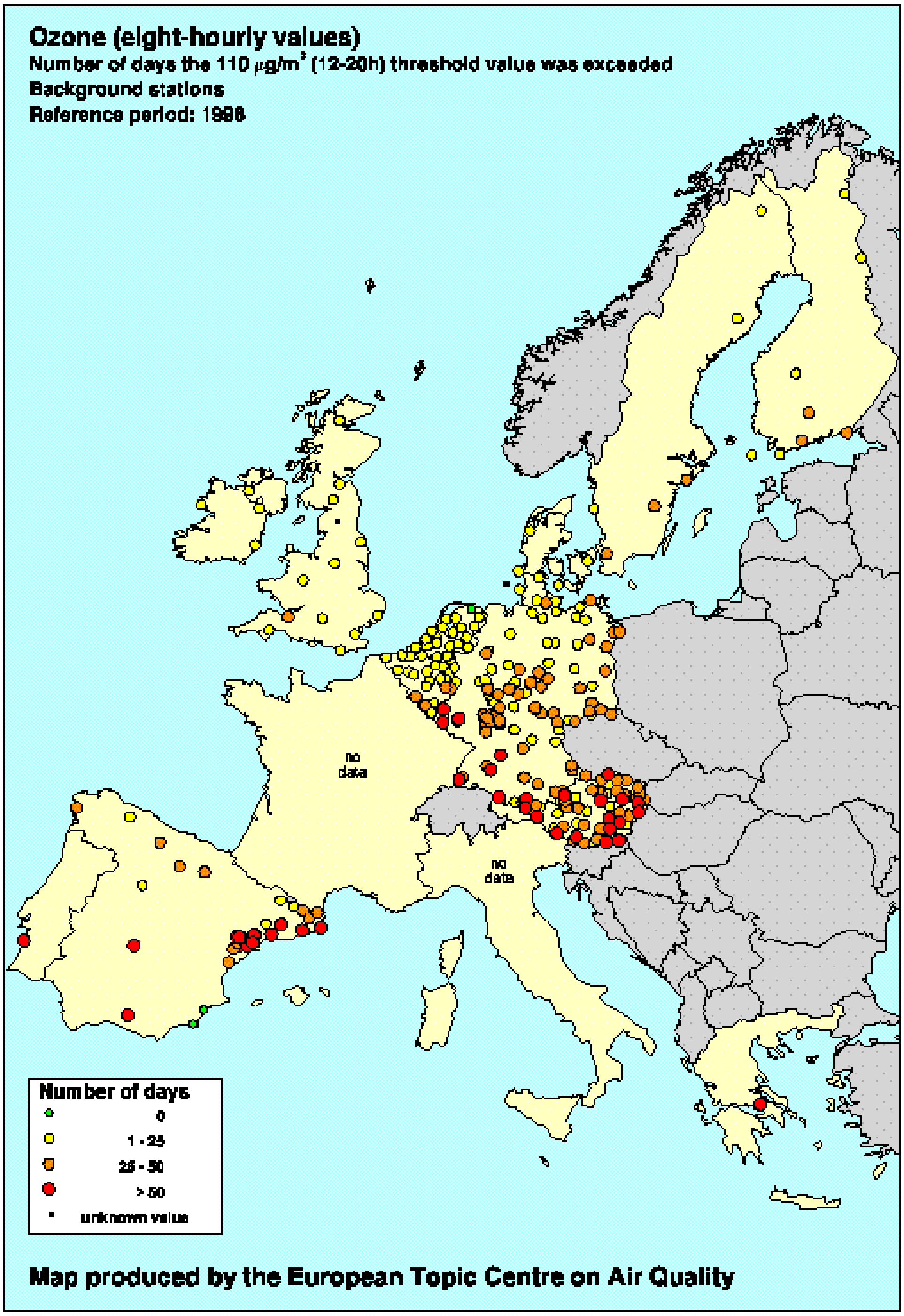
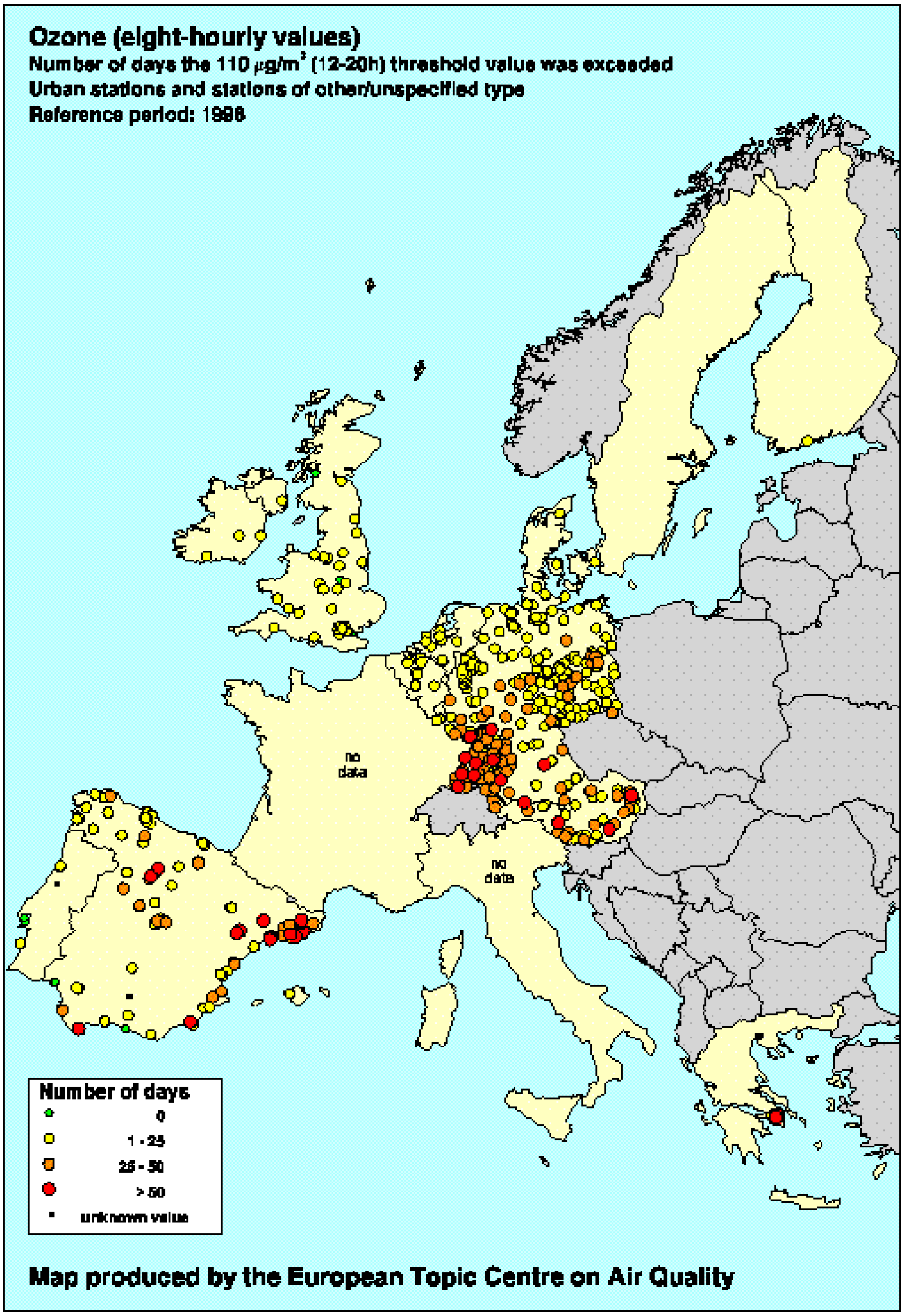


Figure 8. Number of exceedances (in days) and frequency distribution of urban and rural population exposed to eight-hourly concentrations exceeding 110 µg/m^3, 1 January-31 December 1996. Note that information on ozone exceedances which has been made available within the framework of the ozone directive, is estimated to be representative for a total urban population of 65.5 million (that is, about 32% of the EU population living in cities with more than 25 000 inhabitants and 18% of the total population in the EU) and for a total rural population of about 90 million.



Map 5. Number of exceedances of the threshold value for protection of human health (110 µg/m^3 for eight hourly values) observed at background stations; 1 January-31 December 1996; eight-hourly average values for the period 12.00-20.00.



Map 6. Number of exceedances of the threshold value for protection of human health (110 µg/m^3 for eight-hourly values) observed at urban, street and other stations; 1 January-31 December 1996; eight-hourly average values for the period 12.00-20.00.

4.3.2 Exceedances of the threshold values for information and warning of the population

The threshold value for warning of the population (360 µg/m^3, hourly value) was exceeded in 1996 on 21 May at two stations in Athens, Greece: Liosia and Marousi. This episode is an example of 'local' ozone episodes in the Mediterranean region. Other stations in Athens or in its close vicinity reported exceedances of both the 1h - 180 µg/m^3 and 8h - 110 µg/m^3 threshold values on this day; no other Member State reported an exceedance of the threshold of 180 µg/m^3 for this day.

The geographical distribution of the number of exceedances of the threshold value for information of the public (180 µg/m^3, hourly value) is presented in Map 7 for background stations and in Map 8 for urban, street and other stations. Exceedances are reported for 12 Member States: from France and Italy information is lacking and only in Ireland was the 180 µg/m^3 level not reached. Similar to the exceedances of the threshold values of 8-hourly average concentrations, the threshold values for public information occur more frequently at rural stations than at urban or street stations. For urban stations an overview of the number of exceedances weighted according to the population of the city, is presented in Figure 9. From these limited data, it appears likely that about 60% of the urban population and about 80% of the rural population are exposed to ozone concentrations exceeding 180 µg/m^3 for one or more days.

Figure 10 shows the frequency distribution of concentrations in excess of the threshold value for information. Although inci

dentally the threshold value may be exceeded by more than a factor of two, in almost all of the cases the exceedances are less extreme: Figure 10 shows that in nearly all Member States on 75% of the days on which the threshold value was exceeded, the

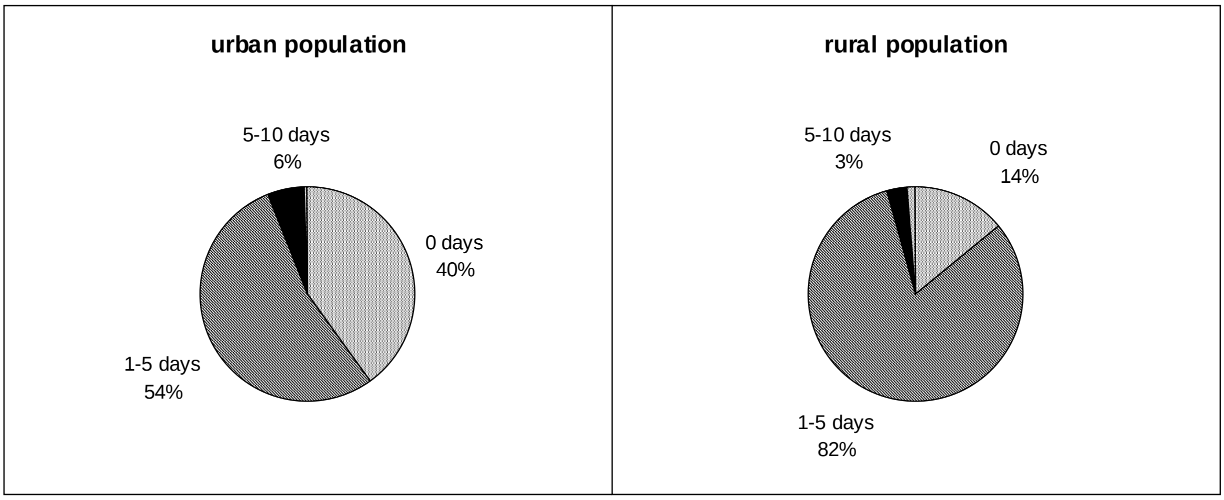
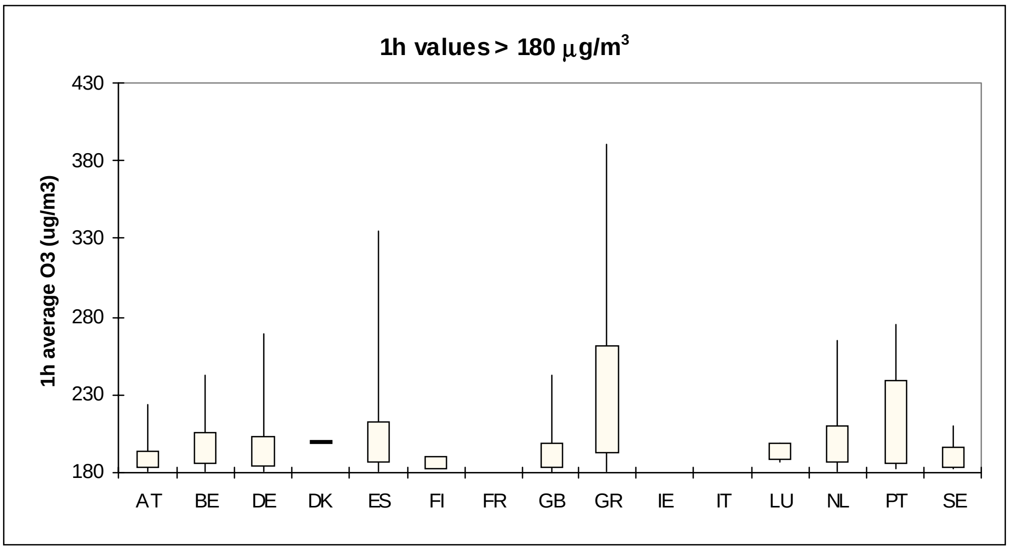


Figure 9. Number of exceedances (in days) and frequency distribution of urban and rural population exposed to hourly ozone concentrations exceeding 180 µg/m^3, 1 January-31 December 1996.

level of 250 µg/m^3 (that is 150% of the threshold value) was not reached.

Exceedances are observed during a large part of the year, starting in spring (22-24 April, exceedances in Germany and Austria) but occur most frequently and geographically most widespread during the summer months. Figure 11 shows the scaled total number of exceedances (summation of occurrence of exceedances over Member States) per day. The most wide-spread episode was on 5-7 June (see the discussion in Sluyter and van Zantvoort, 1996). Although in Figure 11 a correction is made for the differences in network density in the Member States, it is still difficult to estimate the geographical extent of an episode: a scaled value of one might imply that on all stations in one country an exceedance is observed but it also might indicate that in 10 Member States on 10% of the stations an exceedance is observed. For example, the two days with a scaled number of exceedances of 0.7 - 0.75 (8 and 22 July) have a different character: on 8 July the episode was 'local' with more than 60% of the Greek stations having an exceedance whereas on 22 July in six Member States a relative small number of stations showed an exceedance.



	AT	BE	DE	DK	ES	FI	FR	GB	GR	IE	IT	LU	NL	PT	SE
#ex	94	37	613	1	212	2	na	53	138	0	na	8	100	14	6
#st	111	23	369	6	189	10	na	50	13	6	na	5	38	8	6

Figure 10. Frequency distribution of ozone concentrations (hourly values; 1 January - 31 December 1996) in excess of the 180 μg/m^3-threshold for hourly values. For each country the total number of observed exceedances is given in row '#Ex', the number of stations is given in row '#St'. Frequency distributions are presented as Box-Jenkins plots indicating the minimum, the 25-Percentile, the 75-percentile and the maximum value.

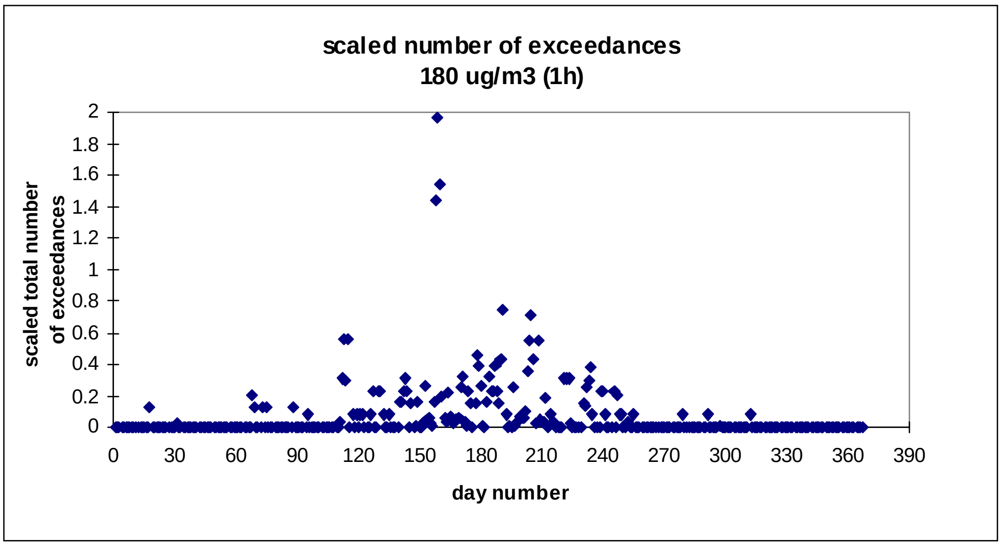
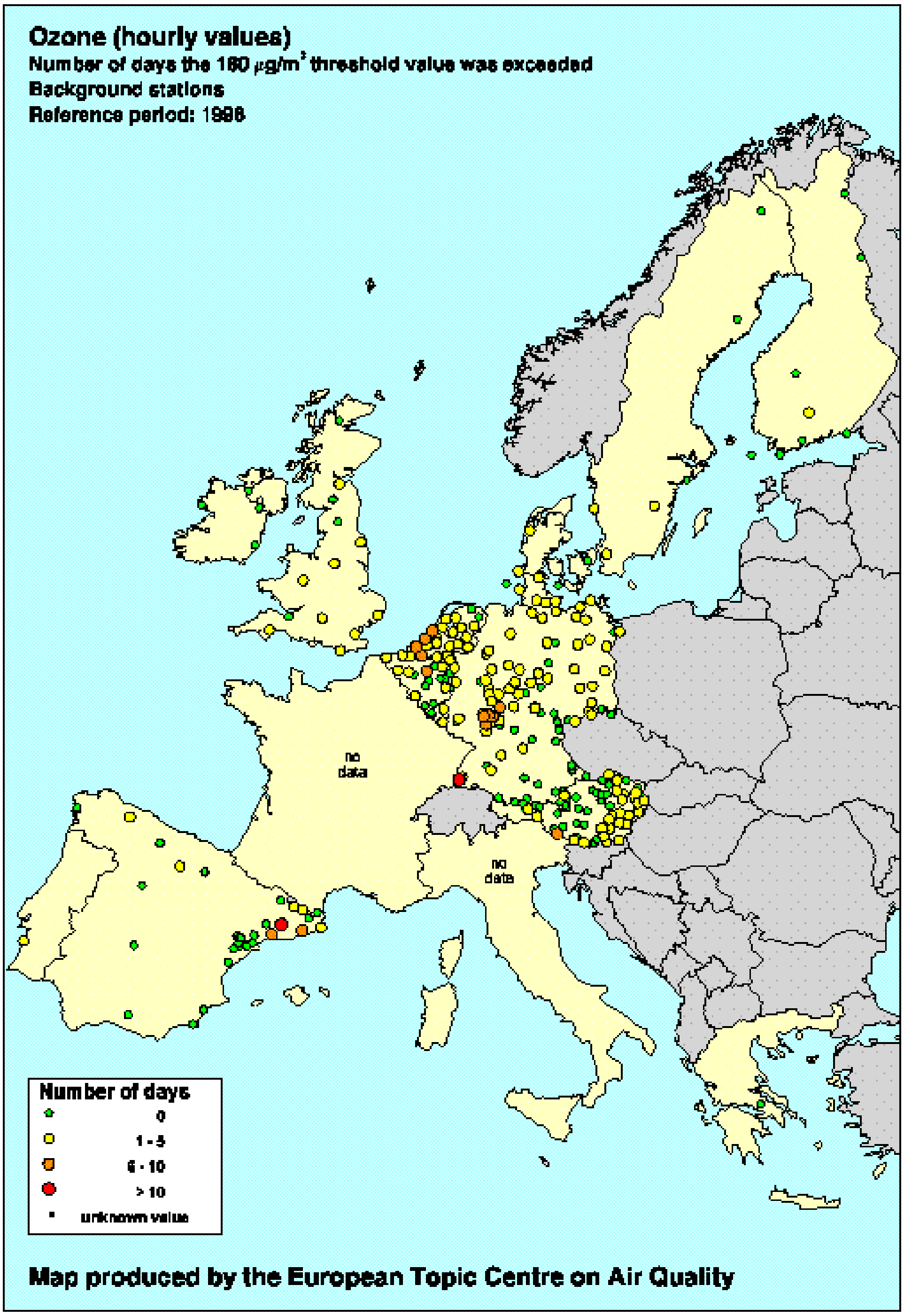
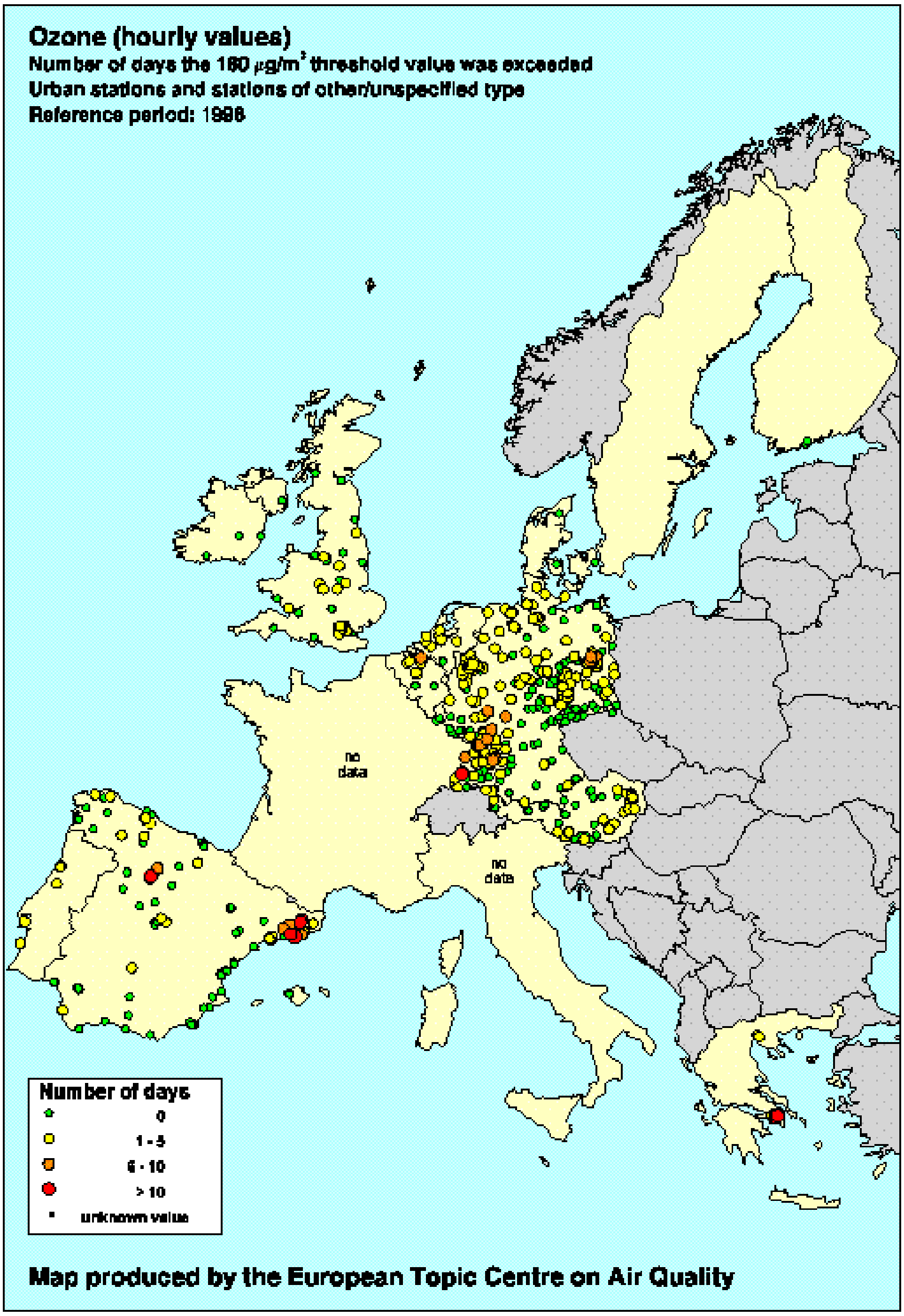


Figure 11. Scaled total number of exceedances (summation over all Member States of the occurrence of exceedances) of the ozone threshold value for information (180 $\mu g/m^3$);
1 January - 31 December 1996.



Map 7. Number of exceedances of the threshold value for information of the population (180 µg/m^3 for hourly values) observed at background stations;1 January-31 December 1996.



Map 8. Number of exceedances of the threshold value for information of the population (180 µg/m^3 for hourly values) observed at urban, street and other stations; 1 January-31 December 1996.

4.3.3 Exceedances of the daily threshold value for protection of vegetation

As Table 4 shows, exceedances of the daily threshold of 65 μg/m^3 were frequently observed in all reporting countries. Stations where the threshold was exceeded on more than 100 days in 1996 are located all over the EU. The geographical distribution of the number of exceedances of the daily threshold is presented in Map 9 for the background stations. In Map 9 an attempt has been made to quantify the area where exceedances are observed. For the background stations a representative radius of 100 km is assumed, see also Map 2. When the "representative areas" of two or more stations overlap, the number of exceedances in this location is estimated by a distance-weighted interpolation. In a negligible part of the total area "covered" by the rural stations (1 440 000 km^2) the 65 μg/m^3 level is not exceeded. In 23% of the area the 65 μg/m^3 level is exceeded on 1-75 days; in 47% of the area on 76-150 days and in 31% of the area on more than 150 days. Exceedances on more than 150 days are reported both by northern and southern Member States (see Map 9).

Figure 12 shows the exposure classes in relation to land-use data. Assuming a 100 km representative radius the current set of rural stations is estimated to cover about 40% of forests and about 50% of arable land on the average; within the EU-15 large differences in coverage between the Member States are observed (Beck and Krzyzanowski, 1997). For the majority of the areas covered by the three land-use types an exceedance on more than 75 days is observed.

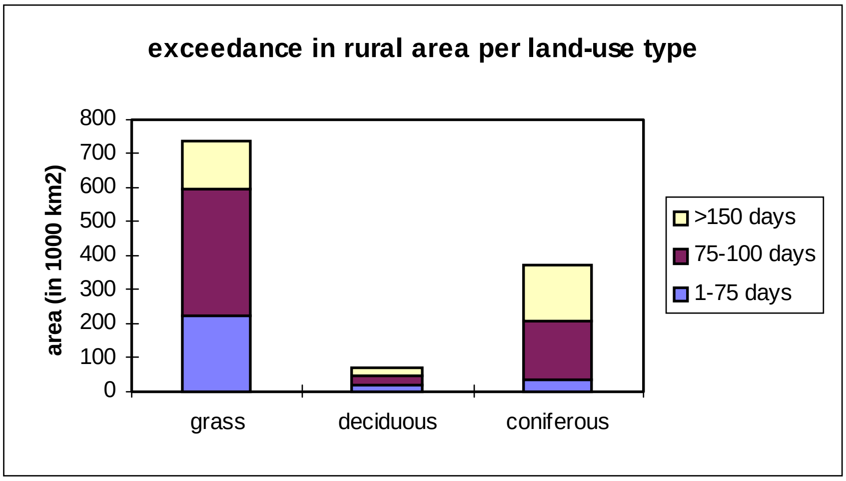
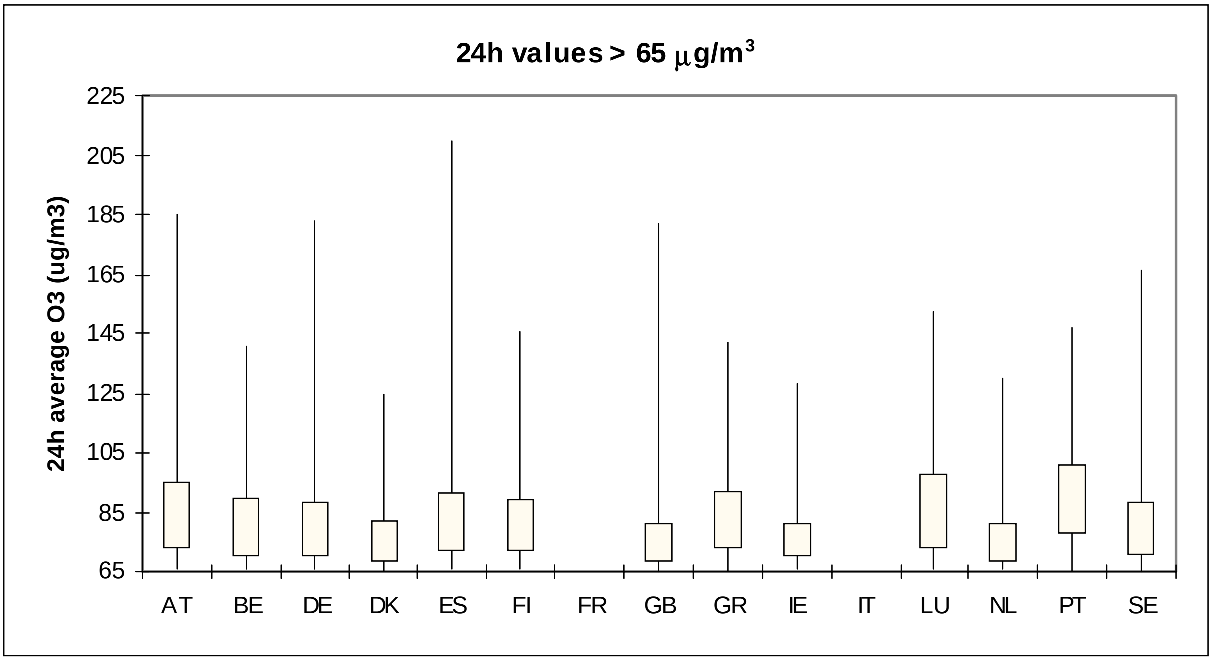


Figure 12. The occurrence of exceedances of the threshold value for protection of vegetation (65 μg/m^3 as daily value; period 1 January - 31 December 1996) averaged over all reporting rural, urban and street stations.

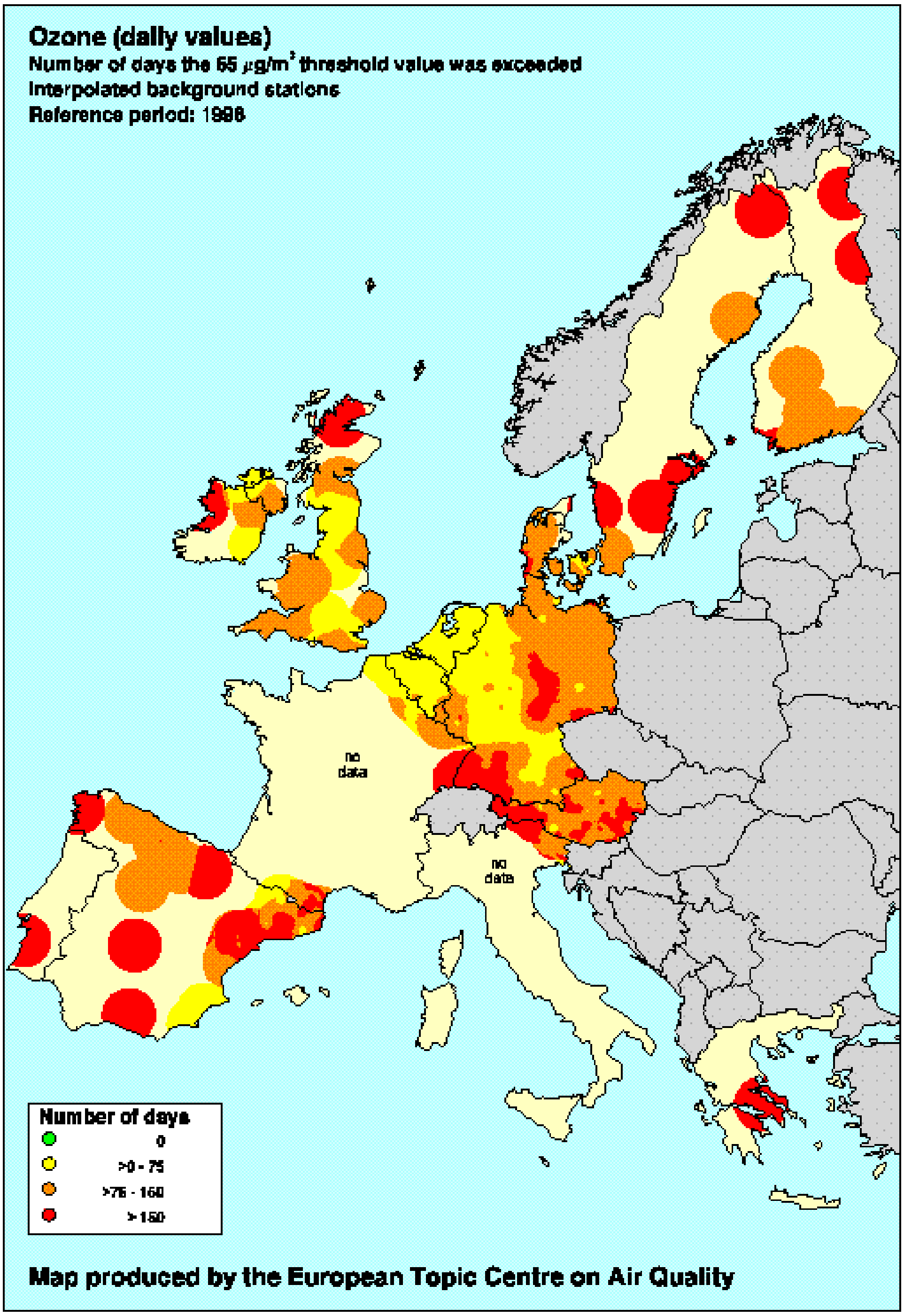
For exceedances of a daily average concentration, the differences between rural and urban stations are more pronounced than is the case for hourly concentrations. In urban areas the low concentrations during the night (caused by interaction with NO_x emissions) reduce the daily average concentrations; in rural areas the decrease in ozone concentrations during the night is generally less strong. In NW Europe, however, the high NO_x emission density might cause also some quenching of ozone at rural sites which explains the relatively low number of exceedances in this region compared both to North and South Europe.

Figure 13 shows the frequency distribution of daily values in excess of 65 µg/m^3. Although extreme values of more than 200 µg/m^3 are observed, in nearly all Member States for 75% of the exceedances the daily average concentration falls between 65 and 98 µg/m^3 (that is 150% of the threshold value). Although the exceedances are most frequently observed in the period March to September, daily values above 65 µg/m^3 are observed in all reporting Member States also during the winter months (January-February and October-December 1996).



	AT	BE	DE	DK	ES	FI	FR	GB	GR	IE	IT	LU	NL	PT	SE
#ex	12046	880	20748	528	13001	1299	na	1677	1342	559	na	354	1056	372	959
#st	111	23	369	6	181	10	na	48	15	6	na	5	38	6	6

Figure 13. Frequency distribution of ozone concentrations (24h values; 1 January - 31 December 1996) in excess of the 65 µg/m^3-threshold for daily values. For each country the total number of observed exceedances is given in row '#Ex', the number of stations is given in row '#St'. Frequency distributions are presented as Box-Jenkins plots indicating the minimum, the 25-Percentile, the 75-percentile and the maximum value.



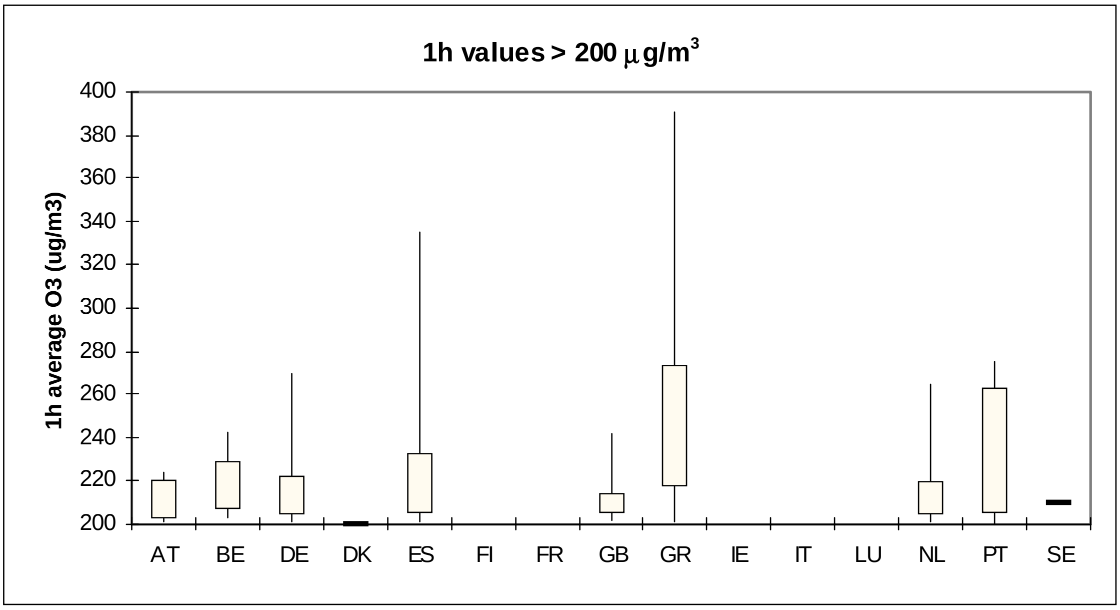
Map 9. Number of exceedances of the threshold value for vegetation (65 µg/m^3 for daily values) observed at background stations; 1 January-31 December 1996. Data is interpolated using inverse distance weighting and a cut-off distance of 100 km.

4.3.4 Exceedance of the hourly threshold value for protection of vegetation

Exceedances of the hourly threshold values for protection of vegetation (200 μg/m^3) are reported by 10 Member States; no exceedances were observed in Finland, Ireland and Luxembourg, see Table 4. The geographical distribution of the number of days on which this hourly threshold value was exceeded is presented in Map 10 for background stations. The map shows that roughly above 60° N this threshold value was not exceeded in 1996; most frequently exceedances are observed in England, Belgium, the Netherlands, Germany and Austria; In Luxembourg the maximum 1h concentration was just below the 200 μg/m^3 threshold level. On the Iberian Peninsula only a limited number of exceedances has been observed.

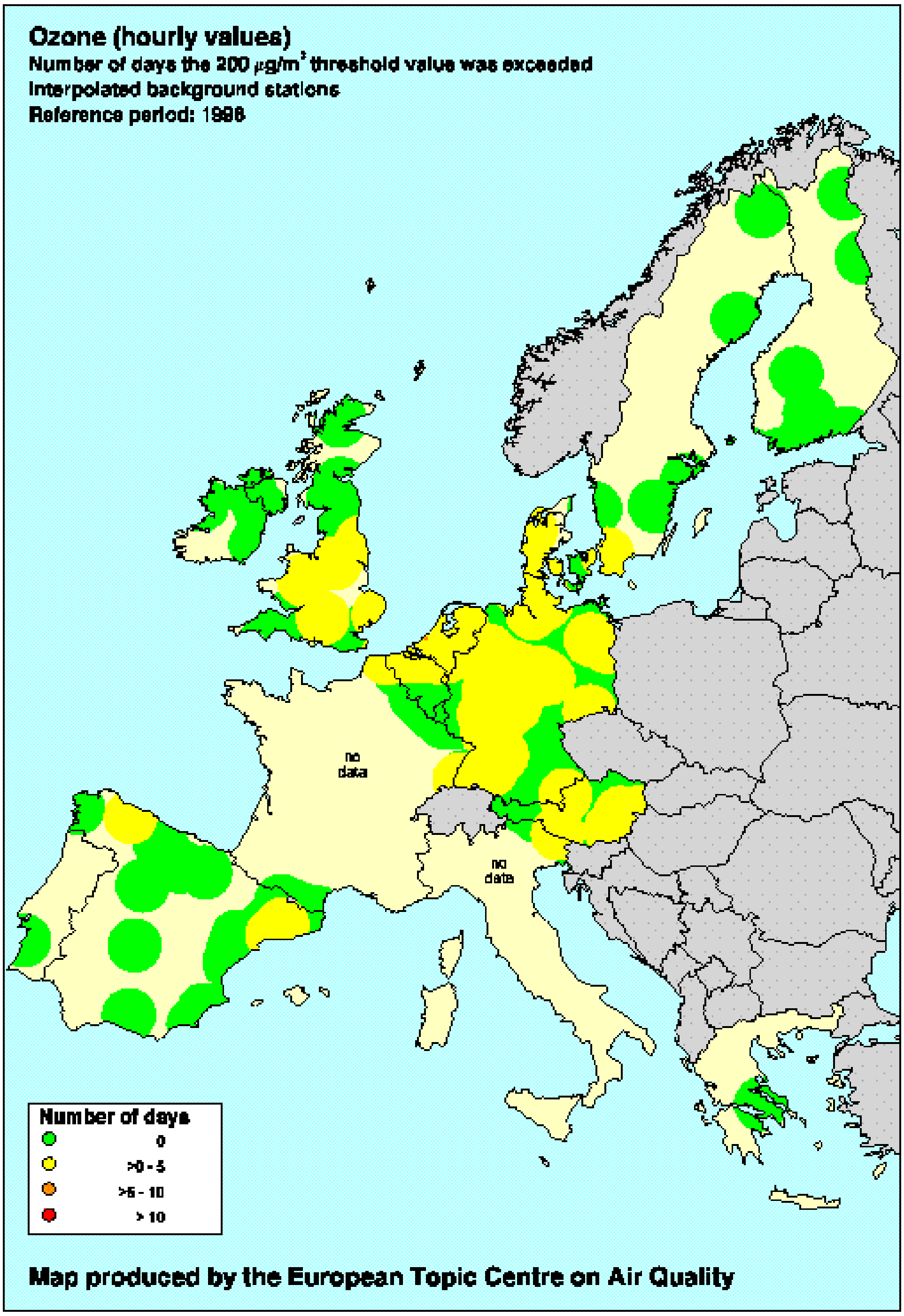
In 56% of the rural regions where data from representative monitoring stations is reported (see Map 2) no exceedances of the 200 μg/m^3 threshold value were observed; in 44% of the area an exceedance is observed during 1-5 days whereas exceedances during more than 5 days were observed at one rural station only**.** For the various land-use classes in 56%, 41% and 31% of the area covered by arable land, broad-leaved forest and coniferous or mixed forest, respectively, the vegetation is exposed to ozone concentrations above the threshold during 1-5 days. Higher number of exceedances (up to 26) were observed at urban/street stations.

The frequency distribution of exceedances of the hourly threshold are presented in Figure 14. For about 75% of the exceedances the ozone levels fall between 200 and 275 μg/m^3.



	AT	BE	DE	DK	ES	FI	FR	GB	GR	IE	IT	LU	NL	PT	SE
#ex	14	11	177	1	84	0	na	13	83	0	na	0	46	6	1
#st	111	23	369	6	189	10	na	50	11	6	na	5	38	8	6

Figure 14. Frequency distribution of ozone concentrations (hourly values; 1 January - 31 December 1996) in excess of the 200 μg/m^3-threshold for hourly values. For each country the total number of observed exceedances is given in row '#Ex', the number of stations is given in row '#St'. Frequency distributions are presented as Box-Jenkins plots indicating the minimum, the 25-Percentile, the 75-percentile and the maximum value.



Map 10. Number of exceedances of the threshold value for vegetation (200 µg/m^3 for hourly values) observed at background stations;1 January-31 December 1996. Data is interpolated using inverse distance weighting and a cut-off distance of 100 km.

4.4 Summer smog episodes in 1996

A first analysis of the episodes during summer 1996 has been presented by the ETC-AQ (Sluyter and van Zantvoort, 1996). Figure 15 gives a graphical representation of the percentage of stations in every Member State that report exceedances of the population information threshold value. From this figure and from information presented in Chapter 4.3 it is clear that the number of episodes covering extended areas of the territory of the EU was small. One of the most widespread episodes occurred on 5-8 June 1996. Map 11 gives an overview of the maximum 1h-average ozone concentrations observed on 7 June 1996. A more detailed discussion on this episode is presented by Sluyter and van Zantvoort (1996).

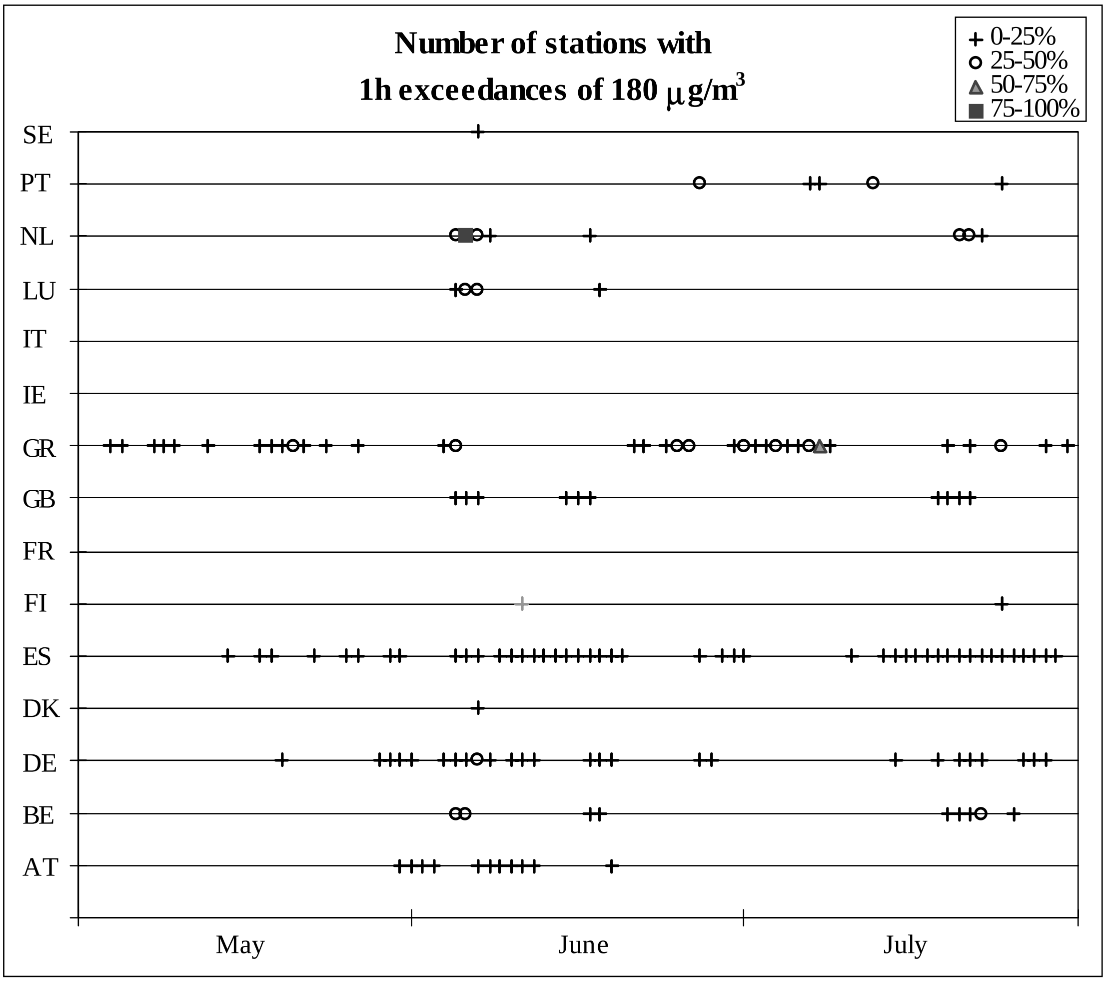
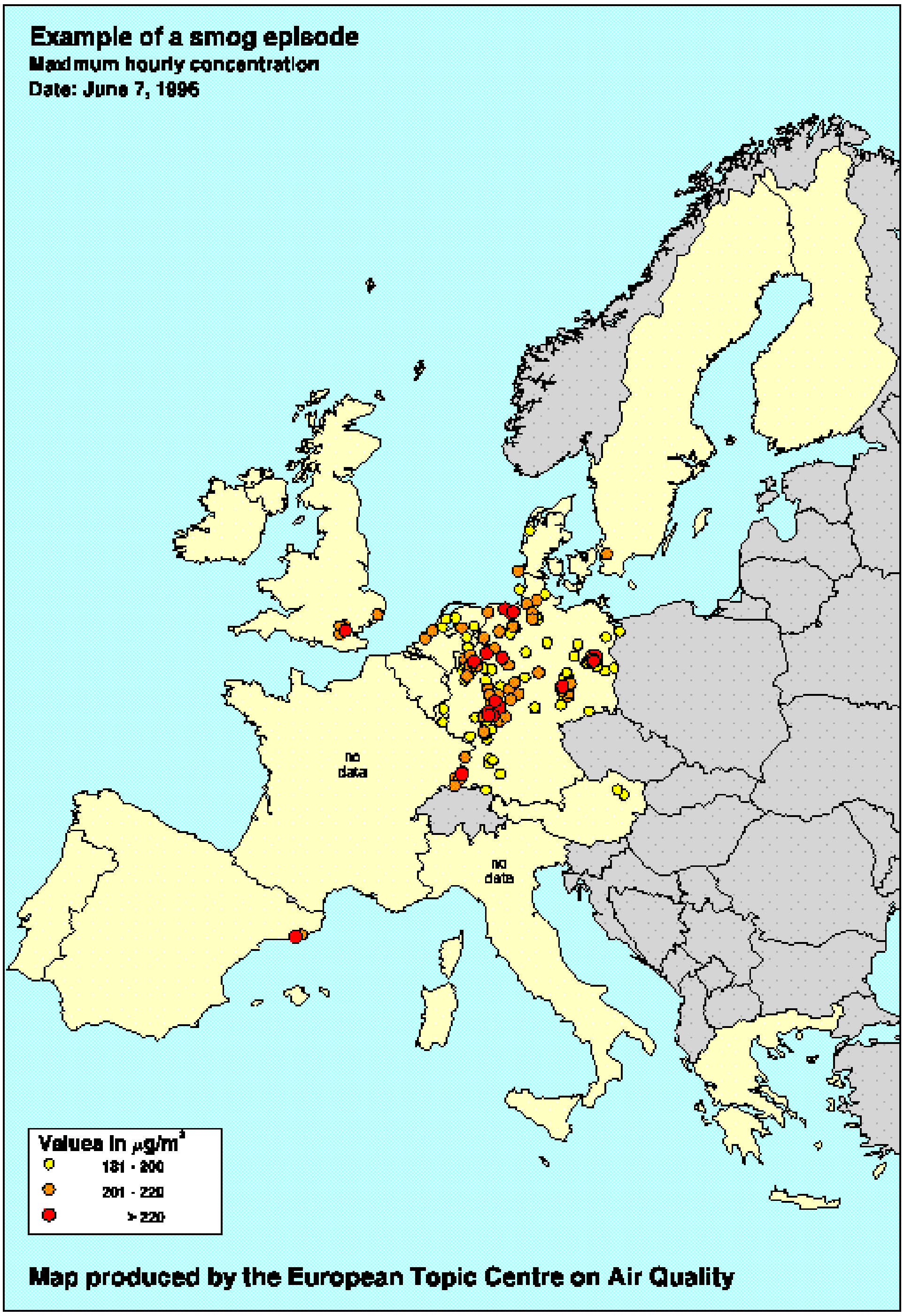


Figure 15. Qualitative overview of exceedances of the 180 µg/m³ population information threshold value (1h) during the period May - July 1996. The symbols represent the percentage of stations in a country which reports at least one exceedance of the threshold during a particular day.



Map 11. Example of an ozone smog episode: hourly ozone concentrations in excess of 180 $\mu g/m^3$ as measured on 7 June 1996.

4.5 Data reported for 1989-1996

Trends in ozone concentrations are expected to result from trends in precursor emissions in Europe and from the increasing trend in hemispheric background ozone concentrations (Borrell and van den Hout, 1995). The magnitude and even the sign of a possible trend might differ from location to location. In a study of trends in concentrations of ozone and related species in the Netherlands and nearby countries Roemer (1996) concluded that the ground level oxidant (sum of ozone and NO_2) concentrations have decreased significantly in the Netherlands from 1981 to 1994 with an average decrease of about 1% per year. For Germany a slightly downward (in the northern part) or slightly upward (in the southern part) trend was noted but probably none of these trends is significant at the 95% confidence interval (Roemer, 1996).

The time series reported in the framework of the ozone directive are too short (1994-1996) to give conclusive answers on an ozone trend in the whole of the EU. However, for various Member States data reports are available for years prior to 1994: for Austria over the period 1993-1996, for Denmark and Finland information for 1992-1996 is available. For the period 1989-1996 data reports are available for four Member States (Belgium, Luxembourg, the Netherlands and United Kingdom), see Figure 16. In a discussion on the time series of 50 and 98 percentile, the reader should be aware that the network (number and location of stations, measuring method etc.) might have been changed during the years. The minimum and maximum values plotted in Figure 16 do not necessarily refer to the same station.

The year-to-year variations in 50-percentile values are relatively small (2 -7 $\mu g/m^3$ on a P50-value in the range of 14-67 $\mu g/m^3$) when compared to the variations in the 98-percentile values (a variation of 11-18 $\mu g/m^3$ for P98-values ranging from 76-145 $\mu g/m^3$, see Figure 16). Peak values of ozone are strongly correlated with temperature mainly because the conditions leading to high temperatures (e.g. strong solar radiation, low wind speeds, continental flows) also trigger photochemical formation. Meteorological fluctuations may cause variations in peak ozone levels that are much larger than the variations due to changes in precursor emissions. A yearly fluctuation of about 15% in 98-percentile value is not exceptional. The aggregated time series given in Figure 16 give a picture which is too scattered to detect any possible trend in ground level ozone concentrations.

At the level of the individual stations a possible trend in ozone levels is examined using the non-parametric Mann-Kendall test (Gilbert, 1987). Only those stations for which data for at least the five years are available have been included in the tests. Table 6 summarises the results for trends in 50 and 98 percentile values. Although some stations show a significant trend, no clear picture for a country or region emerged. Only for the Netherlands is there a clear tendency of a downward trend in the 98-percentile value. This trend, however, mainly results from the high levels observed in 1989 and 1990. Over the period 1991-1996 only three stations produced a significant downward trend. Furthermore at the end 1990/beginning 1991 a new ozone monitor was introduced in the Dutch network (RIVM, personal communication). These data therefore require further analysis. It is not known to what extent similar changes in monitoring practice has influenced the results in other Member States.

Table 6. Trend estimates for 50- and 98-percentile values for individual stations in Belgium, United Kingdom, Luxembourg and the Netherlands; period 1989-1996.

member state	number of stations (1)	slope range ($\mu g/m^3$ per year) (2)
50-percentile		
BE	5 (1,0)	-0.1 ↔ 1.5
GB	19 (3,1)	-0.7 ↔ 1.7
LU	2 (0,0)	0.2 ↔ 1.0
NL	29 (2,9)	-1.8 ↔ 1.5
98 percentile		
BE	5 (1,0)	-6.0 ↔ 2.7
GB	19 (0,1)	-6.0 ↔ 0.7
LU	2 (1,0)	3.6 ↔ 5.2
NL	29 (0,17)	-6.3 ↔ 5.0

(1) in parentheses the number of stations with a significant upward, respectively downward trend (at an $\alpha = 0.10$ significant level) is given;
(2) range in estimated annual trends; results for stations where no significant trend was observed are included in the range estimate.

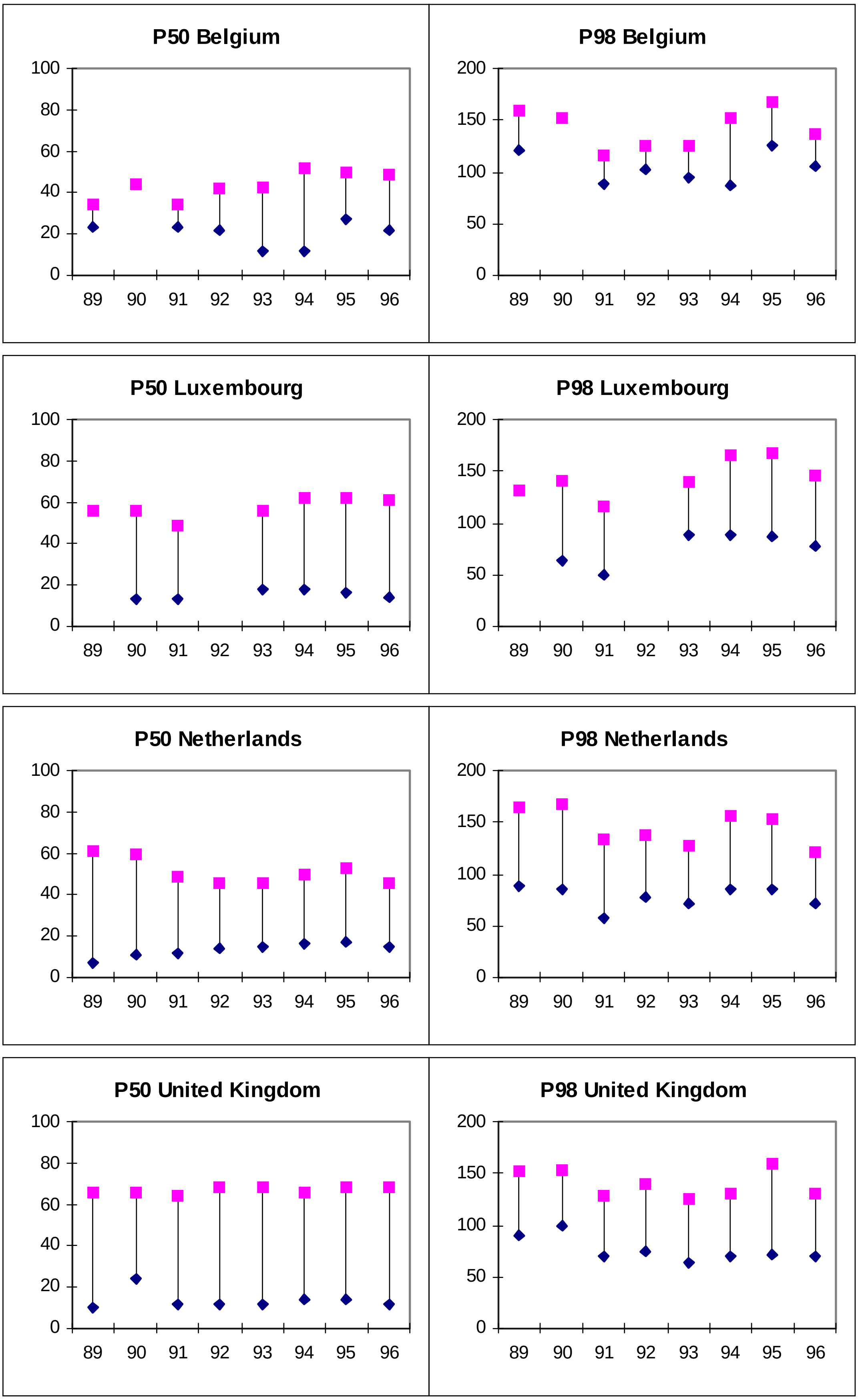


Figure 16. Range in reported 50-percentile values (in $\mu g/m^3$, based on hourly concentrations) and 98-percentile values (in $\mu g/m^3$, based on hourly concentrations) in Belgium, Luxembourg, the Netherlands and United Kingdom in the period 1989-1996.

4.6 Preliminary survey of exceedances in Italy

Information on ozone exceedances was received for 52 Italian stations (for 1995: 68 stations). The coverage both for the land area and for the (urban) population is expected to be insufficient (5 background stations, 22 urban stations). The data were received at a very late stage and were in general inconsistent with the agreed formats. Hence it has not been possible to include the Italian data in all sections of this report. As far as possible the data have been included in the overview Tables 3-6. A complication with the presented data is that only 13 of the 52 stations have a data-coverage of 75% or more. Furthermore, a number of stations report only data over the period July-December. This limits comparison of the Italian situation with the situation in other Member States or in previous years.

The preliminary data indicate that the threshold values set for the protection of human health and the threshold values set for the protection of vegetation were exceeded frequently and substantially in Italy. The threshold value for information of the population was exceeded during at least 86 days being the highest frequency in the EU.

During the smog episode presented in Chapter 4.4 frequent violation of the 180 $\mu g/m^3$ threshold value was observed indicating that this episode is not limited to NW-Europe but has a geographical extent to Southern Europe.

Acknowledgements
The authors are indebted to Herman Hootsen for the cartographic contributions and for all further GIS support.

Note added in proof.
As a member of the EEA, Norway submitted information on ozone exceedances to the Commission following the requirements and formats of the Ozone Directive. The Norwegian data for the year 1996 was received by ETC-AQ on 29 September 1997; it was not possible to include these data in the analysis presented here. However, a survey of the data showed that the Norwegian situation with respect to air pollution by ozone is similar to the situation in the other Scandinavian countries. The data may be summarized as:

- Norway submitted data for 15 monitoring stations (14 rural, one urban station);
- observed maximum 1h concentration is 172 $\mu g/m^3$; maximum observed 8h average concentration is 157 $\mu g/m^3$;
- exceedances of the threshold value of 180 $\mu g/m^3$ has not been observed;
- the threshold value of 110 $\mu g/m^3$ for 8h average concentrations (time period 12.00 - 20.00) has been exceeded 130 times (on average 8.7 times per station);
- the threshold value of 65 $\mu g/m^3$ for daily values has been exceeded 1883 times (on average 126 times per station).

5. CONCLUSIONS AND RECOMMENDATIONS

1. **Data for 1996 were received by the European Commission from 14 Member States.**
   13 Member States provided information on ozone concentrations for a total of 836 monitoring stations. Italy provided information too late to be included fully in this report. From France no information was received.

2. **The spatial coverage and quality documentation of the data need further improvement.**
   Depending on the local situation, the ozone monitoring stations are characterized as rural, urban, street or other (e.g. industrial). Further work on a harmonized classification system is needed.
   The present subset of rural stations is not representative for the land area of the EU: the subset is estimated to cover only 40-50%. The subset of urban stations is insufficient to estimate the exposure of the population living in all cities with more than 25 000 inhabitants: the urban subset covers at most 30% of the urban population.
   Spatial coverage and documentation of the monitoring data quality need improvement if the level of protection of human health and ecosystems in Europe to elevated ozone levels is to be fully assessed. Member States are encouraged to reconsider their ozone measuring networks in the light of the spatial coverage of ozone monitoring stations. It is recommended to improve the documentation on the representativity and on the surrounding of the existing stations.

3. **The threshold value set for the protection of human health was exceeded substantially in all Member States.**
   The threshold value of 110 $\mu g/m^3$ (8h-average) was exceeded substantially (in about 25% of the reported exceedances the 8h-average concentrations exceeded 165 $\mu g/m^3$). The subset of urban stations is assumed to give representative values for the exposure of an urban population of approximately 65 million people. 12% of this population (7.8 million people) is not exposed to ozone levels exceeding the threshold whereas 6% (3.9 million people) is exposed to exceedances during more than 50 days. The number of days with at least one exceedance observed at the reporting stations within a Member State ranges from 12 (Ireland) to 277 (Spain).

4. **The threshold values set for the protection of vegetation were exceeded substantially and in almost all EU Member States.**
   The threshold value of 65 $\mu g/m^3$ (24h-average) is reported to have been exceeded substantially (by up to a factor 3), widely (in all reporting Member States) and frequently (several Member States report exceedances during more than 150 days at some of their stations). Exceedances during more than 150 days are estimated for more than 31% of the area for which the subset of background stations report representative values. The threshold value of 200 $\mu g/m^3$ (hourly average) is exceeded largely and widely (reported by 10 (out of 13) Member States) on a limited number of days.

5. **The threshold value for information of the population was exceeded in almost all EU Member States during a limited number of days.**
Exceedance of the information threshold value of 180 µg/m^3 (1 h average) was reported for stations in 12 (out of 13) Member States. For two stations an exceedance of the warning level of 360 µg/m^3 (1h average) was reported.

6. **It is recommended to improve the reporting of ozone precursors (NO_x, NO_2 and VOC).**
NO_x measurements should be co-located with the ozone monitoring stations as NO_x can be used as an indicator of the station representativeness. Moreover, precursor concentrations will be needed for testing of compliance with VOC and NO_x emission reduction programmes.

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ANNEX I. Observed Exceedances and Annual Statistics

Observed exceedances of ozone threshold values and annual statistics in 1996 at individual monitoring stations reporting in the framework of the Council Directive 92/72/EEC on air pollution by ozone.

Information on ozone exceedances and concentrations for the individual stations reporting in the framework of the Ozone Directive over the period 1 January 1996 - 31 December 1996 is available in computer readable form only. Upon request a diskette containing the following tables is available:

Table I.1: Number of days on which exceedances of threshold values (180 $\mu g/m^3$ and 200 $\mu g/m^3$ for hourly values; 110 $\mu g/m^3$ for 8-hourly values and 65 $\mu g/m^3$ for daily values) were observed at reporting monitoring stations; period 1 January - 31 December 1996.

Table I.2: The longest period of consecutive days on which exceedances of threshold values were observed at reporting monitoring stations; period 1 January - 31 December 1996.

Table I.3: Average length (in days) of periods of consecutive days on which exceedances of threshold values were observed at reporting monitoring stations; period 1 January - 31 December 1996.

Table I.4: Annual statistics (percentiles and maximum values) of hourly and moving eight hourly ozone concentrations for reporting monitoring stations; all concentrations in $\mu g/m^3$; period 1 January - 31 December 1996.

Table I.5: Annual statistics (averaged, 50-, 95- and 98- percentile values) of hourly NO_x concentrations for reporting monitoring stations; all concentrations in $\mu g/m^3$; period 1 January - 31 December 1996.

Table I.6: Annual statistics (averaged, 50-, 95- and 98- percentile values) of hourly NO_2 concentrations for reporting monitoring stations; all concentrations in $\mu g/m^3$; period 1 January - 31 December 1996.

Table I.7: Annual statistics (averaged, 50-, 95- and 98- percentile values) of daily VOC concentrations for reporting monitoring stations; all concentrations in $\mu g/m^3$; period 1 January - 31 December 1996.

Notes to the Tables

Table I.1
Exceedances of the threshold value of 360 μg/m^3 for hourly values has been observed in 1996 at 2 stations:

country	station name & city	date, time	max conc (μg/m^3)
Greece	Liosia, Athens	21 May 1996, 14.00	391
	Marousi	21 May 1996, 13.00	361

In Table I.1 it is also indicated when no exceedance of (one or more) threshold values was observed at the station. This information has not been submitted by the Member States and is inferred from the available data. In cases where the information was insufficient for an unambiguous answer a "?" is printed.

Explanations of headings of Table I.1:

column	*name*	*explanation*
1	codcou	country code;
2	staname	name of monitoring station;
3	incod	code number of monitoring station;
4	ville	city where station is located;
5	180 (1)	number of days on which the 180 μg/m^3 threshold values for 1h average concentrations has been exceeded;
6	200 (1)	number of days on which the 200 μg/m^3 threshold values for 1h average concentrations has been exceeded;
7	110 (8a)	number of days on which the 110 μg/m^3 threshold values for the non-overlapping 8 hourly values between 0.00-8.00, 8.00-16.00 and 16.00 and 24.00 has been exceeded;
8	110 (8b)	number of days on which the 110 μg/m^3 threshold values for the 8 hourly values between 12.00-20.00 has been exceeded;
9	65 (24)	number of days on which the 65 μg/m^3 threshold values for the 24 hourly values has been exceeded;
10	% 1h val	percentage of valid 1h averaged values.

Table I.2:
Explanations of headings of Table I.2:

column	*name*	*explanation*
1	codcou	country code;
2	staname	name of monitoring station;
3	incod	code number of monitoring station;
4	ville	city where station is located;
5	180 (1)	longest period (in days) during which the 180 μg/m^3 threshold values for 1h average concentrations has been exceeded;
6	200 (1)	longest period (in days) during which the 200 μg/m^3 threshold values for 1h average concentrations has been exceeded;
7	110 (8a)	longest period (in days) during which the 110 μg/m^3 threshold values

		for the non-overlapping 8 hourly values between 0.00-8.00, 8.00-16.00 and 16.00 and 24.00 has been exceeded;
8	110 (8b)	longest period (in days) during which the 110 $\mu g/m^3$ threshold values for the 8 hourly values between 12.00-20.00 has been exceeded;
9	65 (24)	longest period (in days) during which the 65 $\mu g/m^3$ threshold values for the 24 hourly values has been exceeded;
10	% 1h val	percentage of valid 1h average values.

Table I.3

Explanations of headings of Table I.3:

column	*name*	*explanation*
1	codcou	country code;
2	staname	name of monitoring station;
3	incod	code number of monitoring station;
4	ville	city where station is located;
5	180 (1)	average length of period (in days) during which the 180 $\mu g/m^3$ threshold values for 1h average concentrations has been exceeded;
6	200 (1)	average length of period (in days) during which the 200 $\mu g/m^3$ threshold values for 1h average concentrations has been exceeded;
7	110 (8a)	average length of period during (in days) which the 110 $\mu g/m^3$ threshold values for the non-overlapping 8 hourly values between 0.00-8.00, 8.00-16.00 and 16.00 and 24.00 has been exceeded;
8	110 (8b)	average length of period (in days) during which the 110 $\mu g/m^3$ threshold values for the 8 hourly values between 12.00-20.00 has been exceeded;
9	65 (24)	average length of period (in days) during which the 65 $\mu g/m^3$ threshold values for the 24 hourly values has been exceeded;
10	% 1h val	percentage of valid 1h average values.

Table I.4

Explanations of headings of Table I.4:

column	*name*	*explanation*
1	codcou	country code;
2	staname	name of monitoring station;
3	incod	code number of monitoring station;
4	ville	city where station is located;
5	1h P50	50 percentile of hourly values ($\mu g/m^3$);
6	1h P98	98 percentile of hourly values ($\mu g/m^3$);
7	1h P99.9	99.9 percentile of hourly values ($\mu g/m^3$) (additional information);
8	1h MAX	maximum value of hourly value ($\mu g/m^3$);
9	% 1h val	percentage of valid 1h average values;
10	8h P50	50 percentile of eight hourly values ($\mu g/m^3$, calculated as a moving average);
11	8h P98	98 percentile of eight hourly values ($\mu g/m^3$);
12	8h P99.9	99.9 percentile of eight hourly values ($\mu g/m^3$) (additional information);
13	8h MAX	maximum value of eight hourly value ($\mu g/m^3$);

14	% 8h val	percentage of valid 8h average values (µg/m^3).

Table I.5
Explanations of headings of Table I.5:

column	*name*	*explanation*
1	codcou	country code;
2	staname	name of monitoring station;
3	incod	code number of monitoring station;
4	ville	city where station is located;
5	AVER	yearly averaged NO_x concentration (µg/m^3);
6	PARP50	50-percentile of hourly NO_x concentration (µg/m^3);
7	PARP90	90-percentile of hourly NO_x concentration (µg/m^3);
8	PARP95	95-percentile of hourly NO_x concentration (µg/m^3);
9	% val	percentage of valid 1h average values.

Table I.6
Explanations of headings of Table I.6:

column	*name*	*explanation*
1	codcou	country code;
2	staname	name of monitoring station;
3	incod	code number of monitoring station;
4	ville	city where station is located;
5	AVER	yearly averaged NO_2 concentration (µg/m^3);
6	PARP50	50-percentile of hourly NO_2 concentration (µg/m^3);
7	PARP90	90-percentile of hourly NO_2 concentration (µg/m^3);
8	PARP95	95-percentile of hourly NO_2 concentration (µg/m^3);
9	% val	percentage of valid 1h average values.

Table I.7
Explanations of headings of Table I.7:

column	*name*	*explanation*
1	codcou	country code;
2	staname	name of monitoring station;
3	incod	code number of monitoring station;
4	ville	city where station is located;
5	AVER	yearly averaged VOC concentration (µg/m^3);
6	PARP50	50-percentile of hourly VOC concentration (µg/m^3);
7	PARP90	90-percentile of hourly VOC concentration (µg/m^3);
8	PARP95	95-percentile of hourly VOC concentration (µg/m^3);
9	% val	percentage of valid 24h average values.

ANNEX II. Phenomenology of ozone concentrations

For a better understanding of the report, some of the main characteristics of ambient ozone are summarized here. For more advanced information on ozone and its photochemical formation the reader is referred to information documents provided by DGXI (Borrell and van den Hout, 1995; Derwent and van den Hout,1995) and to reports prepared in the framework of UN-ECE Convention on long-range transport of air pollution (Malik *et al.*, 1996; Hjellbrekke, 1996; Barrett and Berge, 1996) and EUROTRAC (see e.g. Borrel *et al.*,1997; Hov, 1997).

Ozone is a secondary air pollutant formed in the atmosphere under the influence of sunlight. Ozone formation occurs at all levels in the atmosphere, from ground level up to the stratosphere. Here the discussion is limited to ozone at ground level. It has been shown that under the present conditions in Europe the ozone exposure of humans, vegetation and materials leads to adverse effects.

The precursors of the ozone formation are Volatile Organic Compounds (VOC), carbon monoxide (CO) and nitrogen oxides (NO_x). VOC and CO act as "fuels" as they are oxidized in the process; the nitrogen oxides play an important role as "catalysts": they are not 'consumed' in the formation process but are essential for the continuation of the process. However, nitrogen oxides are consumed in side reactions by which they are further oxidized to nitric acid or nitrates. For the continuation of the photochemical oxidation process a continuous injection of nitrogen oxides is therefore necessary.

The ozone formation takes place on various time and spatial scales: on the local scale as in urban areas as Athens or Milan, on the regional scale as is demonstrated by the photochemical episodes in Central and Northwest Europe and on the hemispheric/global scale. Highly reactive VOCs are important precursors on the local and regional scale whereas the less reactive, relatively long-lived VOCs such as methane contribute to ozone formation on the global/hemispheric scale.

The role of nitrogen oxides is complex and may be different at various distances from the source. In heavily populated areas the ozone concentrations may be lower than the regional concentrations due to chemical scavenging by local nitrogen oxide emissions. This scavenging is presented by the chemical reaction:

$$O_3 + NO \rightarrow NO_2 + O_2 \qquad \text{(R1)}$$

Nitrogen dioxide (NO_2) formed in this reaction can be seen as 'potential ozone' as in the photolysis of NO_2, nitrogen monoxide, NO, and ozone are produced:

$$NO_2\ (+\ O_2) \rightarrow O_3 + NO \qquad \text{(R2)}$$

As both the time scales of the NO-scavenging reaction (R1) and of the NO_2 photolysis are relatively short, an equilibrium between the three components will be established:

$$O_3 + NO \leftrightarrow NO_2 + O_2 \qquad \text{(E1)}$$

Note that the sum of O_3 and NO_2 (frequently indicated as *oxidant* or *Ox*) is independent of the equilibrium. Knowledge on simultaneously measured NO_x concentrations in general and NO_2 concentrations in particular is therefore important for interpretation of ozone levels. The oxidant levels are spatially less variable than the ozone levels. A mapping procedure based on oxidant levels is therefore preferred.

The time scales of photochemical ozone formation are generally longer than the time scale associated with the above reaction R1 and R2 and close to NO_x sources a decrease in ozone concentrations may be observed; at larger distances to the source the ozone levels will increase again. In Figure II.1 the ozone concentration in an air parcel passing a NO_x source is schematically presented.

One of the consequences of this interaction with NO_x is that the representativeness of ozone monitoring stations depends strongly to what extent the station is influenced by local NO_x sources: concentrations measured at a station in a traffic situation will be representative for its direct surroundings only (e.g. less than a few 100 m) whereas a background station may measure concentrations representative for an area of several tens of kilometres. The information requested in Article 4 of the Directive should form the basis on which a representative area for each of the monitoring stations could be defined.

At ground level ozone concentrations generally show a strong diurnal variation. At night concentrations are low, both caused by removal by dry deposition and by titration by NO-emissions according to reaction R1. In the morning concentrations increase, caused not only by the sunlight induced photochemical formation but also by the downward mixing of higher, ozone-rich layers. In the afternoon both processes will become less important and concentrations will decrease again when the loss processes dominate. The maximum concentration is frequently found in the late afternoon, around 16.00. For the eight hour periods reported in the framework of the Ozone Directive, the highest value

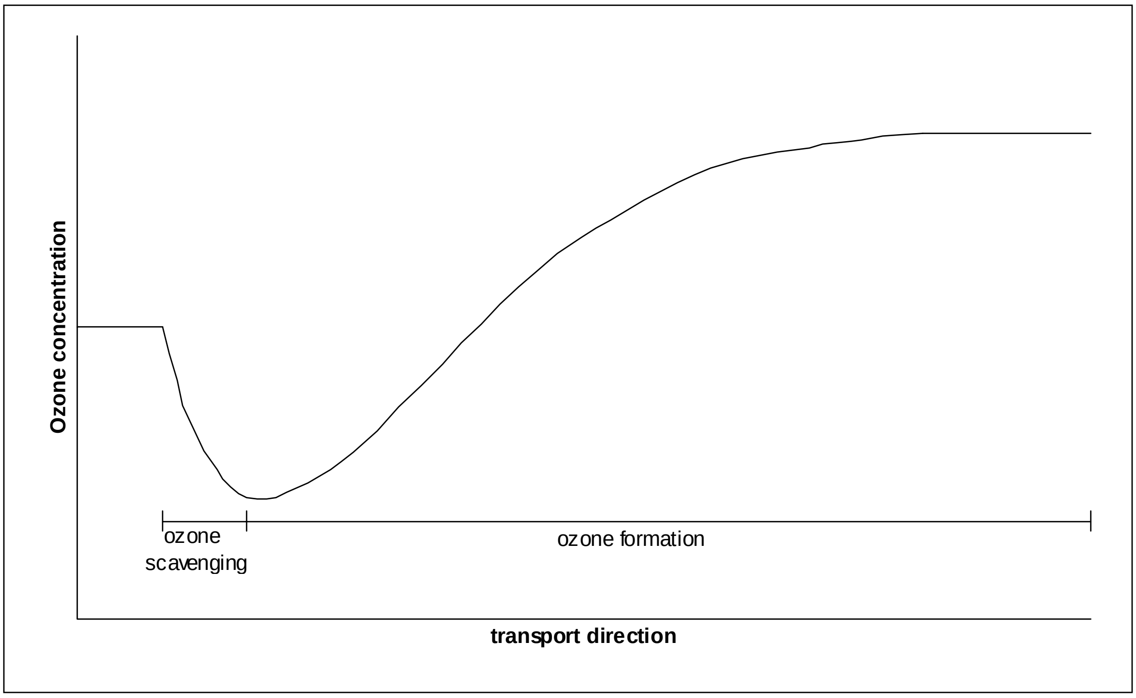

Figure II.1 Schematic presentation of ozone concentrations downwind of a large NO_x source where ozone scavenging will take place.

will generally be observed between 12.00 and 20.00.

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EUROPEAN TOPIC CENTRE ON AIR QUALITY

RIVM NILU NOA DNMI

UNDER CONTRACT
TO THE EUROPEAN
ENVIRONMENT
AGENCY

INFORMATION DOCUMENT CONCERNING AIR POLLUTION BY OZONE

Overview of the situation in the European Union during the 1997 summer season (April-August)

Report to the Commission by the European Environment Agency
European Topic Centre on Air Quality

Rob Sluyter
Esther van Zantvoort

October 1997

rivm
research for
man and environment

1. INTRODUCTION

Ozone is a strong photochemical oxidant which may cause serious health problems and damage to materials and crops. Human exposure to elevated levels of ozone concentrations can give rise to decreases in lung function and inflammatory responses. Symptoms observed are coughing, chest pain, difficulty in breathing, headache and eye irritation. Both laboratory and epidemiological data indicate large variations between individuals in response to episodic O_3 exposure, the effects seem to be more pronounced in children than in adults (WHO, 1995). The World Health Organization (WHO) recommends an 8h protection guide value of 120 µg/m^3 (WHO, 1996) above which symptoms and damage to respiratory functions can be expected to occur.

In view of the harmful effects of photochemical pollution, the Council adopted in 1992 Directive 92/72/EEC on air pollution by ozone (EC, 1992). The Directive defined threshold values, established procedures for harmonised monitoring, for collecting and exchanging data and for information of the public when exceedances of threshold values occur.

The thresholds set by the Directive are presented in Table 1. As far as data reporting is concerned, two types of reporting can be distinguished according to Article 6 of the Directive:

1. Exceedances of the population information and warning thresholds (date, time, duration and maximum concentration) must be reported to the Commission within one month after occurrence (data is not necessarily validated);
2. Exceedances of all threshold values including some additional statistics (percentiles, maxima) must be provided within 6 months after the end of a calendar year (validated data).

Table 1. Threshold values for ozone concentrations set in Directive 92/72/EEC

threshold for:	concentration (in µg/m^3)	averaging period (h)
health protection	110	8
vegetation protection	200	1
“ “	65	24
population information	180	1
population warning	360	1

According to Article 7 of the Directive, the Commission prepares a report summarising all the information transmitted by the Member States at least once a year. The report for the 1996 calendar year will become available together with this document (De Leeuw and van Zantvoort, 1997)

In this document a first assessment is made of the 1997 summer season, based only on the exceedances of the population information and warning thresholds for ozone, which were transmitted by the Member States after the end of each month.

The report is mainly intended to provide fast feedback to the Member States on their data. It also enables the Member States to compare the levels observed in the past summer season with those observed in other Member States. Note that information presented in this document is not necessarily based on validated monitoring data and hence should be considered preliminary.

2. Availability of data

According to the Directive, exceedances of the population information and warning thresholds are to be transmitted to the Commission within one month following the observation. On the basis of the experience gained with the ozone data reporting in 1995, the Commission updated the formats to be used and gave additional guidelines to ensure successful transmission of data. The exchange formats have not been annotated in 1997. In this report, the EU definition of data formats are used as reference. If necessary, files were converted at the European Topic Centre on Air Quality (ETC-AQ) for further processing. In this report all data received by the Commission (DGXI) and forwarded to the ETC-AQ not later than 19 September 1997 have been included in the analysis.

14 Member States provided information on the ozone situation this year. 10 Member States transmitted monthly reports on exceedances occurrence from April-August. Ireland, Denmark, Sweden and Finland did not record any exceedance of the 180 $\mu g/m^3$ threshold this year. No monthly exceedance reports were received from France. It is greatly appreciated by the Commission that Member States were able to transmit data before the formal deadline as set in the Directive. Table 2 presents an overview of observed exceedances per country per month.

Table 2: Overview of observed exceedances per month per country. yes: exceedance of the population information threshold reported, no: no exceedance reported, ?: no reporting received.

	April	**May**	**June**	**July**	**August**
AT	no	yes	no	yes	yes
BE	no	no	yes	no	yes
DE	yes	yes	yes	yes	yes
DK	no	no	no	no	no
ES	no	yes	yes	yes	yes
FI	no	no	no	no	no
FR	?	?	?	?	?
GB	no	no	yes	yes	yes
GR	yes	yes	yes	yes	yes
IE	no	no	no	no	no
IT	yes	yes	yes	yes	yes
LU	no	no	no	yes	yes
NL	no	no	no	no	yes
PT	yes	no	yes	yes	yes
SE	no	no	no	no	no

Member States were requested to check the information made available to the Commission on ozone monitoring sites implemented in the framework of the Directive. For the interpretation of ozone data it is essential to have information on the direct surroundings of the station since the ozone concentration may be scavenged by locally emitted nitrogen oxides or by enhanced dry deposition which might occur for example under a forest canopy. Member States were requested to classify their stations as street, urban background[5], rural or industrial stations as a first description of the environment of the stations.

Only five countries explicitly reported the number of stations scheduled to be operational during summer 1997 (for 1996, all countries reported this information). It is assumed that the number of stations has not changed since 1996 in countries which did not report the number of stations, with the exception of France and Italy. For these countries an estimate of the number of operational stations has been made on the basis of various information received in 1995 and 1996.

Map 1 presents the location of all ozone monitoring stations (street and urban background taken together as 'urban') assumed to be operational during the 1997 summer season.

1070 ozone monitoring sites are assumed to be operational in the framework of the Directive. From the 1070 ozone monitoring stations, 291 stations are situated in rural areas, 326 stations in urban background environments, 189 are street stations and 264 stations are characterised as industrial station or the monitoring environment was not specified.

Note that due to the fact that only exceedances of thresholds were reported, it is not clear whether stations were operational continuously throughout the summer period. It is possible that ozone concentrations exceeded a threshold at a site but was not reported because the monitoring station was temporarily out of operation[6].

In this report exceedances are counted on a daily basis, that is, a day on which a threshold is exceeded at least once, is counted as one exceedance day.

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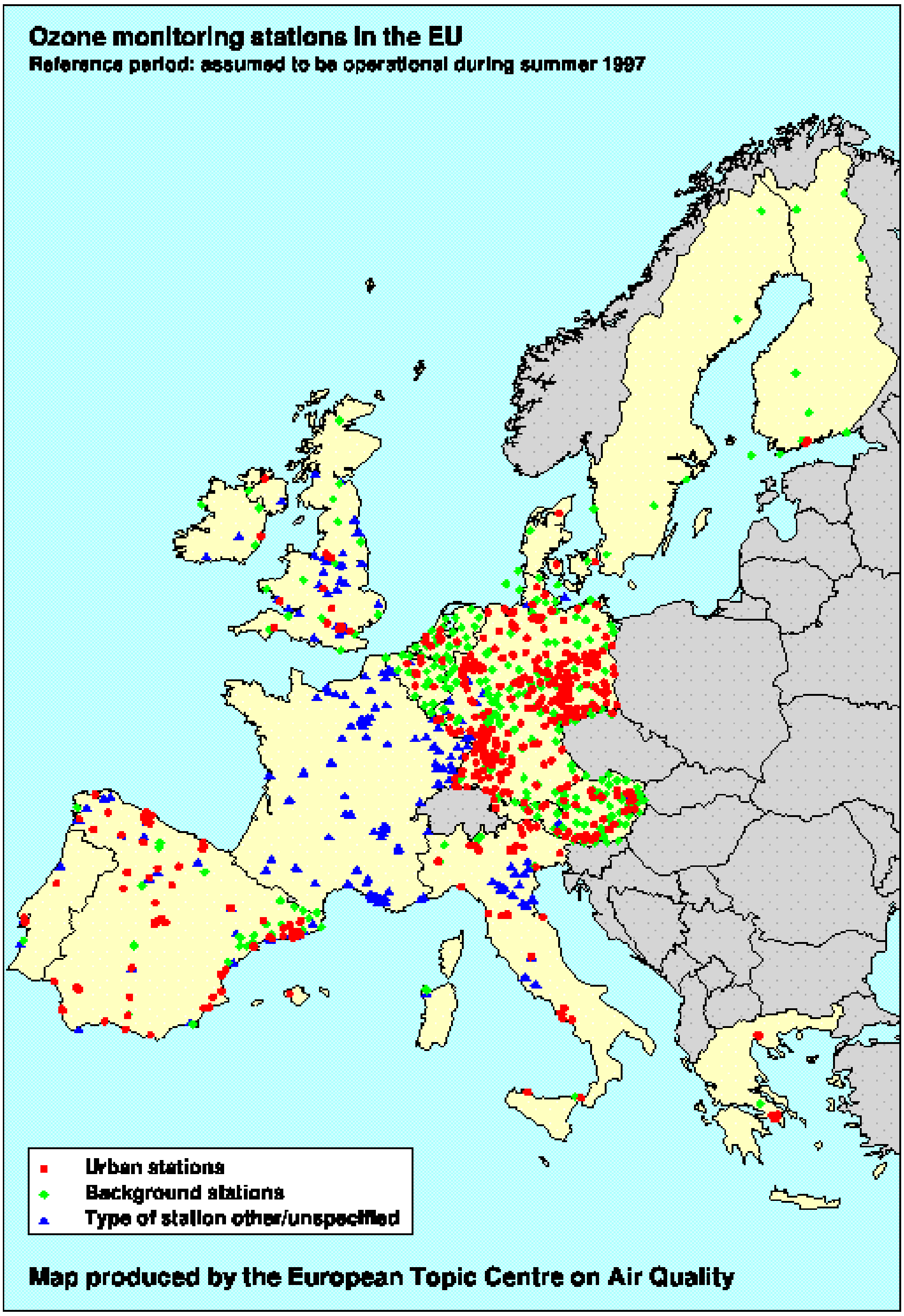
[5] Urban background: station located in the built-up area of the city but not directly influenced by emission sources such as traffic or industry.

[6] The annual report (De Leeuw and van Zantvoort, 1997) gives information on the percentage of time stations were operational, most stations score >90%.



Map 1: Ozone monitoring stations implemented in the framework of Directive 92/72/EEC on air pollution by ozone, scheduled to be operational during 1997.

3. SUMMARY OF DATA REPORTED FOR SUMMER 1997

The threshold for warning of the public (1h> 360 µg/m^3) was exceeded at one station during summer 1997 (Table 3):

Table 3: Observed exceedance of the threshold for warning of the public (1h concentration > 360 µg/m^3) during summer 1997 (April-August).

Country	**City**	**Station**	**Maximum observed hourly concentration (µg/m^3)**	**Date, time**
Greece	Athens	Lykovrissi	383	18-6-97,12.00

During summer 1996 the threshold for warning of the public was also exceeded in the Athens conurbation, although at different stations. The Athens episode will be described in more detail in Chapter 5. Table 4 presents a general overview of the observed exceedances of the threshold for information of the public during April-August 1997 on a country by country basis[7]. As the number of stations differs widely from country to country, the absolute number of exceedances are less suitable for comparison. As in the annual ozone report (De Leeuw and van Zantvoort, 1997) the concept of 'occurrence of exceedances' is used here. Occurrence of exceedances is defined as the total number of exceedances summed over all stations divided by the number of stations.

Table 4: Summary of exceedances of the threshold for information of the public (1h concentration > 180 µg/m^3) during summer 1997 (April-August) on a country by country basis.

	Nr. of stations[I]	**Nr. of stations with exceedance**	**Nr. of days with exceedance**[II]	**Maximum observed concentr. (µg/m^3)**	**Averaged maximum concentr. (µg/m^3)**	**Occurrence of excee-dances**[III]	**Average duration of exceedances (hour)**
AT	114	10(9%)	9	228	196	0.1/1.3	1.7
BE	23	16(70%)	16	277	198	2.8/4.1	3.1
DE	379	225(59%)	41	253	193	1.5/2.6	2.6
DK	6	0	0	<180	<180	0/0	0
ES	173	25(15%)	32	250	198	0.5/3.2	1.7
FI	11	0	0	<180	<180	0/0	0
FR		?	?	?	?	?	?
GB	69	27(39%)	12	318	195	0.8/2.0	2.8
GR	14	7(50%)	44	383	213	6.3/12.6	2.6
IE	6	0	0	<180	<180	0/0	0
IT	80	37(46%)	49	339	205	4.0/8.7	3.1
LU	5	2(40%)	5	203	188	1.0/2.5	2.0
NL	38	25(66%)	9	266	197	1.2/1.8	2.2
PT	8	5(63%)	16	271	201	2.4/3.8	1.4
SE	6	0	0	<180	<180	0.0/0	0
EU	932	379(41%)		383	198	1.2/3.4	2.7

I Number of stations implemented in the framework of the Ozone Directive
II The number of days on which at least one exceedance was observed
III Left figure: averaged over all implemented stations, right figure: averaged over all stations which reported at least one exceedance.

[7] Note that in all tables and figures presented, information for France is not available.

Finland, Denmark, Ireland and Sweden did not observe exceedances of the population information threshold this summer. In other countries, the number of days on which at least one exceedance was observed ranged from 5 in Luxembourg to 49 in Italy. 41% of all stations reported one or more exceedance. On average 3.4 exceedances occurred this year on stations which recorded at least one exceedance. The average maximum hourly concentration during an exceedance of the threshold this year was 198 $\mu g/m^3$.

Table 5 summarises the exceedances on a month by month basis. In the Mediterranean region of Southern Europe frequent exceedances were observed during the stable, warm and sunny summer months. April, May, June and July were on average unfavourable for the formation of ozone in Northern and Western Europe. August was a very hot and sunny month in large parts of Western and Northern Europe resulting in more favourable conditions for the formation of ozone. As a result, August had the highest number of stations reporting exceedances.

Table 5: Summary of exceedances of the threshold for information of the public (1h concentration > 180 $\mu g/m^3$) during summer 1997 (April-August) on a month by month basis.

	Nr. of stations with exceedance[I]	**maximum observed concentration ($\mu g/m^3$)**	**averaged maximum concentration ($\mu g/m^3$)**	**Occurrence of exceedances[II]**	**average duration of exceedances (hr)**
April	6	230	190	0.0/2.8	2.0
May	37	279	193	0.1/1.7	2.0
June	33	383	203	0.1/2.1	2.2
July	99	339	205	0.3/3.2	2.7
August	340	318	196	0.8/2.4	2.7

I The theoretical maximum is 932 stations (all stations which are assumed to be operational during summer 1997 and for which data was transmitted).

II Left figure: averaged over all implemented stations, right figure: averaged over all stations which reported at least one exceedance.

In Figure 1 the number of days per month is presented on which an exceedance was recorded at least at one station in a country. Again, the relative abundance of exceedances in August in Western Europe is striking. Spain, Italy, Greece and Portugal recorded most exceedance days in July. Figure 2 presents the occurrence of exceedances per country on a month by month basis. No monthly pattern is apparent. Exceedances in Greece and Portugal were observed at a limited number of stations; this explains the relatively high occurrence of exceedances in these countries.

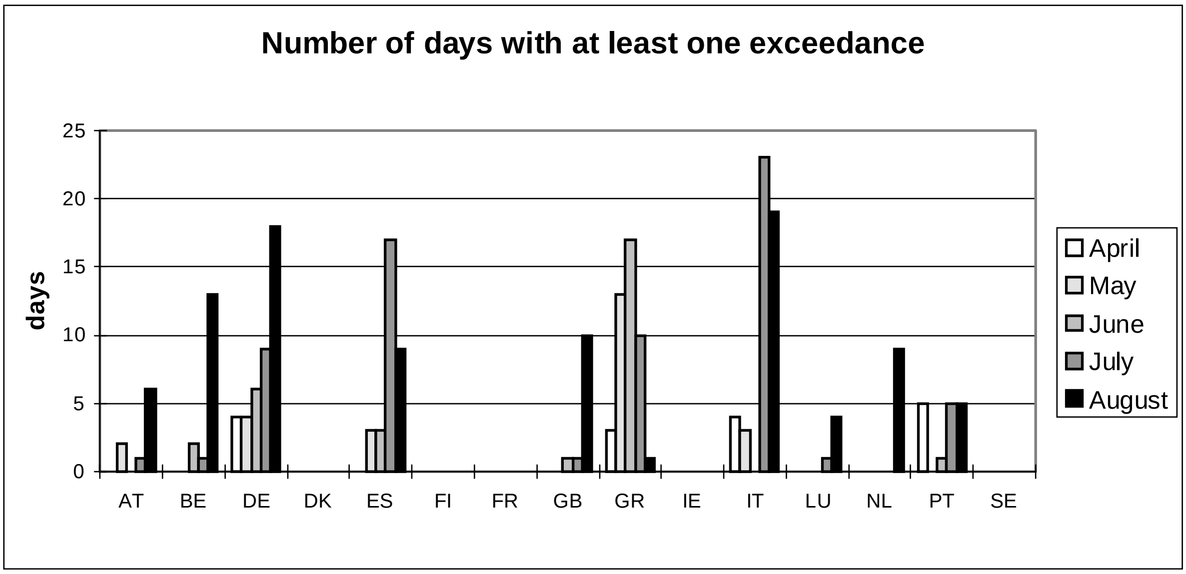


Figure 1: Number of days on which at least one exceedance of the threshold value for information of the public (1h concentration > 180 µg/m^3) was observed per country and per month during summer 1997. Note that data from France is missing, Finland, Denmark, Sweden and Ireland did not report exceedances.

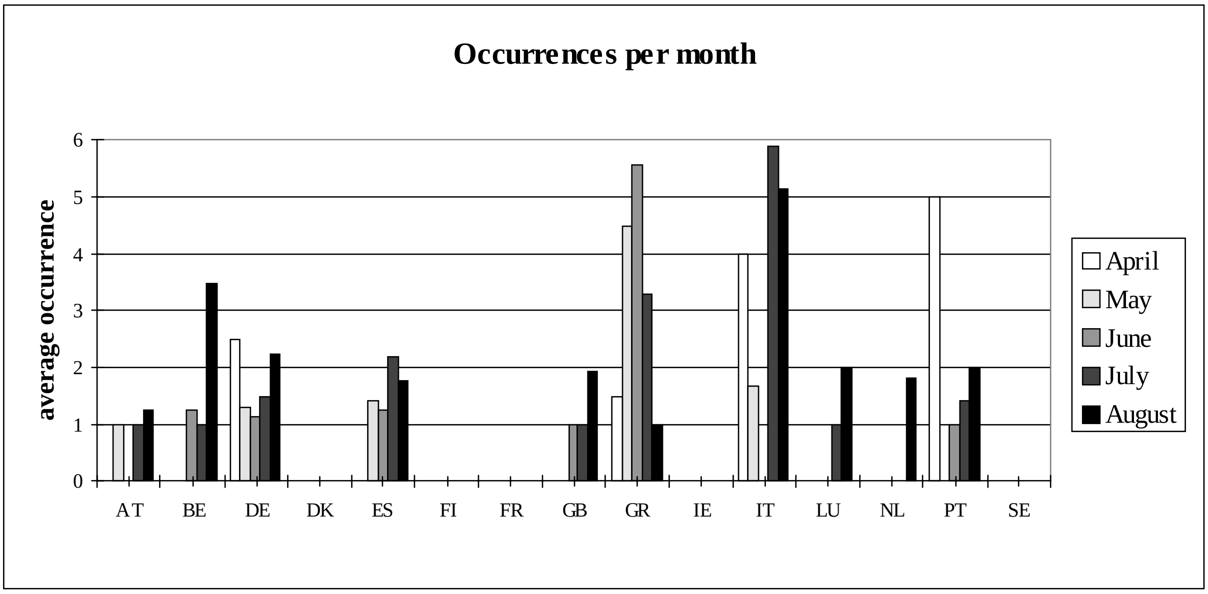


Figure 2: Occurrence of exceedances (in days) of the threshold value for information of the public (1h concentration > 180 µg/m^3) per country on a month by month basis during summer 1997. Note that data from France is missing, Finland, Denmark, Sweden and Ireland did not report exceedances.

The average occurrence of exceedances (in days) in each country of the threshold for information of the public by station type (rural, urban and street) is presented in Figure 3. The occurrence of exceedances generally decreases in the order rural-urban-street. Stations for which the type was not specified are excluded from this figure.

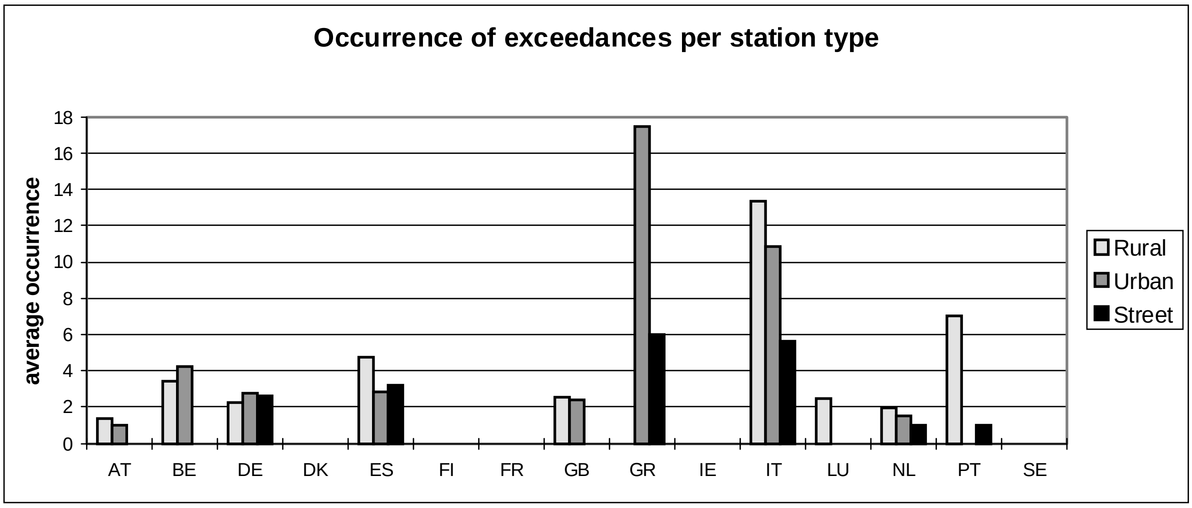
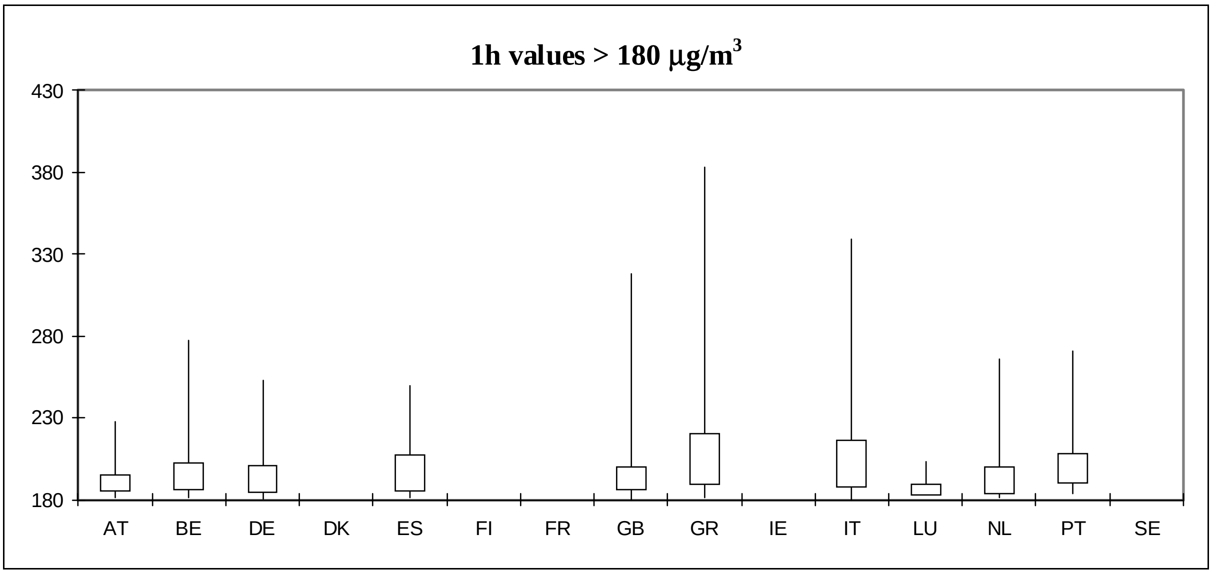


Figure 3: Average occurrence of exceedances (in days) of the threshold for information of the public (1h concentration > 180 µg/m^3) by station type (rural, urban and street) and country during summer 1997. Note that data from France is missing, Finland, Denmark, Sweden and Ireland did not report exceedances.

Figure 4 shows the frequency distribution of hourly ozone concentrations in excess of the threshold value using Box-Jenkins plots. For each Member State the Box-Jenkins plot indicates the minimum (here the minimum is 180 µg/m^3), the maximum, the 25 percentile and the 75 percentile value of the exceedances. The figure shows that during 25% of all observed exceedances, the maximum hourly concentration recorded was just above the 180 µg/m^3 threshold. 75% of all maximum exceedances recorded were below 206 µg/m^3.



	AT	BE	DE	DK	ES	FI	FR	GB	GR	IE	IT	LU	NL	PT	SE
#Ex	13	65	581	.	79	.	?	54	88	.	321	5	45	19	.
#St	10	16	225	.	25	.	?	27	7	.	37	2	25	5	.

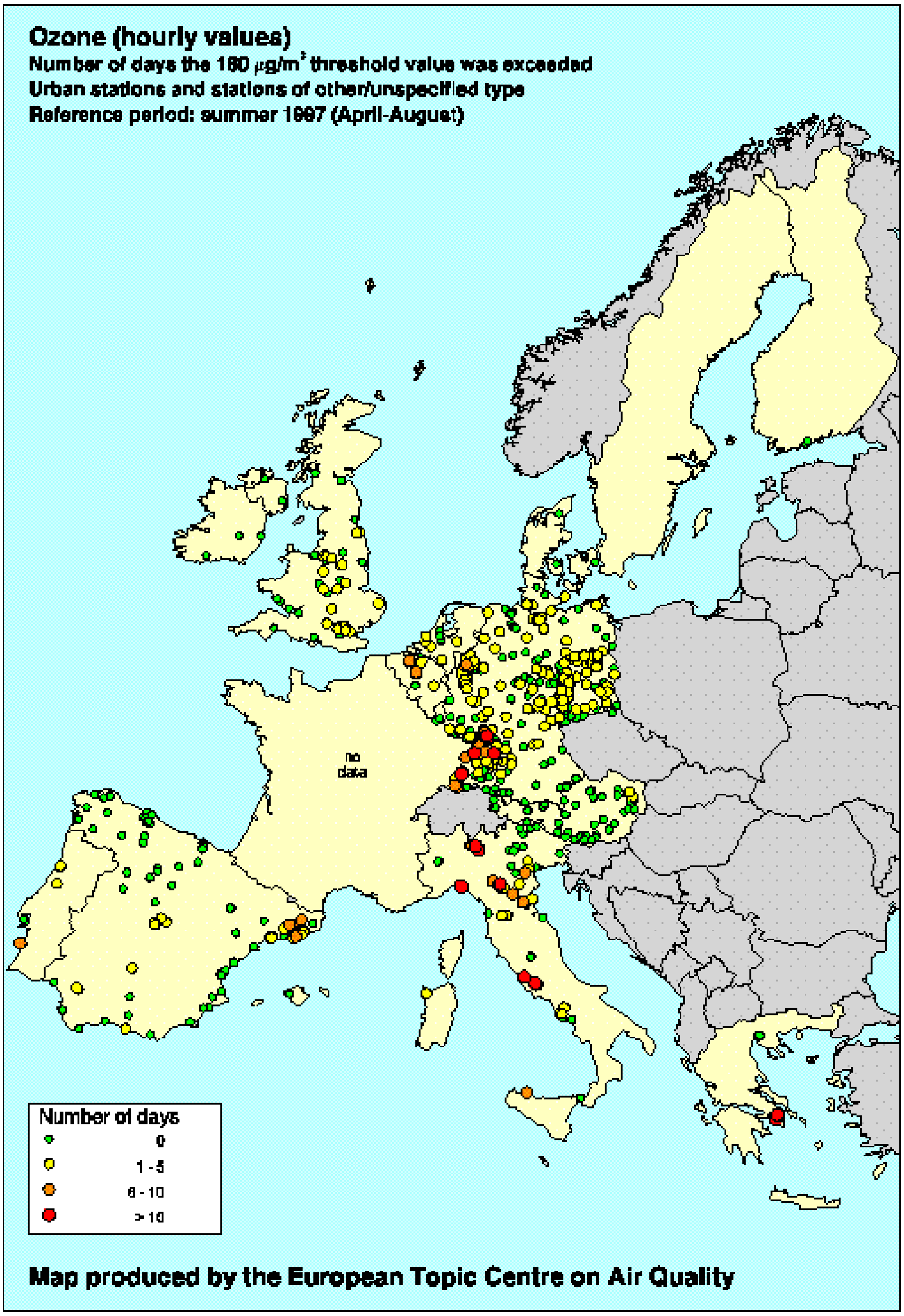
Figure 4: Frequency distribution of ozone concentrations in excess of the 180 µg/m^3 threshold for hourly values (April-August 1997). For each country the total number of observed exceedances is given in row '#Ex', the number of stations is given in row '#St'. Frequency distributions are presented as Box-Jenkins plots indicating the minimum, the 25-Percentile, the 75-Percentile and the maximum value.

3.1 Geographical distribution

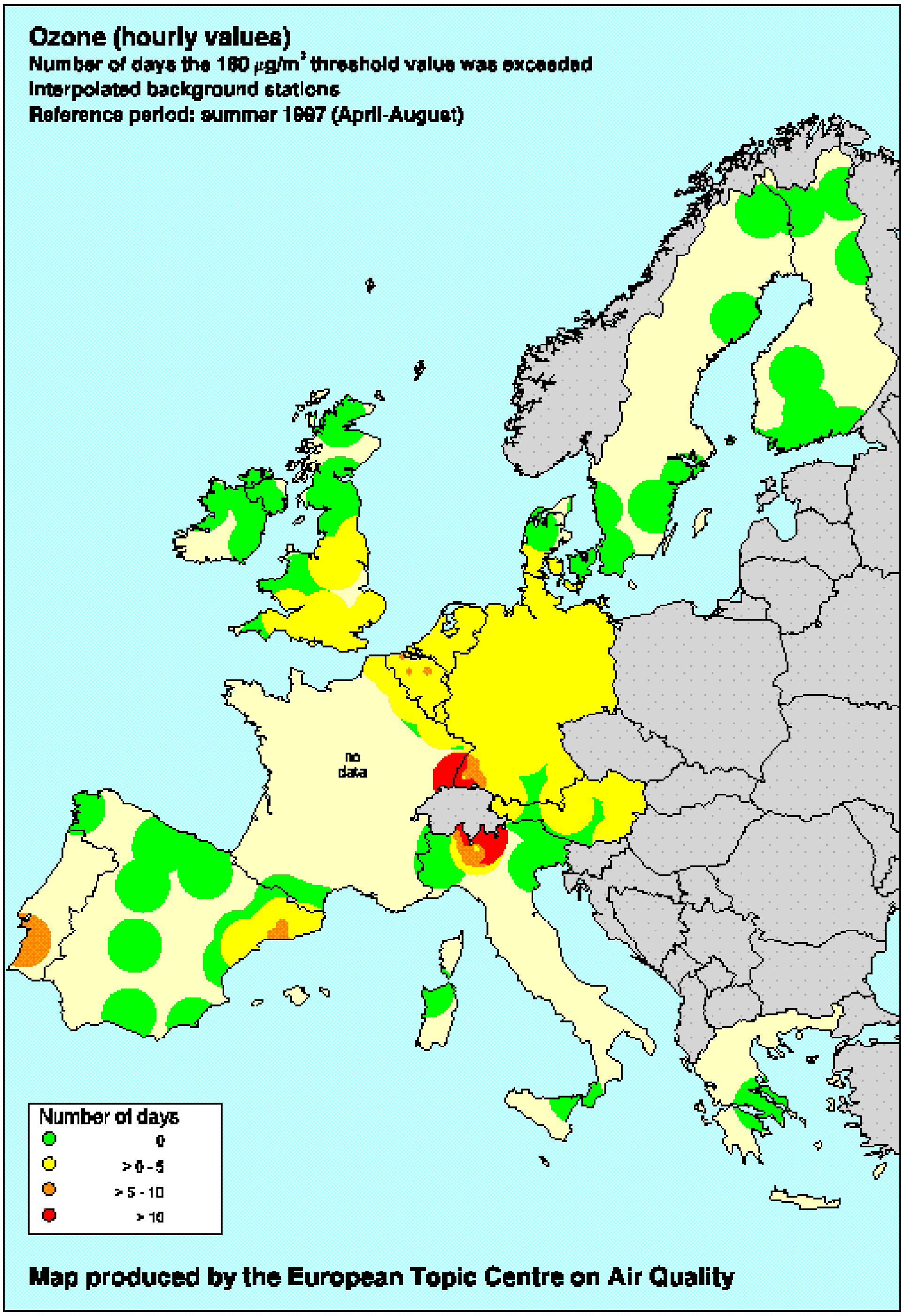
Maps 2 and 3 show the geographical distribution of the number of days on which the threshold value for information of the public was exceeded for urban[8] and background stations, respectively. Exceedance data for urban stations are presented as dots. Note that information for France is missing and that stations of unspecified type are also plotted in this map. The exceedance data for rural stations are interpolated using simple inverse distance weighting and a tentatively estimated 'radius of representativeness' of 100 km. Note that this radius might be different for the various regions in Europe.

The number of days on which exceedances were observed at urban stations and stations of unspecified type in Northern and Western Europe ranges from 0 in Finland, Sweden, Denmark, Ireland and large parts of Austria to more than 10 on some stations in South-Western Germany. No consistent spatial pattern is apparent in the Mediterranean region. Some stations did not report any exceedance, other stations in Italy and Greece reported more than 10 exceedances.

[8] Exceedances reported from stations of unspecified type are also plotted in this map.



Map 2: Number of exceedances of the threshold value for the information of the public (1h > 180 $\mu g/m^3$) observed at urban/street stations and stations of unspecified type. Summer 1997 (April-August).



Map 3: Number of exceedances of the threshold value for the information of the public (1h > 180 µg/m^3) observed at background stations. Summer 1997 data (April-August), interpolated using inverse distance weighting, cut-off distance of 100 km.

3.2 Comparison with previous years

Exceedances observed during the 1997 summer period were compared to exceedances observed during the same period in 1996 and 1995[9]. France did not report exceedances of the population information threshold in 1997 and was left out of the analysis to ensure comparability between the years. Italy was not taken into account in the analysis because 1996 data was incomplete and inconsistent.

Figure 5.a presents the average exceedance duration[10] of the population information threshold, Figure 5.b the average occurrence and Figure 5.c presents the average maximum concentration observed during exceedances.

All indicators show lowest values in 1997 compared to 1996 and 1995. Since most ozone stations are operational in Northern and Western Europe (ca. 70% in 1997) exceedance statistics are strongly influenced by the meteorological conditions in this area. For example, in 1995 Germany, Netherlands and Belgium reported 81% of all exceedances.

In 1995 a number of heat waves were recorded in northern and western Europe and conditions were favourable for high ozone levels on many days. During summer 1996, relatively clean and cool Atlantic air masses prevailed on many days in northern and western Europe. Subsequently, the number and duration of exceedances as well as the maximum concentrations observed were lower than in 1995. Relatively clean and cool Atlantic air masses also prevailed during April-July 1997 and hardly any exceedance was observed in northern and western Europe.

August 1997 was very hot and sunny in large parts of northern and western Europe[11]. The number and duration of exceedances as well as the maximum concentrations observed during exceedances were however much lower as those observed during other recent hot and sunny months. In Ireland, Finland, Sweden and Denmark the threshold was even not exceeded.

First analysis has shown that the relatively low number of exceedances in August might be explained by the position of the dominating high pressure cell. The high pressure cell was, on average, situated above Scotland - southern Norway resulting in a NE circulation above large parts of northern and western Europe. Relatively clean air masses originating from the Baltic area and western Russia dominated above northern and western Europe. Due to subsidence the air could be characterised as dry (sunny) and hot.

During other warm and sunny months in recent years, the dominating high pressure cell was located (on average) over the continent resulting in the transportation of relatively polluted air to western and northern Europe with a E-SE circulation and more situations in which air masses became stagnant.

[9] 1995, 1996: Validated exceedance statistics as transmitted by Member States were used for this purpose.
[10] Averaged over all stations which reported at least one exceedance.
[11] For example, August 1997 was the hottest August since the beginning of measurements in 1706 in the Netherlands.

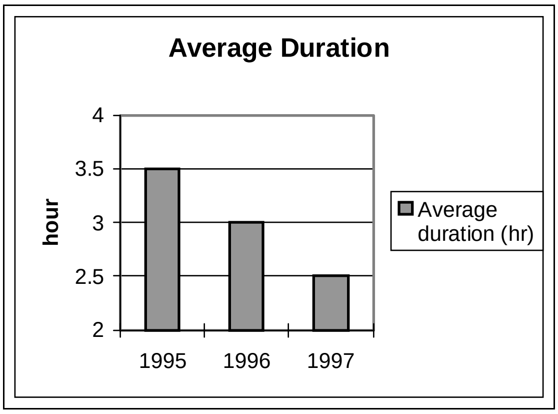


Figure 5.a: Average duration in hours of exceedances during summer 1995, 1996 and 1997 (April-August, based on 13 Member States).

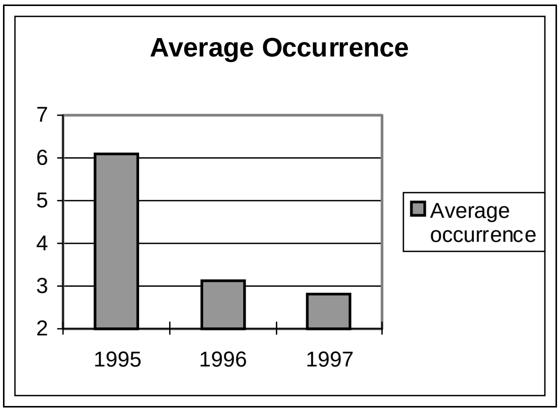


Figure 5.b: Average occurrence (nr) of exceedances at stations which reported at least one exceedance during summer 1995, 1996 and 1997 (April-August, based on 13 Member States).

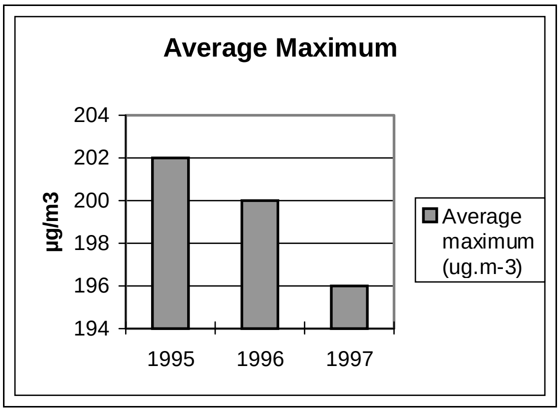


Figure 5.c: Average maximum concentration (µg/m^3) observed during exceedances (April-August, based on 13 Member States).

It is difficult to assess a possible trend in the number, duration and severity of exceedances of the threshold for information of the public which in its turn could indicate a possible trend in precursor emissions, because:

- High ozone levels (in this case exceedances of the population information threshold) are mainly observed during periods with warm and sunny weather. Especially in western and northern Europe, the year-to-year variations in meteorological conditions favourable for high ozone levels are large. The resulting variations in exceedance statistics can obscure a possible trend due to changes in precursor emissions. It is at the moment not possible to correct for this variability on a country by country basis nor for the complete EU territory;

- Exceedances statistics are available for only three years which is a very short time series to assess a possible trend;

- The number of stations implemented in the framework of the Ozone Directive increased by ca. 20% over the last three years. The increased territorial coverage can have implications for the number of exceedances observed. Also, a changing ratio between the number of rural and urban/street stations can have implications for the number of observed exceedances since peak ozone levels will on average be lower in urban areas than in rural areas.

4. EXPOSURE TO EXCEEDANCES

4.1 Population exposure

The actual outdoor exposure of the population to ozone is difficult to estimate. In addition to estimating the spatial distribution and time variation of the ozone concentration, the location and physical activity level of the population should be known. Since detailed data about these variables is not available, the description of exposure must be limited to estimating the number of people who possibly experienced (‘were potentially exposed to’) at least one exceedance of ozone concentrations above the information threshold value during summer 1997.

For urban areas, using a Geographical Information System, the location of urban stations was combined with information on the European population provided by Eurostat (EUROSTAT, 1996). This database lists ca. 2100 cities in the EU with more than 25 000 inhabitants. It is calculated that from a total EU population of ca. 362 million, ca. 195 million people live in these cities. Approximately 75 million people live in cities in which at least one ozone station was operational during the 1997 summer season (38% of the total EU urban population or 21% of the total EU population).

157 cities reported at least one exceedance of the population information threshold value. Approximately 25 million people in these cities[12] (34% of the urban population living in cities with operational monitors) were potentially exposed to at least one exceedance. The urban exposure estimates are presented in Figure 9.

The results should be interpreted with great care. In many cities, only one station is operational and exceedances at such a station were attributed to the whole urban population. The current description of station types is imprecise and for a substantial number completely missing. Nevertheless, it is obvious that urban population exposure estimates cannot be based on monitoring results alone, since monitoring stations cover only 38% of the total urban population.

The number of people “potentially exposed” as calculated for this report cannot be compared with the calculated number published in last year’s report (Sluyter and van Zantvoort, 1996). This year calculations were made for the period April-August (1996: April-July). Moreover, the population database used was updated and the number of stations (coverage) has increased.

[12] This figure cannot be compared directly with figures provided in earlier reports covering summer 1994 and summer 1995 as the basis for calculation was not the same.

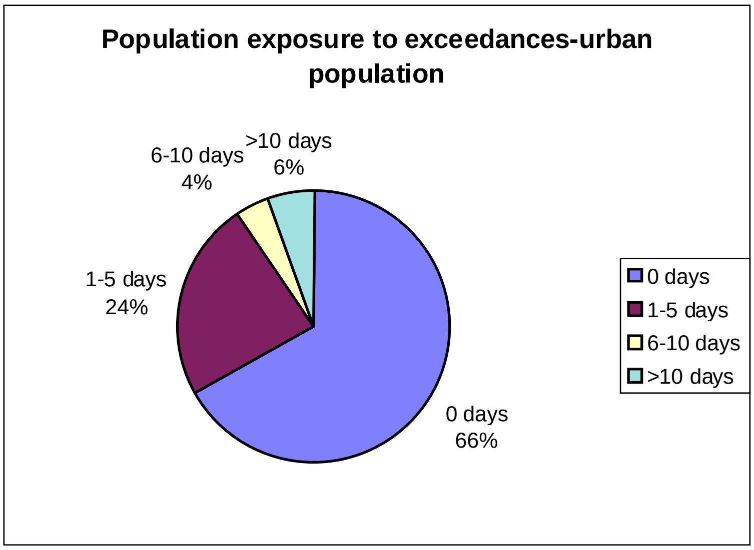


Figure 9: Number of exceedances (in days) and frequency distribution of urban population potentially exposed to hourly ozone concentrations exceeding 180 µg/m^3, April-August 1997. (Representative for an urban population of 75 million (38% of the EU urban population) living in cities with more than 25 000 inhabitants; 21% of the total EU population).

For rural areas, the number of people potentially exposed to at least one exceedance could not be calculated. The interpolated exceedance 'field' (Map 3) is rather fragmented. Moreover, no rural population database is available at the moment. However, as ozone levels are in general higher in rural areas than in cities, it is anticipated that a larger fraction of the rural population will be potentially exposed to exceedances than in cities.

4.2 Territorial exposure

The interpolated exceedance map for rural locations with an assumed radius of representativeness is too fragmented to draw firm conclusions on spatial patterns. The rural stations cover approximately 48% of the EU territory. The area where exceedances were observed, calculated on the basis of the interpolated map, is approximately 49% of the total area covered by background stations which is estimated at 23% of the total EU territory. These figures are comparable to those observed during summer 1996.

5. MAIN OZONE EPISODES

Ozone formation and destruction is dependent on emissions, concentrations and ratios of precursors (mainly VOC, CO and NO_X), and on the amount and intensity of sunlight. Important in this respect is the role of nitrogen oxide emissions. In urban areas, the ozone concentrations may be lower than the rural ('background') concentrations due to chemical scavenging by local nitrogen oxide emissions (see for example Figure 3, which shows that the occurrences of exceedances are in general highest at rural stations).

Episodes, periods with elevated ozone levels, will mainly occur during periods of warm sunny weather. In the Mediterranean countries, having prolonged spells of hot and sunny weather during the summer, ozone can quickly be formed and high levels can occur on many days and in the vicinity of urban centres. In northern Europe the build up of ozone is slower due to the more moderate weather conditions. Here, highest levels will generally be found downwind of cities. Figure 6 presents a graphical representation of the percentage of stations in every Member State that reported exceedances of the threshold value for population information (180 $\mu g/m^3$ for hourly values) during the 1997 summer season.

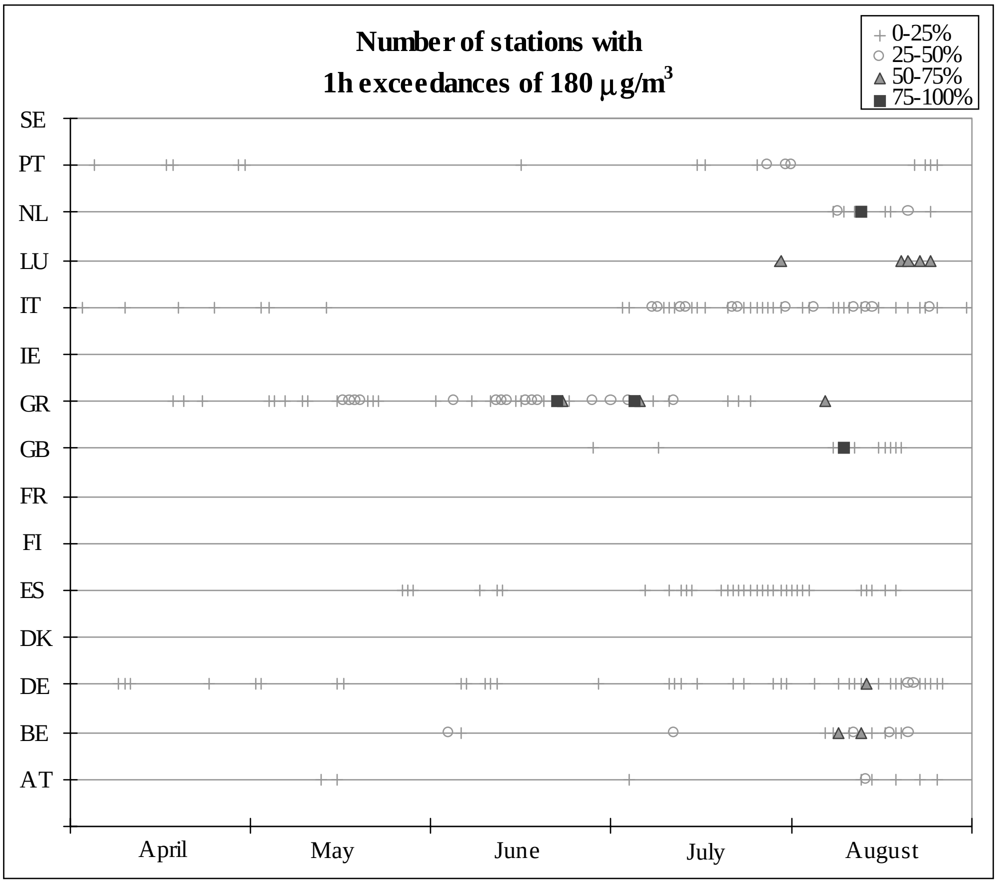


Figure 6: Qualitative overview of exceedances of the 180 $\mu g/m^3$ population information threshold value (1h) during the period April - August 1997. The symbols represent the percentage of stations which observed at least one exceedance of the threshold for the information of the public during a particular day. Note: data from France is missing.

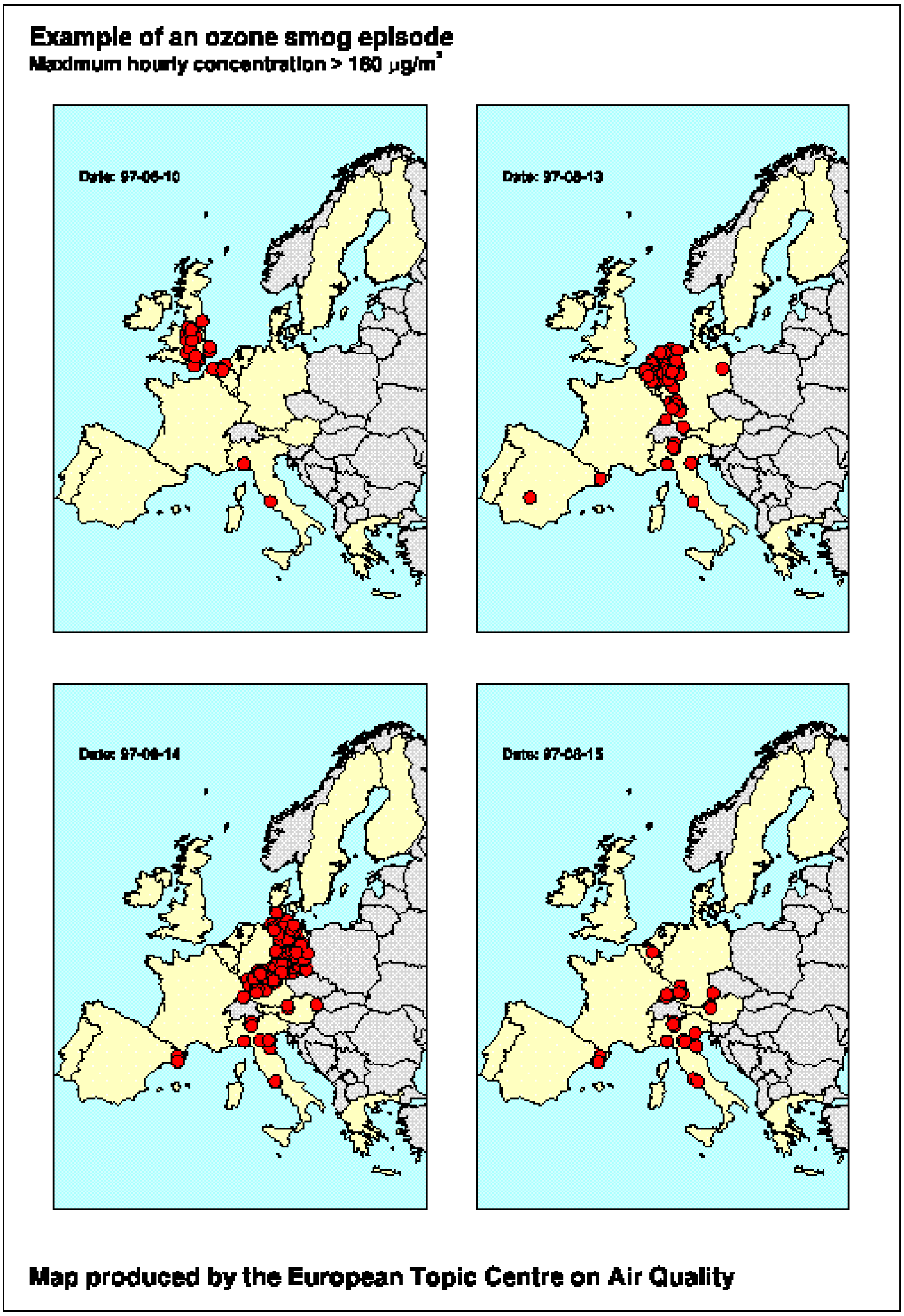
From Figure 6 it is clear that the number of episodes covering extended areas of the European territory was limited during April-July 1997. As already mentioned in Section 3, weather conditions in western and northern Europe were often unfavourable for the build-up of ozone. On many days cool and relatively clean Atlantic air masses prevailed in northern and western European countries.

More frequent exceedances were observed in August. The most widespread northern European episode this summer occurred between 10 and 14 August. Map 4 presents an overview of the sites which observed an exceedance on 10, 13 14 and 15 August 1997[13]. In the text box, the conditions leading to this episode are described in more detail. In contrast, in southern Europe frequent exceedances are observed throughout the reporting period.

The episode of 10-14 August 1997[14]

During the first days of August, a high pressure cell formed over Scotland- southern Scandinavia. This resulted in a NE circulation over a large part of northern and western Europe with sunny skies and high temperatures. The air mass present was relatively clean. On 10 August, the high pressure cell had slightly shifted position to the east and in combination with a depression west of Ireland the circulation became SE, first in the United Kingdom, transporting more polluted air from the continent to the west. Exceedances were observed in the United Kingdom and Belgium. The synoptical situation remained more or less stable till 12 August with exceedances concentrated in the United Kingdom, Belgium, Netherlands and the western part of Germany. A cold front, behind it relatively clean Atlantic air, moved in from the west on 13 August ending the episode in the United Kingdom. Preceding the cold front, under sunny skies and tropical temperatures, exceedances were observed on a large scale in Benelux and Germany. On 14 August, the cold front was positioned over the central part of Germany ending the episode in Benelux and the western part of Germany. On 15 August, the relatively clean Atlantic air had reached the eastern part of Germany and this ended the episode.

[13] Note that the exceedances during this episode on 11 and 12 August are not presented. The situation on those two days was comparable with 10 August.
[14] Although no data for France was received, it is to be expected that exceedances also occurred in France during this episode.



Map 4: Example of a smog episode: stations which reported an hourly ozone concentration in excess of 180 µg/m³, 8-14 August 1997 (all station types). Note that data from France is missing.

Figure 7 presents the maximum hourly ozone values recorded in the Athens conurbation (Greece) as an example of a local ozone episode in the Mediterranean region. The threshold for warning of the public (1h >360 µg/m^3) was exceeded in Athens. Note that not all stations presented reported exceedances on every day during this period. More information on the specific conditions leading to these particular episodes is not yet available to the authors of this report.

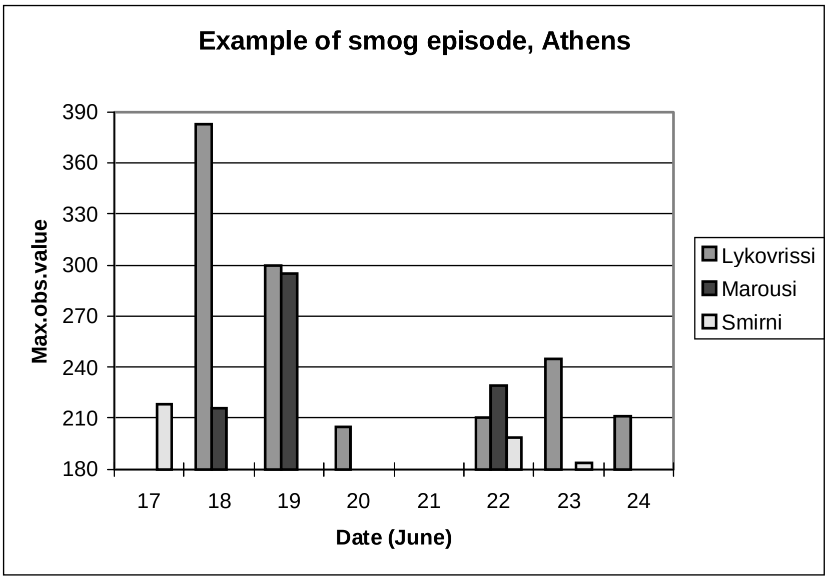


Figure 7: Example of a local ozone episode, Athens 17-24 June 1997. Maximum observed 1h values (µg/m^3) on stations in the Athens conurbation which observed an exceedance of at least 180 µg/m^3 (1h).

Figure 8 presents the maximum hourly ozone values recorded at the Cavaliere station in Rome (Italy) during exceedances of the population information threshold in the period July-August. It is an example of a station in the Mediterranean region at which frequent exceedances are observed throughout the summer period.

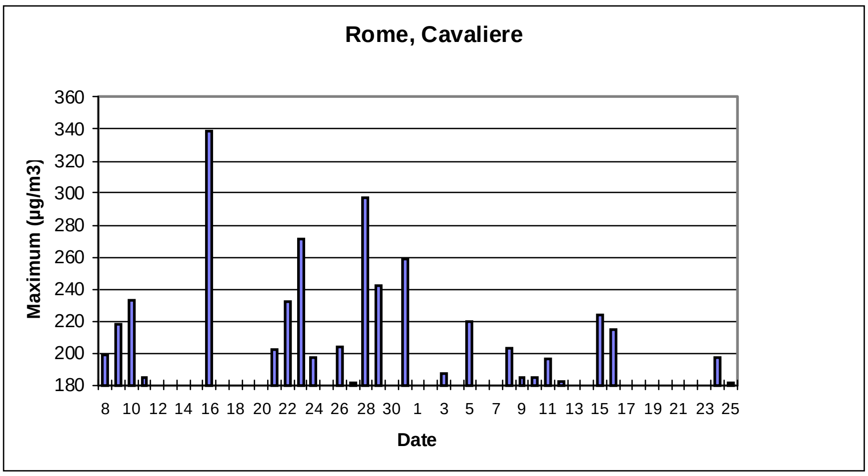


Figure 8: Example of a station with frequent exceedances throughout the summer period, Cavaliere, Rome (Italy), July-August 1997. Maximum observed 1h values (µg/m^3) observed during an exceedance of at least 180 µg/m^3 (1h).

6. CONCLUSIONS

This report presents a first evaluation of the reported exceedances of the threshold value for information and warning of the public during summer 1997 (April-August). Information is not necessarily based on validated monitoring data and hence the conclusions drawn should be considered preliminary.

Information on the occurrence of exceedances has been received from all EU Member States for the months April, May, June, July and August with the exception of France. The quality of the exceedance information supplied was good and largely according to EU specifications. Improvements can be made for a number of countries as far as characterization of stations is concerned. Some countries did not supply meta information on stations. 1070 monitoring stations were assumed to be operational this summer.

The threshold for warning of the public (1h > 360 $\mu g/m^3$) was exceeded at one stations during summer 1997; Lykovrissi (Athens, Greece) on 18 June 1997.

The threshold for information of the public (1h > 180 $\mu g/m^3$) has been exceeded in all Member States with the exception of Ireland, Denmark, Finland and Sweden.

The number of days on which at least one exceedance was observed ranged from five in Luxembourg to 49 in Italy. 41% of all stations reported one or more exceedance. On average 3.4 exceedances occurred this year on stations which recorded at least one exceedance. The average length of an episode was 2.7 hours.

The number of stations which reported an exceedance, the occurrence of exceedances at those stations and maximum concentrations during episodes this year were lower than during the 1995 and 1996 summer seasons. This time series is too short to link this decrease to declining pre-cursor emissions. The difference can mainly be attributed to year-to-year weather variability. Especially in northern and western Europe, the weather conditions during the 1997 summer season were on average less favourable for high ozone levels than during the 1995 and 1996 summer seasons. This year, cool and relatively clean Atlantic air masses prevailed on many days during April-July. Although August was a hot and sunny month in large parts of northern and western Europe, relatively clean air masses originating from the Baltic area/western Russia prevailed on many days (N-NE circulation).

A first estimate was made of the percentage of the urban population exposed to at least one exceedance of the population information threshold. Approximately 75 million people live in cities in which one or more ozone stations were operational during the 1997 summer season (38% of the total EU urban population or 21% of the total EU population). 157 cities reported at least one exceedance of the population information threshold value. Approximately 25 million people in these cities were potentially exposed to at least one exceedance. However this estimate should be interpreted with great care. In many cities, only one station is operational and exceedances are unlikely to represent the potential exposure of the complete urban population.

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